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Linda Candy · Ernest Edmonds
Fabrizio Poltronieri

Explorations in Art and Technology

Second Edition

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ISSN 2195-9056 ISSN 2195-9064 (electronic)
Springer Series on Cultural Computing
ISBN 978-1-4471-7366-3 ISBN 978-1-4471-7367-0 (eBook)
https://doi.org/10.1007/978-1-4471-7367-0

Library of Congress Control Number: 2018942931

This Springer imprint is published by the registered company Springer-Verlag London Ltd. part of Springer Nature
The registered company address is: The Campus, 4 Crinan Street, London, N1 9XW, United Kingdom

In Memory of Emma Candy and Roy Stringer

Foreword to the Second Edition

The field of art, science and technology has matured significantly in the 16 years since this book was first published. It now has its own acronym—STEAM: Science, Technology, Engineering, Art and Mathematics—which bestows a new academic credibility and dawning acceptance. The 'lumbering dinosaurs with their fortress faculties' are slowly and I suspect reluctantly changing. The commitment and contributions of Linda Candy and Ernest Edmonds have been instrumental in enabling this change. Not only have they championed the value of the field but they have also pioneered the development of art as research, or practice-based action research. It's an activity that has lent a new and necessary credibility to the arts as the traditional, studio-based, art schools merged with their more academically focussed university neighbours.

In 2002, when I wrote the original foreword, the field was on the cusp of emerging from decades of neglect. The same year the CACHe research project: Computer Arts, Contexts, Histories, etc. began at Birkbeck College in London led by Charlie Gere and myself. We were funded by the then relatively new Arts and Humanities Research Board, and the aims of the project were to research, document, preserve and contextualize the early development of the computational arts in the UK from the 1960s to the 1980s. The project re-energized the Computer Arts Society—CAS—that had been founded in 1968, just after the Cybernetic Serendipity exhibition, curated by Jasia Reichardt, was held at London's ICA. CACHe built up a valuable and ongoing relationship between the CAS and the Victoria & Albert Museum and helped the V&A acquire two important archives of early computer art which established their reputation amongst the main international institutions collecting work in the area.

So it is a great pleasure for me to revisit my foreword for this revised edition of Explorations in Art and Technology. The original publication fulfilled its promise to be a 'keystone reference', and it has made a noteworthy contribution to the development of the field over the years. This new edition with significant new and revised content should continue this influence and consolidate the book's reputation as one of our field's canonical texts.

Paul Brown
Ocean Shores, Australia
February 2018

Foreword to the First Edition

I was born in 1947, the year before American artist Charles Biederman published Art as the Evolution of Visual Knowledge. In that central year of the twentieth century, he gave art a focal place in the new scholarship of consciousness and cognition. Now, at the dawn of a new millennium, some scientists suggest that art is one of the few activities that distinguish homo sapiens from our hominid ancestors. It would seem that art is not only a powerful and uniquely human language that helps us engage with and comprehend and communicate our universe: perhaps, it is art amongst all human endeavours that defines who we are.

With the advent of the computer and in the context of the twentieth-century international art and technology movement, many artists began to explore the boundaries of cybernetics, cognition and artificial intelligence. In the late 1960s and 1970s, some were amongst the pioneers who defined an entirely new field of study now known as artificial life. By the end of the century, we were using terms like computational paradigm to describe the proliferating knowledge base that had been uniquely enabled by digital technology.

And now, some 50 years after Biederman's pioneering publication, it is possible to bring together some of the key practitioners whose work has helped define the intersection of art and technology. All have been associated in some way with the Creativity and Cognition Research Studio (C&CRS) programme at Loughborough University.

It is perhaps apt that a university that was founded in the 1960s in a small English market town should have provided the venue for one of the world's most dynamic interdisciplinary research programmes addressing this exciting area. I grow ever disenchanted by the traditional universities—those lumbering dinosaurs with their fortress faculties designed only to defend discipline against discipline whose economic rationalism both undermines and actively discourages collaboration whilst simultaneously ossifying the past at the expense of the future.

The dualism invoked by CP Snow's 'two cultures' is at last being eroded. A new synthesis is emerging, slowly to be sure, but wasn't it Kuhn himself who suggested that 'disciplines change when old men die'? But disciplines are changing: science is accommodating the qualitative and art the quantitative. We can no longer hold dear to the modernist and simplistic grand narratives of science as the logical 'left brain' expression of human endeavour and of art as the lateral 'right lobe' activity.

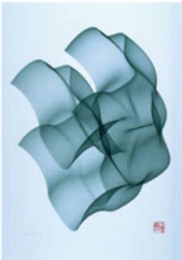
In their introductory chapters, Linda Candy and Ernest Edmonds provide a valuable background and introduction to the book's themes. They plot a history of art and science collaborations and trace the origins and context of the C&CRS. Much of the work of the centre has investigated the technological needs of artists and how to meet them. Several of the chapters describe projects they have undertaken. These are complemented by essays by pioneers and practitioners whose work has helped define the field and its achievements and needs.

Art and technology were associated with the period of late modernism in the twentieth century. The field suffered when it was rejected by the youthful and aggressive post-modernists who, like all children, deny their heritage. However, I am glad to see that this important historical contribution is being re-addressed and re-contextualized by a more mature generation who can now acknowledge the continuity of history and the connectivity of ideas.

These essays make an exceptional and essential publication. I am grateful to the authors whose commitment and effort over several decades has made such a book possible. It comes at an important time and will provide a valuable keystone reference. The historical contributions are especially welcome. Some of the pioneers have already returned their elements to the matrix. Soon it will no longer be possible to write about this period in the first person singular.

Paul Brown
The Sunshine Coast
February 2002

"Any sufficiently advanced technology is indistinguishable from magic."
Arthur C. Clarke, 1962: Profiles of the Future



"I did not want answers that might show up on the monitor seemingly by magic."
Michael Kidner, 1996

"Art does not reproduce the visible: rather, it makes visible."
Paul Klee, 1958: Inward Vision

"Digital Technology may enable what is already there to be seen."
Michael Quantril, 1999

Preface to the Second Edition

The first edition of this book was published in the very early years of the twenty-first century and by now in 2018, the technologies have advanced enormously and expanded in their influence. Smartphones and tablets abound and social media seems to dominate our lives. Not surprisingly, the exploration of these technologies by artists has kept pace with this expansion. However, it is interesting to notice that many of the conceptual issues that were significant and challenging in 2002 remain so in 2018. The traditional art world, the big galleries, the fairs, have still to catch up with the cutting edge of art that seriously explores computer code, communications and the new world that computers have created. Perhaps when we are approaching 2040, a different story can be told. However, the practice of and the research into art and technology have flourished and we do have new art forms and a better understanding of the field. Today, we see that there is still much to explore and no shortage of new challenges. This second edition of the book acknowledges these changes and explores the current challenges.

For this second edition, we have been joined by Fabrizio Poltronieri, who both adds his own perspective and brings his knowledge of the work of South America into the mix. The book has been reorganized in certain ways, and the core chapters have been updated in the light of recent developments. We have taken a hard look at the collection of contributions from artists and those who collaborate with them. We have added a range of new contributors, often younger artists, and grouped the contributions to relate to relevant chapters. These new texts add life and an up-to-date perspective on the core concern of the book, the provision of a picture of the fast changing world in which artists are exploring the potential and the meaning of new and emerging digital technologies.

In the first edition of the book, we included a Note of Thanks, reprinted, with our thanks repeated, in this edition. Sadly, four important people have passed away since 2002: we remain grateful for our invaluable conversations with the late Marvin Minsky; Michael Kidner's unflinching encouragement continues to inspire us beyond his lifetime; Harold Cohen, who passed away in 2016, was a pioneer and leader in this field whose contribution cannot be over-estimated. Finally, the memory of our late daughter, Emma Candy who supported us and contributed to the design of the book, influences everything that we do and write.

Linda Candy and Ernest Edmonds
Sydney, Australia
February 2018

Preface to the First Edition

Imagine a scene: in a darkened room a moving image is projected onto a large screen. In front of it, several people are moving rapidly in different directions, waving their arms and simultaneously watching the screen. They might be laughing or chatting with one another or quietly observing the shapes, colours and sounds that are continually changing as if in reaction to the movements of those present. As a matter of fact that is exactly what is happening. In today's world of art and technology, this is an interactive or 'participatory' art experience. Together, artists and technologists have created spaces in which infrared sensors detect people's movements and by detecting the movements in the space, a computer generates visual images and sounds which are displayed so that everyone can see the artwork as it evolves.

Experiments in art that involve audience participation have been taking place for some time and, because they subvert conventional expectations about the nature of art, they can appear in unexpected quarters and sometimes in disguise. The Millennium Dome of the Year 2000 in London received extensive media coverage and was the butt of many jokes. Some things, however, escaped press attention. One, in particular, is an interesting reflection on our current ideas of what is art and what is play. Few of the thousands who crowded into the Play Zone realized that the games they were enjoying were originally experiments in art. The innovative art and technology projects that gave rise to the Iamascope were direct descendants of Cybernetic Serendipity, the groundbreaking computer art show of 1968.

Interest in play and games is now a common theme in art. It might take the form of a sculpture that invites touching or climbing, as well as viewing, or a community project initiated by an artist, but created by people living in the same building who record their daily experiences in text and images. There are even computer games designed by artists. The link between play and art is participation. Participation in interactive art brings with it the kind of engagement in the creative process that is normally denied the art viewing public. Interaction is central to art practice today but is not part of conventional gallery culture. The new art and technology experiences do not necessarily fit comfortably into familiar cultural contexts. Being in interactive spaces is engaging and interesting. Children and adults too can have fun with this kind of experimental art. It is one example of the new forms and the new audience relationships that are developing at the intersection of art and technology.

This book is an exploration of creative practice in art and technology. It brings together artists, technologists and researchers who have written about emerging correspondences between virtual and physical worlds, between human and machine processes, between abstract concepts and their physical realizations, between music and visualization and between film and painting. It is a story of new visions and new forms.

Digital art is not always recognized by the conventions of traditional art culture. It has a different character and form that means it is not necessarily reliant upon the usual outlets for artworks such as the public and commercial gallery system. The digital world lends itself to new modes of dissemination and, indeed, many of the practitioners are attracted to it for that very reason. The Internet, the vast system of computers that form a communicating network throughout the world, has opened up many access and delivery options for art.

The book arose from research into the intersection of art and technology through a series of artist-in-residence projects. Artists worked with technologists to develop new artworks, whilst researchers gathered information in order to learn as much as possible about the creative processes involved. A practice-based action research approach was used to investigate the creative process in a real context and as it takes place. One aim was to learn how to evolve strategies for developing responsive environments for art and technology innovation. We learn that creative practice offers new challenges and inspirations for the technologist as well as the artist and that artist and technologist need to find imaginative ways forward together if they are to realize their ambitions and gain mutual benefit. Most important, successful collaboration involves developing effective and personal partnerships that sustain creativity over time.

There are significant changes in art practice taking place as a result of the potential that digital technology offers. Artists are facing considerable demands upon artistic concepts and art-making skills alike. It is those very challenges that make it exciting. Digital technology can perform a number of roles in art practice: it can act as an aid to the artist by making multidimensional visualizations of an image; it can perform a direct role in the artwork itself by controlling movement or sound or a combination of elements; it can carry out instructions to create the contours and configuration of a work by generating instructions for laser cuttings or high-quality screen printing. Some of the artists represented in this book combine all these roles of the technology in their work. All are using the unique characteristics of digital technology to advance their art practice. This collection of experiences and viewpoints provides a picture of this changing world as it is taking place at the start of the twenty-first century.

A Note of Thanks First Edition

The contributors to this book are associated with Creativity and Cognition Research Studios either as artist-in-residents, speakers or exhibitors. We wish to thank them for their participation in those events and for their cooperation in the production of this book. We would also like to acknowledge many other people who could not make a written contribution but who, nevertheless, played significant roles in the work that gave rise to the book: thank you to Helmut Bez, Rob Doyle, Pip Greasely, Antonia Kelly, Peter Lowe, Simon Nee, Mike North, Kip Sahnsi, Sarah Tierney, Greg Turner, Paul Wormald and Bill Marshall. We would also like to mention the people active in the fields of art, technology and human–computer interaction whose support we have enjoyed over the years. The lively exchanges of views and, of course, the personal friendships that have developed, have contributed to our work in so many ways: with thanks to Ken Baynes, Steve Bell, Maggie Boden, Paul Brown, Nigel Cross, Anita Cross, Ben Shneiderman, Bronac Ferran, Gerhard Fischer, John Gero, Bryan Lawson, Kenji Mase, Marvin Minsky, Kumiyo Nakakoji, Patricia Railing, Doug Riecken, Steve Scrivener and Steve Willats. Finally, we are most grateful to Meroë Candy, Judith Mottram, Tom Hewett and Ingrid Holt whose thoughtful comments and useful tips helped us hone the ideas and the writing.

Funding support was provided from the following organizations:

Loughborough University: The School of Art and Design, Department of Computer Science and Department of Design and Technology
The Arts Council of England
East Midlands Regional Arts, UK
National Association for Fine Art Education in collaboration with the National Arts Association: Access to Art Colleges Scheme (AA2A)
Year of the Artist (YOTA) National Lottery Scheme, UK
Higher Education Funding Council of England and Wales (HEFCE)

Engineering and Physical Sciences Research Council, UK (EPSRC)
Silicon Graphics Ltd.
Drexel University USA: Department of Psychology and Department of Mathematics and Computer Science.

Linda Candy and Ernest Edmonds
Loughborough
February 2002

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About the Authors

Linda Candy is a writer and researcher who lives and works in Australia and England. Linda has Bachelor of Arts (B.A.), a Masters by research (M.Phil.) in computer-aided learning and a Ph.D. in Computer Science. She was senior researcher on leading interdisciplinary projects including the COSTART project: Artists and Technologists in Collaboration. Her main research areas are creative practice, interaction design and evaluation. She has conducted studies of creative people including the designer of the Lotus bicycle and has published widely. She is a member of several international conference programme committees and has carried out many projects in collaboration with industry. She was founding co-chair of the international symposia on Creativity and Cognition and Strategic Knowledge and Concept Formation and has over 25 years' experience in research into creativity, design and digital art. She has written over 100 papers and articles about the creative process, the role of computers and the methodologies for investigating these areas of research. Edited books include *Interacting: Art, Research and the Creative Practitioner* and *Interactive Experience in the Digital Age: Evaluating New Art Practice*. For further details, see: http://www.lindacandy.com.

Ernest Edmonds is an artist researcher who pioneered the field of computational art from the late 1960s. In 2017, he received the ACM SIGGRAPH Distinguished Artist Award for Lifetime Achievement in Digital Art. His recent exhibitions include retrospectives at Tsinghua University, Beijing, and De Montfort University, Leicester. He also recently exhibited with four other computer art pioneers in *Algorithmic Signs* at the Fondazione Bevilacqua La Masa, San Marco, Venice. Edmonds' skills are transdisciplinary and in 2017 he won the SIGCHI Lifetime Achievement Award for the Practice of Computer Human Interaction. He has been Head of a University Computer Science Department and a Dean. In the 1970s, he pioneered the supervision of practice-based Ph.Ds and has over 300 publications on human–computer interaction, creativity and computer-based art. He is currently

Professor of Computational Art at De Montfort University, Chair of the Board of ISEA International and Editor-in-Chief of the Springer Cultural Computing book series. His work was recently described in the book by Francesca Franco, *Generative Systems Art: The Work of Ernest Edmonds,* Routledge, 2017. For further details, see: http://www.ernestedmonds.com.

Fabrizio Poltronieri (b. 1976) is a computer artist, researcher and curator with a special interest in the relationships between Art, Digital Media, Design and Technology. His expertise is in the development of creative coding and its exchanges with philosophical questions. He is a member of IOCT (Institute of Creative Technologies) at De Montfort University, Leicester and holds a Ph.D. in Semiotics from the Pontifical Catholic University of São Paulo (PUC/SP), Brazil. In 2011–2012, he was awarded a fellowship to develop a Postdoctoral research project on the early days of computer art at the Royal College of Art in London. One of the outcomes of this research was a major exhibition with four pioneer computer artists. This exhibition entitled 'Primary Codes' featured artworks and talks by Ernest Edmonds, Frieder Nake, Harold Cohen and Paul Brown and took place in Rio de Janeiro in 2015. His second Postdoctoral research was at Leuphana Universität's Gamification Lab, in Lüneburg, Germany on how the video games' universe, the notions of gamification and post-history affect language production mediated by digital apparatuses. This research led to the chapter Communicology, apparatus, and post-history: Vilém Flusser's concepts applied to video games and gamification, published in Rethinking gamification. For further details http://www.fabriziopoltronieri.com.

Contributors

Priscila Arantes is a researcher, curator and professor based in São Paulo. She is the director and curator of the Paço das Artes since 2007. She developed post-doctoral research at Penn State University (USA) and currently teaches in the graduate programme in Design at the Universidade Anhembi Morumbi. Between 2007 and 2011, she was the Programme Director of the Museu da Imagem e Som. In 2010, she was a member of the editorial board of the Bienal de São Paulo's *Revista Polo de Arte Contemporânea*. She has served a juror at Capes/MEC and was member of the history, theory and criticism committee of the ANPAP. Among her publications are the books *Arte@Mídia: perspectivas da estética digital* (Senac, 2005); and *Re/escrituras da arte contemporânea: história, arquivo e mídia* (Sulinas, 2015).

Joan Ashworth is an artist working in moving image with a background in stop-frame animation. While studying graphic design at Newport, Gwent, she was introduced to animation, both drawn and stop-frame. She immediately embraced animation as a means of expression and specialized in stop-frame animation for the majority of her degree, as it combined the study of many aspects of art, design and film. Later, studying film-making at the National Film and Television School, Beaconsfield, Buckinghamshire, she also explored live action. She graduated in June 1987 with an 18-minute film The Web, based on Mervyn Peake's Titus Groan, the first book of the Gormenghast trilogy. This was made using stop-frame animation with puppets made of soft leather. The Web was shown at film festivals worldwide, winning the Mari Kuttna Prize for Best British Animation 1987 and broadcast on Channel 4. In September 1987, she set up a production company, 3 Peach Animation, with two partners, Martin Greaves (Producer, NFTS) and Andy Staveley (Director, Royal College of Art). The partners closed 3 Peach in 1997, and she and Greaves set up Seed Fold Films to pursue personal projects.

Cesar Baio is an artist, professor and researcher with background in electronics and media studies. He developed his Ph.D.'s at the *Pontifícia Universidade Católica de São Paulo* with a graduate internship at the *Vilém Flusser Archive* at the *Universität der Künste*, Berlin. During 2017 and 2018, he was visiting Artist–Researcher at *i-DAT*, at *Plymouth University*, UK. He is professor and co-founded of the Graduated Program in Arts of the *Federal University of Ceará*, Brazil, where he coordinates the *actLAB—Laboratório de Pesquisa em Arte, Ciência e Tecnologia*. His Ph.D. investigated how the emergent media technologies reshape the models of representations consolidated in traditional media. His hypothesis suggests the raising of a performative regime of the image, thought by the different forms of relation between bodies and technological interfaces. The series of videos, photos, interactive installations and urban interventions produced by him discuss the insertion of the technology into the cultural practices and power structures. Author of the book 'Máquinas de Imagem: Arte, Tecnologia e Pós-virtualidade' (Machines of Image: Art, Technology and Post-Virtuality), he has published in academic journals and collections. He has participated in conferences, seminars and exhibitions in Brazil and abroad. For further details, see: http://www.cesarbaio.net.

Andrew Bluff is a digital artist, software engineer and researcher at the University of Technology Sydney. Following his Ph.D. research combining immersive technology, interactive art and live performance, he is currently investigating new methods for mixed reality storytelling as a Postdoctoral Research Fellow at the UTS Animal Logic Academy. His technology-based works commonly feature immersive virtual environments that interact with live musicians, dancers or audience members in a fluid and semi-abstract way to create a synesthetic interdependence of sound, vision and movement. In addition to collaborating on major performance works including Stalker Theatre's *Dot and the Kangaroo, Creature:Interactions* and Alon Ilsar's *The Hour*, he has created mobile music apps including DrumStudio and Mobile Phone Orchestra. He has also worked as a software engineer, creating award winning audiovisual software including Vista2 by Jands, the SmartConsole by SmartAV and Pixus by Fairlight Media. For further details, see: http://www.rollerchimp.com.

Sean Clark was born in Eastbourne in 1965 and grew up in West Sussex. He studied Computer Science at Loughborough University before becoming a Researcher at the LUTCHI Research Centre there. He developed an interest in computer-based arts in the mid-1990s and began exhibiting his own digital artwork in 2000. He has since gone on to show work nationally and internationally. He has an M.A. in Digital Arts from Camberwell College of Arts and is currently working towards a practice-based Ph.D. in systems theory and digital art at De Montfort University in Leicester. His core interests are the creative exploration of flow and connectedness and the application of systems thinking to arts practice. In 2016, he was the co-winner with Esther Rolinson, of the inaugural ArtCHI award in San Jose, CA and the Lumen Prize for 3D/Sculpture in London, UK. For further details, see: http://www.seanclark.me.uk.

Harold Cohen was an English painter with an established international reputation when he went to the University of California at San Diego (UCSD) in 1968 for a 1-year visiting professorship. His first experience with computing followed almost immediately, and he never returned to London. He is the author of the celebrated AARON programme, an ongoing research effort in autonomous machine (art-making) intelligence which began when he was a Visiting Scholar at Stanford University's Artificial Intelligence Laboratory in 1973. Together, he and AARON have exhibited at London's Tate Gallery, the Brooklyn Museum, the San Francisco Museum of Modern Art, Amsterdam's Stedelijk Museum and many more of the world's major art spaces. They have also been shown at science centres, including the Ontario Science Centre, the Boston Science Museum and the Los Angeles Museum of Science and Industry. He represented the US in the World Fair in Tsukuba, Japan, in 1985. He has a permanent exhibit in Boston's Computer Museum and has given invited papers on his work at major international conferences on artificial intelligence, computer graphics and art technologies. His work is widely cited, and it is the subject of Pamela McCorduck's *AARON's CODE: Meta-Art, Artificial Intelligence and the Work of Harold Cohen*. The painting machine with which AARON coloured real drawings was premiered at the Computer Museum in Boston in 1995. He died on April 27, 2016 at his home in Encinitas, California at the aged of 87 years. Further details http://www.aaronshome.com/aaron/aaron/index.html.

Brigid Mary Costello is an interactive artist and researcher. She began her career with a focus on the moving image and the practice of cinematography, working as cinematographer on award winning short films and documentaries. She now creates computer-based installations that work with current and past traditions of interactive moving images, exploring the powerful relationship between a body and an interface. In her practice, she has also focused on creating playful experiences, producing works that go beyond conventions of fun and explore the full affective possibilities of play. Her current research for the forthcoming Springer book *Rhythm, Play and Interaction Design* focuses on the bodily experience of rhythm within interaction design practice. She lectures in interaction design at the University of New South Wales in Sydney, Australia. She is also an Associate of the Creativity and Cognition Studios at the University of Technology, Sydney.

Dave Everitt's interests include the implications of the interdisciplinary sciences in creative work, integer patterns (especially magic squares and cubes), the history of number symbolism, order and disorder in mathematical and natural pattern, and computer programming culture. His early work at Nottingham Trent University involved music, visual images, photography, collaborative work and installation. From 1997 as an Artist–Researcher at Loughborough University's computer science department, he began to combine computing with creative activities. In 2000–2002, this spawned collaborative public projects with other artists working in the field. He has been a group and solo recipient of Arts Council England awards, and a member of several steering groups and arts advisory panels. He is currently an independent research fellow at the Institute of Creative Technologies, De Montfort University, Leicester, a lecturer in web technologies, and director of EcoVisum.com. He is active in experimental music, including a performance with the Royal Philharmonic 'Sharp Edge' group, and collaborations with digital and improvisational musicians. He has delivered presentations on emerging technology and usability, on the experience of being an artist collaborating with computer programmers, and has worked as a mediator between artists and programmers. For further details, see: http://daveeveritt.org.

Thomas Hewett is Professor Emeritus of Psychology and Computer Science at Drexel University where for many years he taught courses on Cognitive Psychology, The Psychology of Human Computer Interaction (HCI), The Psychology of HCI Design and Problem Solving and Creativity. He has been Visiting Fellow, Visiting Professor or Visiting Researcher at the University of Vienna, Vienna, Austria, Tampere University, Tampere, Finland, Twente University, Hengelo, The Netherlands, Loughborough University, Loughborough, UK, University of the Aegean, Syros, Greece, and the Battelle Pacific Northwest National Laboratory, Richland, WA, USA. More recently, he was Visiting Professor at the Creativity and Cognition Studios, Faculty of Information Technology, University of Technology Sydney, Australia, and Cognos Distinguished Visiting Scientist at The Human Oriented Technology Laboratory, Carleton University, Ottawa, Canada. For several years, he regularly offered a professional development tutorial on cognitive aspects of interactive system design to interaction designers at both conferences and in-house training sessions. In some of those years, he also taught a weeklong course on Human Problem Solving for the User System Interaction programme at the Technical University of Eindhoven, The Netherlands. Research interests have included identifying areas in which computers can facilitate creative knowledge work, scientific problem-solving environments and networked engineering design.

Beverley Hood is an artist and lecturer in Design at Edinburgh College of Art, University of Edinburgh. She studied Sculpture and Electronic Imaging at Duncan of Jordanstone College of Art, Dundee and Nova Scotia College of Art & Design, Halifax, Canada. Her creative practice interrogates the impact of technology on relationships, the body and human experience, through the creation of practice-based projects and writing. A longstanding research interest is live performance using technology and interdisciplinary collaboration. She is a member of the RAFT and DISIGN research groups at Edinburgh College of Art, and the Centre for Creative and Relational Enquiry, at the University of Edinburgh. She is also a member of the Art & Ethics Research Group (AERG), a Mason Institute research project, at the University of Edinburgh, that draws upon diverse approaches and methodologies from the arts and humanities in conversation with scientific and medical practitioners. For further details, see: http://www.bhood.co.uk and http://www.eca.ed.ac.uk/profile/beverley-hood.

Jean-Pierre Husquinet was born in Ougrée, Belgium and studied art at the Royal Academy for Arts in Liège between 1973 and 1979. He is a painter, a musician, a sculptor, a printer and an editor. In 1979, he began to specialize in silk screen printing and in 1982 began to work in a geometric way. He is co-founder and co-editor of the magazine *Mesures Art International*. His first works using rope as a material date from 1993 with an installation in the woods of Horion-Hozémont in Belgium. In 1995, he began teaching at the art school of Valenciennes in France. He exhibits regularly, mainly making installations in different sites, natural and industrial, throughout Europe, and in Korea, Russia, Estonia, and Senegal, where he also takes part in musical performances. In 1998, he realized his first audio CD with four musicians and is preparing another one which includes musical and visual correspondence work. He participated in the making of two books with the poets Julien Blaine and Dominique Sampiero and created many portfolios with various artists. He is now working on a new kind of catalogue which is concerned with a subject between anthropology and modernity.

Fré Ilgen (b. 1956, The Netherlands), based in Berlin, is a sculptor, painter and a theorist and curator. His paintings, sculptures and mobiles depict a reality that is not a solid mass but a swirling movement of shifting relationships, using abstract as well as figurative forms. He combines features from Western and Eastern cultures and philosophies, like from the Baroque and Indian sunyata. His extensive interest in visual perception and his interest in neuroscience motivate him exploring artworks that are visually powerful, appealing in dynamic compositions, defying gravity and simulating continuous change. These purposely cause a pleasant bewilderment in the viewer, because his works do not offer any singular narrative besides a fusion of the positive and negative in life. His interests and knowledge span across times and cultures. Exhibitions include more than 45 solo exhibitions and more than 150 group exhibitions in galleries, museums, corporations, foundations and at art fairs and biennials (incl. the 56th Venice Biennial). He moderates the award winning 'Checkpoint Ilgen' idealistic art salon, which he and his wife Jacqueline host in Berlin. He lectures widely at universities, fine art academies, galleries and international conferences, like in Europe, USA, East Asia. For further details, see: http://www.freilgen.com.

INCOSE Paolo Ruffino, Matteo Cremonesi, Davide Prati and Filippo Cuttica have been working together since 2006 as the art collective IOCOSE. IOCOSE's art investigates the after-failure moment of the teleological narratives of technological and cultural development, in regards to both their enthusiastic and pessimistic visions. They have been exhibiting internationally at several art institutions and festivals, including Venice Biennale (2011, 2013), Tate Modern (London, 2011), Science Gallery (Dublin, 2012), Jeu de Paume (Paris, 2011), FACT (Liverpool, 2012), Transmediale (Berlin, 2013, 2015), Fotomuseum Winterthur (Switzerland, 2017), iMAL (Brussels, 2018), MAMbo (Bologna, 2018) and featured in publications such as Wired magazine, The Creators Project, Flash Art, Neural, Liberation, Der Spiegel, El Pais. For further details, see: http://iocose.org.

Andrew Johnston is a researcher and interaction/software designer based in Sydney, Australia. His work focuses on the design of systems that support experimental, exploratory approaches to interaction, and the experiences and practices of the people who use them. In recent years, he has created large-scale interactive projection systems for dance and physical theatre performances in collaboration with Stalker Theatre. Productions featuring his work have toured internationally and been attended by more than 30,000 people to date. He is Associate Professor at the University of Technology Sydney, where he works as the Research and Course Director of the UTS Animal Logic Academy, a unique, professionally equipped studio focusing on the creative application and design of digital technologies. He also co-directs the Creativity and Cognition Studios, an interdisciplinary research group working at the intersection of performance, art and technology. For further details, see: andrewjohnston.net.

Michael Kidner was born in 1917 in the UK. He received an honours degree in history and anthropology at Cambridge University in 1939 and from 1940 to 1946 served in the Canadian Army. He studied art in London and Paris between 1947 and 1953. In 1957, his work was included in Metavisual, Tachiste and Abstract Art in England, the first post-war exhibition of British abstract art. From 1957, he began his search for the objective use of colour leading to stripe and wave paintings emphasizing colour interaction. From 1966, he began to use colour as a code in conjunction with shape and his Columns work reflected the relationship between two and three dimensions. In the 1970s and 1980s, he explored wavy grid lines in which the area in between the lines become the structural elements of a space expressing infinity and the use of elastic cloth and fiberglass rods express spatial tension where the rods define the contour. From 1996, his imagery incorporated pentagon shapes and tulle material where the purpose is to undermine the gestalt. His distinguished career included many honours, prizes and international shows. He taught at Bath Academy of Art, Corsham from 1962–82 and was Visiting Lecturer at The Slade School of Fine Art from 1975–1979 and Chelsea School of Art from 1981–85. He co-founded the Systems Group with Jeffrey Steele and others in 1969. His work is in many important collections including those of Tate Britain, The Royal Academy, The British Arts Council, as well as in Portugal, Germany, Poland, Hungary, Vienna, Tokyo Russia and America. In 2004, he was elected as a senior Royal Academician. Latterly, he was to see a considerable revival of interest in his work, as general critical interest returned to the abstract painting of the 1960s and early 70s. He continued to work in his studio until his death in 2009.

Graziele Lautenschlaeger is a Brazilian media artist and researcher interested in practices at the intersection between Art and Science, searching to potentialize the poetic and symbolic layers of technological artefacts. Since 2014, she has been Ph.D. candidate in the Institut für Kulturwissenschaft at Humboldt-Universität zu Berlin She graduated in Image and Sound from the Federal University of São Carlos (2002–2005) and her Master's degree was conducted in the Architecture and Urbanism Department of the University of São Paulo, where she collaborated with Nomads.usp—Centre for Interactive Living Studies (2007–2010). In 2008, she was a master exchange student in the Interface Culture Department at Kunstuniversität Linz, Austria and in 2010 she lectured at the Digital Design course at Uniara (Centro Universitário de Araraquara) in Brazil. Between 2011 and 2013, she was a cultural agent at SESC SP (The Social Service of Commerce in São Paulo), curating and producing programmes in Media Art, Digital Culture and Dance. As a visiting researcher and resident artist, she has been to Lagear (Graphics Laboratory for Architecture Experience) at the Federal University of Minas Gerais (2010–2011), LabMIS (Museu da Imagem e Som) in São Paulo (2011) and Salzamt Atelierhaus in Linz (2012). For further details, see: http://www.grazielelautenschlaeger.com.

Jay Alan Yim and Marlena Novak The collaborative localStyle was founded in Amsterdam in 2000 by Marlena Novak and Jay Alan Yim. Their goal is to use the senses to trigger reassessment of existing situations, beginning in 2003 to address issues of climate change and resource extraction, and expanding since 2006 to focus on non-human others via themes as varied as the mating behaviour of hermaphroditic marine flatworms, the sonification of electric fish from the Amazon, experimental Eurasian blackbird grammar and the presumptive logic underlying human taxonomic systems. These intermedia works—a practice that includes experimental 3D media, video, sound, interactive installations, live performance with electronics, audience participation and resistance gardening—have been presented in museums, galleries and alternative venues in more than 40 cities worldwide. Novak studied at Carnegie Mellon University and Northwestern University; she is an Adjunct Assistant Professor at the School of the Art Institute of Chicago, in the Department of Film, Video, New Media and Animation. Yim studied music composition at the University of California Santa Barbara, the Royal College of Music, and Harvard, and computer music at Stanford and MIT. He currently teaches at Northwestern University. For further details, see: http://www.localstyle.tv.

Colin Machin graduated from Hatfield Polytechnic in 1971 with a first-class honours degree in computer science, and went on to study for a Ph.D. in computer science. His work investigated the relationship between the design of computer hardware and that of the operating system, culminating in the design and implementation of a novel variable micro-code computer system and accompanying operating system. He was awarded a Ph.D. in 1976. From 1974 to 1976, he remained at Hatfield Polytechnic as a lecturer before moving to Loughborough University, where he took up a post as lecturer in the Department of Computer Studies (now Computer Science), an appointment held to the present. A sometime member of the British Computer Society's Computer Art Special Interest Group, his contribution to the current debate stems from his expertise in real-time, microprocessor-based control systems. This is just the kind of technology that is required to power digital artworks. One of his particular interests outside of work is photography. Rather than simply taking photographs for posterity, he participates in the activities of a local photographic society and enters local, regional and national photographic competitions and exhibitions.

Manfred Mohr born on 8 June, 1938 in Pforzheim, Germany, worked in Paris from 1963 to 1983 and has lived and worked in New York since 1981. In 1960, he was making Action paintings and in 1961 received the school prize for art of the city of Pforzheim. In 1962, he began the exclusive use of black and white as a means of visual and aesthetic expression. In 1965, he studied lithography at the Ecole des Beaux Arts, Paris and his geometric experiments led to hard-edge painting. In 1968, his first one-man exhibition took place at the Daniel Templon Gallery, Paris. In 1972, sequential computer drawings were introduced and he began to work on fixed structures. He received awards at the World Print Competition, 1973, San Francisco, and the 10th Biennial in Ljubljana. In 1977, he began to work with the 4D hypercube and graph theory and in 1987 renewed the work on the 4D hypercube and extended the work to the 5D and 6D hypercube rotation and their projection as generators of signs. In 1990, he received the Golden Nica at Prix Ars Electronica in Linz and the Camille Graeser Prize in Zürich. In 1994, the first comprehensive monograph on him was published by Waser-Verlag, Zürich and in 1997 he was elected a member of the group, American Abstract Artists. In 1998, he started to use colour, after using black and white for more than three decades to show the complexity of the work through differentiation.

Alex Murray-Leslie is an artist–researcher and co-founder of the art band Chicks on Speed. Her practice-based research focuses on the design and development of somatic wearable musical instruments with a focus on computer-enhanced foot devices for theatrical audiovisual expression. She has performed and exhibited solo and with Chicks on Speed internationally in key art & science institutes, foundations and Biennales, including MoMA New York, Centre Pompidou Paris, Tate Modern, London, 55th and 56th Venice Biennale, ZKM Centre for Art and Media, Karlsruhe, Thyssen-Bornemisza Art Contemporary 21, Vienna, Art Electronica, Linz, Milani Gallery Brisbane, Artspace Sydney, Deitch Projects, New York, Dundee Contemporary Arts and at The National Museum of Modern Art, Kyoto. She is currently adjunct faculty at Interface Cultures and Fashion & Technology, The University of Art and Design, Linz, Research Associate, (CRCDM) Centre for Research Creation in Digital Media, Sunway University, Kuala Lumpur, Research Affiliate at CCC (Critical Curatorial Cybernetic studies) HEAD, The University of Art and Design, Geneva and Artist Fellow at Pier 9, Autodesk, San Francisco.

Frieder Nake born on December 16, 1938 in Stuttgart, Germany, is a mathematician, computer scientist and pioneer of computer art. He is best known internationally for his contributions to the earliest manifestations of computer art. His first exhibition of computer art was in Stuttgart in 1965, with Georg Nees, and in

1968 he took part in the London exhibition Cybernetic Serendipity. He has been a professor of interactive computer graphics at the Department of Computer Science, Bremen, since 1972. After studying mathematics at the University of Stuttgart, where he earned his Diploma and doctoral degrees (in probability theory), he taught in Stuttgart, Toronto and Vancouver, before coming to Bremen. Since 2005, he has also been teaching at the University of the Arts, Bremen. He won the First Prize of the Computer Art Contest of Computers & Automation in 1966. His book *Ästhetik als Informationsverarbeitung* (1974) is one of the first to study connections between aesthetics, computing and information theory.

German Alfonso Nunez is a postdoctoral fellow at the University of São Paulo, Brazil. There he holds a grant from the São Paulo Research Foundation (FAPESP) for his research 'From concretism to the amusement park? The course of technological art in the Brazilian artistic field'. Aiming a social history of the artistic practices concerned with the use and dissemination of electronic or digital technology, he contrasts the Brazilian case with its European and US counterparts. As a practitioner, since 2007 he is a member of the artistic collective known as [+zero], which has exhibited in countries such as Austria, Romania, UK and Brazil.

Jack Ox is creative director of the nonprofit Intermedia Projects Inc. She began as an artist who used research as the method behind her art works. Now she is taking the procedures developed as an artist to the scientific and engineering world of visualization. She presented a paper at IEEE VIZ conference in Paris and is a Ph.D. with a dissertation on 'Manifestations of Conceptual Metaphor and Blending Theories in Science, Design and Art' from Swinburne University of Technology, Melbourne, AU. She is also a longtime member of Leonardo Journal of the International Society for the Arts, Sciences and Technology's editorial board, and has served as both a Research Assistant Professor in art and art history and Research Associate Professor of music at the University of New Mexico (UNM). She is presently a Research Associate with the Center for Advanced Research Computing (CARC) UNM and a Research Fellow at the Art/Sci Center in ATEC, at UTDallas. Her 30-year career of mapping musical scores to paintings such as Kurt Schwitters's intermedia masterpiece, *Ursonate*, Debussy's *Nuages, The Gridjam, J.S.Bach's Ein feste Burg ist unser Gott, BWV 80, Bruckner's Eighth Symphony, and Stravinsky's Symphony in Three Movements is here:* intermediaprojects.org/pages/UrForSale.html.

Michael Quantrill is an artist whose work traverses scientific research and fine art. From 1987 to 1992, he worked as a programmer after which, he left the computing industry and began to formalize his interest in art practice. After studying art and design at Riley College, Hull in 1994, he studied fine art at Loughborough College of Art and Design in 1995. In 1997, he began an ongoing association with the Creativity and Cognition Research Studios at Loughborough University where he began to integrate his drawing practice with advanced computing technology. In 1998, he worked with Manu Uniyal on the ArtParty98 project. This involved a collaborative drawing tool that allowed a number of individuals from international locations to draw on a virtual whiteboard simultaneously. In 2000, he received funding under the Year of the Artist scheme to continue his work. Also in 2000, he formed the Emergency Art Lab with Dave Everitt, culminating in a commission to present work at the Wired and Dangerous Conference in Leicester, UK. In 2001, the Emergency Art Lab was commissioned to perform Club Confessional in the UK and Holland. He has written a number of papers and presented his work and ideas at various international conferences.

Esther Rolinson is an award winning UK-based artist who makes light installations and sculptural works through drawing. Working since 1999, she has major permanent installations in the UK and exhibits her works internationally. Her drawings are exhibited in their own right, and examples of her two-dimensional works have been acquired for the Victoria and Albert Museum Digital Art Collection. She makes drawings in experimental ways to understand structures and sensations, often using simple systems to render overall complex forms. She extends her drawing techniques to develop physical forms and movement sequences that underpin the programming of light movements in her installations. *Her* intuitively built structures and light movements become extendable sculptural systems. They are rendered on various scales and in flexible compositions whilst retaining the same underlying principles of construction. She employs internationally recognized manufacturers and consultants to achieve her pieces and also makes sculptural components by hand in her creative studio practice. *Her* hand-folded acrylic and programmed light installation *Flown*, developed in collaboration with programmer *Sean Clark*, won the Lumen Global Digital Arts Prize, Sculptural and 3D Award 2016 and the inaugural ArtCHI Prize, San Jose, California, 2016. For further details, see: http://www.estherrolinson.co.uk.

Anthony Rowe (b. 1964) is an artist, designer and researcher. He founded digital arts group Squidsoup in 1997, with the aim of creating immersive, emotive and intuitive experiences that merge the physical and the virtual. Squidsoup's groundbreaking work has been seen by millions of people on five continents, at institutions and events as varied as Sydney Opera House (AUS), Salisbury Cathedral (UK), SIGGRAPH (USA) and Ars Electronica (AU). He was Associate Professor of Interaction Design at the Oslo School of Architecture and Design (2009–2014); the same institute that awarded his Ph.D. He received an honorary mention in the Ars Electronica Awards (2017), and previously worked as an illustrator, photographer and sailor, crossing the Atlantic solo (1988). For further details see: http://www.squidsoup.org.

Andre Schappo has engaged in diverse aspects of technology and human support functions through his employment as an IT manager. His working life started at the age of 16 as a farm worker followed by numerous jobs, including agricultural mechanic and barman. His first experience of computing was attending a course on Cobol programming as a mature student. This was followed by a Higher National Diploma and then a Degree Course at Leicester Polytechnic (now De Montfort University). Since then he has been involved in research in various areas, including graphics languages, image processing, colour perception and management and computer supported co-operative work. In 1985, he joined Loughborough University as a member of the computer science technical team. Later, he took on a dual role in the support services for the department and the computing services function. He had responsibility for Apple Macintosh systems across the campus. This enabled him to extend an already strong network of contacts throughout the university which proved to be very important when he joined the COSTART project in 1998 as a technology coordinator. He fervently believes in the superiority of the Macintosh platform for both end users and systems people. He has found that most artists he has met also prefer the Macintosh and so, apart from his interest in art, it is also a common ground between him and the artists.

Jennifer Seevinck is an electronic artist and researcher who creates digital, interactive art systems. Her practice is driven by conceptual questioning and design for audience experience. Themes driving the work include emergence, landscape, data and novel, physical interfaces. Qualitative research into people's experience of interactive art systems is also conducted alongside the practice. The integration of research and practice are key to her approach as practice informs the directions of research enquiry while evaluation research also informs the practice. She has exhibited at conferences and contemporary art galleries in Beijing, Tokyo, Australia and the U.S.A. Research publications include the recent book 'Emergence in Interactive Art' (Springer, 2017). In creating art, she has collaborated with community artists on creative interactive visualizations for the physically disabled, through to working with scientists on their data and artistic visualizations. In the distant past, she was a research scientist in the USA, project managing and designing for virtual reality training applications; and she has developed many interactive arts and interactive applications using state-of-the-art interaction technologies and applied to data visualization, medicine, space and engineering, to date. Currently, she is an academic at the Creative Industries at Queensland University of Technology, Australia. For further details, see: http://www.smartnoise.net.

Christa Sommerer and Laurent Mignonneau are internationally renowned media artists working in the field of interactive computer installation. They are Professors at the University of Art and Design in Linz Austria where they head the Department for Interface Culture at the Institute for Media. Sommerer and Mignonneau previously held positions as Professors at the IAMAS International Academy of Media Arts and Sciences in Gifu, Japan and as Researchers and Artistic Directors at the ATR Media Integration and Communications Research Lab in Kyoto Japan. Sommerer originally studied biology (botany) at the University of Vienna and modern sculpture and art education at the Academy of Fine Arts in Vienna. Mignonneau studied modern Art and Video Art at the 'Ecole des Beaux Arts' in Angouleme, France where he received his masters' degree. They completed their Ph.D. degrees from CAiiA-STAR, University of Wales College of Art, Newport, UK and the University of Kobe Japan, respectively. They have won mayor international media awards, for example, the 'Golden Nica' Ars Electronica Award for Interactive Art 1994 (Linz, Austria), the 'Ovation Award' of the Interactive Media Festival 1995 (Los Angeles, USA), the 'Multi Media Award'95' of the Multimedia Association

Japan and the 'World Technology Award' in London (2001). For further details, see: http://www.interface.ufg.ac.at/christa-laurent/BIOGRAPHY/Biography.html.

Stelarc is an Australian artist who has performed extensively in Japan, Europe and the USA, including new music, dance festivals and experimental theatre. He was a keynote speaker at Creativity and Cognition 1996 and CHI2002. He has used medical imaging, prosthetics, robotics, virtual reality systems and the Internet to explore and extend the parameters of the body. In 1997, he was appointed Honorary Professor of Art and Robotics at Carnegie Mellon University, Pittsburgh. In 2000, he was awarded an Honorary Degree of Laws by Monash University. He has completed Visiting Artist positions in Art and Technology, at the Faculty of Art and Design at Ohio State University in Columbus in 2002, 2003 and 2004. He has been Principal Research Fellow in the Performance Arts Digital Research Unit and a Visiting Professor at The Nottingham Trent University, UK. Between 2006 and 2011, he was Senior Research Fellow and Visiting Artist at the MARCS Lab, University of Western Sydney, Australia and Chair in Performance Art, School of Arts, Brunel University, Uxbridge, UK. In 2010, he received a special projects grant from the Australia Council and was also awarded the Prix Ars Electronica Hybrid Arts Prize. In 2012, he was the recipient of the Michael Cook Performance and Body Artist Award. In 2015, he received the Australia Council's Emerging and Experimental Arts Award. He is presently a Distinguished Research Fellow in the School of Design and Art, Curtin University. His artwork is represented by the Scott Livesey Galleries Melbourne. For further details, see: http://stelarc.org.

Joan Truckenbrod has exhibited her artwork internationally, including the IBM Gallery in New York City, the Smithsonian Institution in Washington DC, Museu de Arte Moderna in Rio de Janeiro and Musee d'Art Modern de la ville de Paris. Her work has been shown in one person exhibits in Chicago, Berlin and London. In 2000 and 2001, she had one person exhibition in Paris and Wiesbaden, Germany. Collections such as Parade Publications in New York and ISA Holding in London include her work. She is a Professor in the Art and Technology Department at the School of the Art Institute of Chicago. Her artwork is represented by FLATFILE Gallery in Chicago, Galerie de Gegenwart in Wiesbaden, Germany, Colville Place Gallery in London, and the Williams Gallery in Princeton, New Jersey. She has received a Scandinavian American Foundation Fellowship and a Fulbright Fellowship, research scholar's award. Her work has been featured recently in an article, Instantanés sur l'art électronique à Chicago, Computer Art@Chicago in artpress #246, May 1999, as well as in Computers in the Visual Arts (1998), Art in the Electronic Age (1993), Photographic Possibilities (1991) and Digital Visions (1987). She published her book *Creative Computer Imaging* in 1988.

Manumaya Uniyal was a doctoral student in the department of computer science at Loughborough University at the time of the COSTART project. His areas of study involved economics, computer graphics, computer animation and virtual reality. In 1996, he completed his Masters' degree in computer visualization and animation at Bournemouth University, UK. From 1996 to 1997, he worked at the

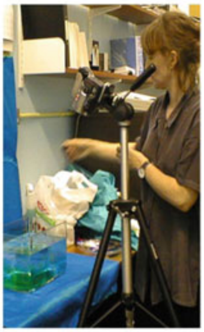
National Institute of Design (NID), Ahmedabad, Gujarat in India. At NID, he was involved in planning and setting up a computer animation laboratory. In 1997, he received a postgraduate scholarship and joined the LUTCHI Research Centre, Loughborough University where he worked on a number of projects covering a wide range of areas. In 1998 with Michael Quantrill, he developed the ArtParty98 project. The project involved a collaborative drawing tool that allowed a number of individuals from international locations to draw on a virtual whiteboard simultaneously. The live artworks were projected on a wall in the nightclub of Loughborough university student's union. He also worked on the Gallery of Future project at Loughborough University. During his research, he has conducted workshops and projects in the UK, India and Sweden and has written papers examining the application of virtual reality in the areas of law, health and tourism.

Roman Verostko Professor Emeritus at Minneapolis College of Art and Design, trained as a painter and art historian and exhibited his first use of electronics in 1967, the Psalms in Sound and Image. With the advent of the personal computer, he gradually developed a personal expert system that includes his own software driving tech pens and paintbrushes mounted on pen plotters. Recipient of the Golden Plotter First Prize (1994, Gladbeck, Germany) and an Ars Electronica honourable mention (1993), his work has been shown in art and technology exhibitions on four continents including Genetic Art—Artificial Life in Linz, 1993 and the ARTEC'95 Biennial in Nagoya, Japan. A past board member of the Inter-Society for Electronic Art (ISEA) and Programme Director for the 4th International Symposium on Electronic Art, he has published articles and lectured internationally on the subject of Art and Algorithm. Recent works include an illuminated binary version of a universal Turing machine and a pen-plotted mural spanning 40 ft in the Frey Science and Engineering Centre at the University of St Thomas, St Paul, Minneapolis. For further details, see: http://www.verostko.com.

George Whale is an artist and software engineer with special interests in drawing, print and computer-mediated creative collaboration. He obtained an honours degree in fine art from Portsmouth Polytechnic in 1983 and a Masters' degree in computing in design from Middlesex Polytechnic in 1989. Previously he was a Research Associate at Loughborough University School of Art and Design, and he worked as a community artist, as a commercial designer and printer and as a graphics software developer. One of the original team members of the London Institute research project, The Integration of Computers, Print Technology and Printmaking (1994–1998), he has been involved in a number of digital collaborations, has exhibited prints internationally and is co-author of *Digital Printmaking* (A & C Black, London). His current research is directed towards modelling some of the cognitive processes underlying observational drawing activity. To the extent that this approach enables drawing strategies to be made explicit and their pictorial consequences to be understood, he believes that this research will have specific relevance to the future teaching and learning of observational drawing.

What fascinates me about a machine is the experience of a physical and intellectual extension of myself. Manfred Mohr

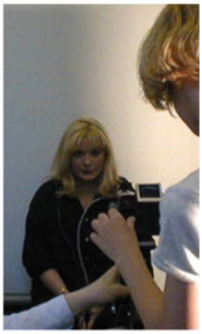
I want to refine my methods of working and find more ways of using the benefits with the pleasures of the tactile and physical. Joan Ashworth



The more than 150 years old history of the 'new medium' photography has already shown that a new technology definitely may add important creative possibilities, without ever really excluding painting or sculpture. Fré Ilgen

In digital art I want to go somewhere I have never imagined going in painting or performance. Ray Ward

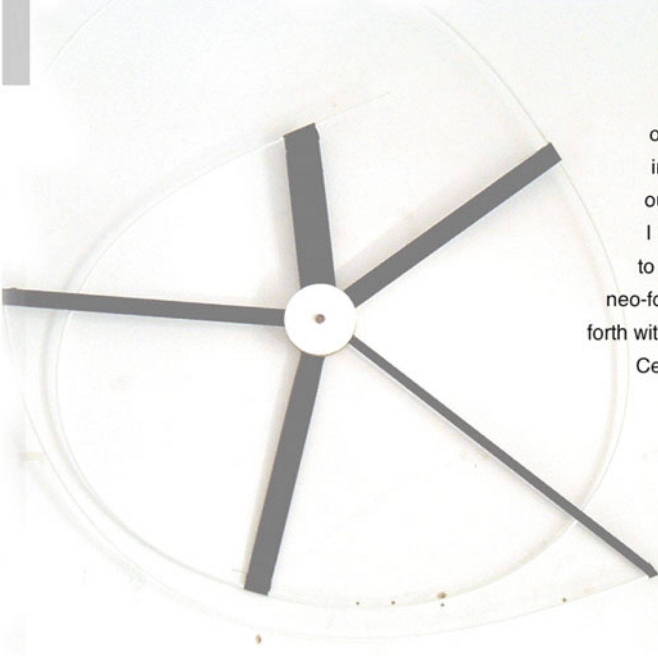
Using digital technology seems to give potential for creating a different type of relationship between object and viewer. Esther Rolinson



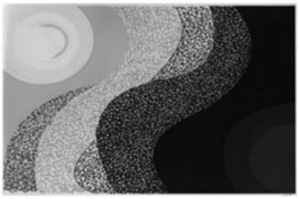
Part I
History

History

It is no longer enough to speak of the convergence or reciprocity of art and science ...but to specify which art and which science, and, by what means they might fruitfully interact. Roy Ascott



The algorist programs of my time will then fade into an archaic past and our code will look quaint. I hope I live long enough to savor the rebirth of this neo-formalist art as it springs forth with vibrant life in the 21st Century. Roman Verostko



And this isn't merely a technological revolution. We are being swept forward in an accelerating cultural revolution of unprecedented scale. Harold Cohen

Theme: History

Fabrizio Poltronieri, Linda Candy and Ernest Edmonds

The technologies that have been most important to artists in recent times have mostly been digital. Art using digital technology was first shown in exhibitions of computer art in 1965, both in Germany and in the USA. One of the artists who showed in that year was Frieder Nake. In 1966, Billy Kluver founded Experiments in Art and Technology, E.A.T., in New York. By 1968 a small number of artists were using computers, in various ways, to produce their work. One of those was Manfred Mohr. This chapter includes reflections by Nake and Mohr as well as an interview with Kluver. Together, these provide valuable insights into the early explorations of art and modern technology. The later developments are briefly reviewed and the history of interactive art described, illustrated by a range of example works. The core chapter is followed by eight contributions on art and technology exploration since the 1960s from artists and historians.

Introduction

The connection between art and computer technology has not been a natural one in the public mind in the recent past. Until the invention of the World Wide Web in 1989, computers were associated mainly with calculations, science, banking and word processing. However, from the early days of computers, some people had always been interested in using them to create art. Computer graphics as art, were first seen by the public in an exhibition of works by Georg Nees[1] at the Studio Galerie, University of Stuttgart in January 1965. The exhibition, which was opened

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_1

by Max Bense,[2] showed works produced with a graph plotter and generated by computer programs written by Nees himself. Later in the same year, A. Michael Noll and Bela Julesz[3] showed computer graphics at the Howard Wise Gallery in New York and, in November, Frieder Nake[4] exhibited his computer graphics at the Wendelin Niedlich Galerie, also in Stuttgart. He recalls that distant beginning and the personalities involved later in this chapter. For a few people, at least, a new era in art and technology had begun.

Some of the outcomes of the early explorations in computers in art were shown at the Cybernetic Serendipity exhibition held at the Institute for Contemporary Art in London in 1968 (Reichardt 1968). It was curated by Jasia Reichardt who also produced one of the first books on the subject 'The Computer in Art' (Reichardt 1971). The 1965 exhibitions, the 1968 Cybernetic Serendipity event and Reichardt's 1971 book all demonstrated the coming together of technologists and artists in collaborations of one form or another. Sometimes it was hard to know who was the artist and who was the technologist, a distinction that was, perhaps, irrelevant in any case. In her book, Reichardt associates concrete poetry and computer art with art movements that had no masterpieces associated with them, but nevertheless, are significant both socially and artistically:

> The salient points are that both these movements are international, that they are motivated by the use of media, technique and method, rather than an ideology, and that those participating in them come from a variety of professions, disciplines and walks of life. Not all concrete poets are in facts poets, and very few so-called computer artists are in fact what we usually mean by 'artists'. (Reichardt 1971: 7)

A case in point is Frieder Nake, who showed his work in a 1965 exhibition.

Personal Recollections of a Distant Beginning, by Frieder Nake

> On an afternoon in late January, 1965, Max Bense had invited the usual crowd of intellectuals, artists, and hangers-on to his *Studiengalerie* up in the ivory tower that housed his institute of philosophy at the University of Stuttgart. Bense was well-known, by the time, to a dedicated international group of avant-garde artists, writers, and thinkers for his critical rationalism and, in particular, his theory of information aesthetics. Shannon's and Weaver's concept of information defined the background for attempts by Bense and his students to invent quantitative measures of the aesthetics of objects.
>
> Many artists had exhibited their works, or had read their texts, in the *Studiengalerie*. It had become a place for all those who shared the view that generating works of art ("aesthetic objects") was as rational an activity as anything in the natural sciences. But now the announcement of this *vernissage* promised something really new, something never (or hardly ever) heard of: computer generated art.
>
> Georg Nees, a mathematician at Siemens in Erlangen, exhibited a small set of no more than ten line drawings. A little brochure appeared for the occasion in the series *rot* (no. 19 of the series). It contained six reproductions of computer drawings accompanied by short descriptions of the algorithmic essence of each of the graphics. The brochure also carried a text in the style of a manifesto by Bense: "Projects of generative aesthetics".

A flock of artists from the Stuttgart Academy of Fine Arts, and from the city were present. Among them, if I recall correctly, Anton Stankowski, Heinz Trökes, K. R. H. Sonderborg, Herbert W. Kapitzki. Some of them became nervous, hostile, furious. Some left. If these pictures were done by use of a computer, how could they possibly be art. The idea was ridiculous! Where was the inspiration, the intuition, the creative act? What the heck could be the message of these pictures? They were nothing but black straight lines on white paper, combined into simple geometric shapes. Variations, combinatorics, randomness. Indeed, randomness had played an important role in the generative process whereby a digital computer had controlled a flat-bed drawing machine, the remarkable Zuse Z64 Graphomat, to output the graphics.

But even randomness, the artists learned, was not really random but only calculated pseudo-randomness, the type of randomness possible on a digital computer. A fake, from start to end, christened as art …!

Max Bense, observing the unrest among his guests and friends, was provocative as always but, at the same time, made an attempt to dampen their protests. He quickly invented the term "artificial art" to distinguish the computer products from human pictures. A great idea, it seems to me: Generative art was artificial art. Chomsky's generative grammar and Minsky's artificial intelligence were combined into a new approach to one of the most cherished human endeavours. The birth of digital art became the birth of artificial art. In 1965, in Stutttgart, a new page in the book of artificiality was turned over.

For me as a young and innocent witness of the scene, all this was exciting and puzzling. How seriously these famous people seemed to be taking something that, to me, was every day and business as usual. Only a few kilometres away from the location of this world-wide first exhibition of computer art, at the computing centre of the university, I had programmed drawings quite similar to some of George Nees'. Sets, bundles, and structures of straight lines, determined by calculated randomness and put on paper by a computer controlled drawing device—it existed all up there, at the centre, too. It had been my job as a student assistant to develop from scratch a basic program package to control the same Graphomat drawing machine that Nees had access to, but from a different computer platform. This job was finished by mid 1964. As one set of test pictures, I had chosen random line patterns of different kinds.

Now I discovered that elsewhere, others had had similar ideas. But to top this, Nees had dared to exhibit the works and claim they were fine art, albeit only artificial art. Why then shouldn‘t I dare do the same?

I approached Wendelin Niedlich, a bookseller, art gallery owner, and cultural institution in Stuttgart. To my surprise, he agreed to mount a show later that year. So in November of 1965, a second exhibition of computer generated art took place in Stuttgart. The set that Georg Nees had shown earlier was included as an add-on to an exhibition of a substantially larger collection of my works. Around the time I learned that, in the USA, A. Michael Noll and Bela Julesz had had a show at the Howard Wise Gallery in New York already in April that same year. Noll was awarded the first prize of the computer art contest of the journal, *Computers and Automation*, in August, 1965. 1965 marks the year of three such events.

The press, television, some art colleges, symposia got interested in what I did. A great time started for a young mathematician who had become an artist. In 1966, Computers and Automation honoured me with the first prize in their contest. In 1969, Georg Nees published his doctoral dissertation. It became the first ever, I believe, on computer art. Max Bense had been his advisor.

Projects of generative art played a role motivating Jasia Reichardt to assemble that now historic show, Cybernetic Serendipity, at the Institute of Contemporary Art in London, in the summer of 1968. By far not as well-known is a series of symposia, exhibitions, even an international journal (*Bit International*) that were initiated and directed by the late Boris Kelemen and his colleagues at the Galleries of the City of Zagreb, Yugoslavia.[5] Concrete and constructivist art then met emerging computer art in a socialist country. The country doesn't exist anymore. How about the art?

Frieder Nake, University of Bremen, 2001

The 1965 exhibitions and *Cybernetic Serendipity* were not the only signs in the 1960s of the emerging importance of the computer in the arts. The interdisciplinary art, science and technology journal, Leonardo, was founded in 1968.[6] Subsequently, in 1969, the Computer Arts Society was formed in London to promote the creative use of computers in the arts. This society staged *Event One* in the same year, at the Royal College of Art in London, and began a lively debate through its bulletin, 'Page' which continued into the 1980s (Page 1968–1981).

In 1966, Billy Kluver founded *Experiments in* Art *and Technology*-E.A.T., in New York (Hultén 1968). He had been an Assistant Professor of Electrical Engineering, at the University of California at Berkeley, and was subsequently at Bell Telephone Laboratories. In the early 1960s, he collaborated with artists on works of art incorporating new technology, including Jean Tinguely, Jasper Johns, Yvonne Rainer, Robert Rauschenberg, John Cage and Andy Warhol. Garnet Hertz interviewed him about E.A.T. in 1995. That interview forms the next section.

E.A.T. An Interview with Billy Kluver[7] by Garnet Hertz[8]

Garnet Hertz: In an attempt to bring technologists and artists together, Experiments in Art and Technology was formed in 1966. E.A.T., as the group was called, existed to link artists and engineers in collaborative projects. The apparently impossible gap of engineering and art was explicitly spanned for the first time. At the forefront of this movement was the electrical engineer Billy Kluver, a Ph.D. in electrical engineering, who was equally involved in the contemporary art scene.

To get to the historical bottom of E.A.T. and the art and technology movement, I tracked down Billy Kluver in New York. Still directing E.A.T. after thirty years, he shared with me his memories, thoughts, and goals.

H: What were some of the original ideas and goals in the formation of E.A.T.?

Billy Kluver: The goal from the beginning was to provide new materials for artists in the form of technology. A shift happened because, from my own experience, I had worked in 1960 with Tinguely to do the machine that destroyed itself in the Garden of MoMA. At that time, I employed—or coerced—a lot of my co-workers at Bell Labs to work on the project.

When I saw that, I realized that the engineers could help the artists; the engineers themselves could be the materials for the artists. After the event, I got besieged by a lot of artists in New York like Andy Warhol, Robert Rauschenberg, Jasper Johns—all of them. Robert Whitman and Rauschenberg put the notion together that it should be a collaboration between artists and engineers, where they were equally represented. The idea was that a one to one collaboration could produce something that neither of the two could individually foresee. And that was the basis for the whole thing, and the system developed from there.

We had to do a lot of 'propaganda' because in the 1960s the difference between art and engineering was an enormous canyon. We understood that we had to recruit engineers—that was the barrier we had to go through.

This whole thing spread within a year or two all over the United States. So, when an artist phoned in and said: "I have this problem." we had one person on the staff that would find an engineer to help them out—and that was it.

The other thing that we did from the very beginning was organize large projects. The first one of course was NINE EVENINGS in 1966, out of which E.A.T. actually came. The main breakthrough in NINE EVENINGS was scale. Everybody in New York was there. Practically every artist in New York helped make it a go, and about 10,000 spectators saw it. Since then we have initiated forty to fifty projects, the last one happening last summer in Northern Greenland. So those are the two operations of E.A.T.: matching and making projects.

H: I have a quote here … "Kluver saw many parallels between contemporary art and science, both of which were concerned basically with the investigation of life … a vision of American technological genius humanized and made wiser by the imaginative perception of artists …" Does that accurately describe your goal?

K: Well, it could be said better than that … The way I see it is that artists provide non-artists—engineers or whomever—a certain number of things which non-artists do not possess. The engineer expands his vision and gets involved with problems which are not the kind of rational problems that come up in his daily routine. And the engineer becomes committed because it becomes a fascinating technological problem that nobody else would have raised.

If the engineer gets involved with the kinds of questions that an artist would raise, then the activities of the engineer goes closer towards that of humanity … Now, this is all sort of philosophical—in practice it has to do with doing it.

H: So, is technology a transparent medium that artists should be able to use … there's not really a moral side to technology?

K: Well, no. The artists have shaped technology. They have helped make technology more human. They automatically will because they're artists. That's by definition. If they do something it automatically comes out human. There's no way you can come out and say that if art is the driving force in a technological situation that it will come out with destructive ideas. That's not possible. But what happens, of course, is that the artist widens the vision of the engineer.

H: And so artists can provide a conscience or humanizing element to the technology?

K: Yes, that's what I mean … but that's saying it too much. There might be other consciousness that come from other sources than art. I think there is a huge consciousness inside technology that hasn't been tapped.

H: It seemed like the whole art and technology movement of the late 1960s seemed to lose some of its initial momentum in the 1970s—at least that's the impression that the postmodern texts give …

K: The texts are horrible—one of the amusing things is that they tell us we've done things we never did. But—the question of the momentum already in the first newsletter we said that if we were successful we would disappear. We would disappear because there is really no function like E.A.T. that needs to exist in society if we were successful. It would be perfectly natural for an artist to be able to contact an engineer him or herself. If it was natural, why should we be involved? And that's what we have stated from the beginning—and of course that is what has happened. The universities, the computer graphic societies, artist societies, and organizations like your own—it was inevitable.

People in New York wanted us to move in, to set up labs with all of the equipment, but we constantly refused. It was not a matter of institutionalizing. I'm very pleased that the initial attitude was like that because it meant that we could still exist. To institutionalize anything in this area is dangerous and self-destructive. It's just a matter of solving problems, and you can do that forever.

H: It makes sense that people critical of E.A.T. have misinterpreted it as being very institutionalized—when in reality it is quite the opposite.
K: The main thing is that we never anticipated in the growth in the late sixties—and you had to take care of it—so you needed a staff. Everybody then immediately thought "Oh my God, they're making a lot of money". Actually, you can't believe all of the debts that we had. I saved E.A.T. by selling every artwork I had, not by making money. I sold things that would have made me a billionaire if I would have held on to them.
H: How do you "match" artists through E.A.T.?
K: Almost anybody who calls us, we help. I never ask to see people's paintings or anything that they do. Usually the conversation starts off with "I have a problem …" After that, I always ask the same three questions when somebody calls me about something: (1) How big is it, (2) How many people are going to see it, and (3) Is it inside or outside? If there is no answer to any one of these three questions—like "It could be as big as you want", or "It could be inside or outside"—you know that he or she has no idea of what they're doing. They haven't taken into account the reality of the project. If you can get down to the reality of the problem, you can usually solve it in a few minutes. It's amazing how simple it is to find the answer.

While matching, I always have the artist call the engineer directly. There is a lot of intimidation there in the first place. E.A.T.'s most important role is to eliminate the initial intimidation. Once the engineer and the artist get to talk together—if there is anything there—it will happen. If there isn't, it will die in ten seconds. It's happened that way for over thirty years.

H: So there's no mission of E.A.T. overtaking the art scene …
K: Overtake? It's already been overtaken. Namely that people can talk about it without being terrified. This has been what I've said since the early sixties. Nobody then could believe that an artist could talk to an engineer … For example, do you know the group called S.R.L.?
H: Yeah, Survival Research Laboratories with Mark Pauline …
K: We talk now and then. I see them as being brilliant—just totally brilliant. He is of the next generation and he understands how the business of "getting things done". And that's what it's all about—GETTING IT DONE—that's the key to all of it. Artists will often be intimidated by "Oh, it's a problem"—they think a power plug is an enemy.
H: So, what if somebody were to call you the "Godfather of Technology and Art"?
K: Well, I guess in a way it's probably true. However, Tatlin is to me the real Godfather —the constructivist artist. That group embraced technology, and embraced it in terms of art.

Many people wanted E.A.T. to be about art and science, but I insisted it be art and technology. Art and science have really nothing to do with each other. Science is science and art is art. Technology is the material and the physicality. However, as far as that goes— other people would have to agree with you, but I think that's probably true—that I would be the Godfather of Art and Technology.

Interview date: April 19th, 1995

Systems into Art

The period from the mid to late 1960s was an exciting time in experimental art. Frieder Nake demonstrates both the energy of the time and the tensions between the technologist and artist roles. Kluver even says that "nobody then could believe that an artist could talk to an engineer". This tension, between technology and art remains, in a lesser form, even today. In some ways, it is a persistent theme of this book. To a few people in the 1960s and to many today, however, it is seen as a creative tension driving forward the development of new art.

Both Frieder Nake and Billy Kluver refer to the artistic tradition of Constructivism.[9] New movements in Russian art in the early part of the 20th Century provided an important context to the arrival of new technology in art. An even earlier starting point for the story of computers in art could be Malevich's essay of 1919, "On new systems in art" (Malevich 1968). In it, he introduces the notion of making art with the help of "a law for the constructional inter-relationships of forms", by which he meant the language, or system of form, rather than representations of the visual world. Patricia Railing, in "From Science to Systems of Art" (Railing 1989) shows how Malevich looked towards science to give a formal basis to his art. Developments of such notions were widespread in the 20th Century, for example, in a discussion of the influences on British Systems movement, Stephen Bann says:

> It is not the recurrence of the rectangle in Van Doesburg's work which needs to engage us, but the series of relationships between rectangles and the extent to which those relationships can be adequately formalised. (Bann 1972)

Malevich's insight into science and systems came well before the advent of computers, but at a time when mathematical logicians were developing theories that proved to be very important for the invention of the computer. This work on mathematical logic was investigating particular kinds of system, known as formal systems. These are sets of precise rules that apply to finite sets of objects rather like the rules of chess and the chess pieces. Such systems are fundamental in computer programming. A computer is basically a logical machine that manipulates systems of symbols. The symbols have formal rules that determine how they relate to one another, rather as the pieces on a chess board can be placed in very many different arrangements, but only ones in which certain rules are obeyed. When a computer manipulates such a system, it automatically moves the pieces, keeping within the rules, and searches for a result, such as check-mate. Another example of such a system is a collection of shapes with defined correspondences between them, such as a Lego™ set (Lego). In effect, the computer can re-arrange the pieces in any way, but only so that the rules, that determine how they fit, are followed.

The output that a computer produces, be it text, sounds, drawings or movement, is generated by a mapping from a set of internal symbols to a set of physical entities such as marks, sounds or actions. The internal symbols, in turn, are determined by the operation of a formal system. For all its ability to calculate quickly or put images on screens or paper, it is the operation of formal systems that is at the core of what is unique about the computer. For artists with an interest in systems, the computer was a natural and irresistible medium to explore. Whilst a role for logical systems in art is both possible and interesting, the concrete realization of formal systems in logical machines, i.e. computers, brought new possibilities into play. The formal systems became dynamic as, in effect, they became expressed in computer programs. Whereas before, formal systems were abstract and manipulated by human action, now a machine existed that could perform such manipulation automatically. It became possible, for example, to build machines that could play chess. This meant that an important step forward from Malevich's concept of systems in art was taken by the artists who adopted programming in the 1960s. Each of them approached the subject from his or her personal point of view and not all of them would use the term 'system' in relation to their art, but if they programmed, they certainly used a system in practice.

As Frieder Nake explained above, Max Bense discussed 'generative art' in his essay "Projects of generative aesthetics" (Bense 1971). To quote him, "… generative aesthetics is an 'aesthetics of production', which makes possible the methodical production of aesthetic states, by dividing this process into a finite number of distinct and separate steps which are capable of formulation" and, specifically, "… I want to mention the computer graphics made by Georg Nees at Siemens in Erlangen which were developed deliberately as aesthetic objects. The programming was done in ALGOL and the random number generator was used to provide the stochastic dispersal of graphic elements, e.g. the positioning of connecting squares." Nees and Nake exhibited together in late 1965 and "when Manfred Mohr, who knew Nake, started producing drawings with a computer program in 1968 he termed it "generative art." (Boden and Edmonds 2009). As we see in the following contribution by Mohr, he still uses this term".

Generative Art by Manfred Mohr

In my artistic development, I did not have the typical constructivist background (Rickey 1967). I was an action painter and jazz musician. Through a development of consciousness, I detached myself from spontaneous expressions and turned myself to a more constructivist and, therefore, geometric expression (Keiner et al. 1994). Beyond this, my art developed into an algorithmic art in which inventing rules (algorithms) is the starting point and basis of my research. These compositional rules are not necessarily based on already imaginable forms, but on abstract and systematic processes. My rules are parametric rules, which means that at certain points in the process, conditions have to be set for which, in some cases, random choices can be employed.

In my work, similar to a journey, only the starting point and a theoretical destination is known. What happens during the journey is often unexpected and surprising. Even though my work process is rational and systematic, as well as controlled by visual criteria at all times, it is always open to surprises. With such parametric rules, the actual image is created as the result of a process. Since 1973, in my research, I have been concentrating on fracturing the symmetry of a cube, without questioning the structure of the cube as a "system". This disturbance or disintegration of symmetry is the basic generator of new constructions and relationships. What I am interested in are the two-dimensional signs, "etres graphiques" resulting from the projection of the lines of a cube. I describe them as unstable signs because they evoke visual unrest.

My artwork is always the result of a calculation. At the same time, however, it is not a mathematical art, but rather an expression of my artistic experience. The rules I invent reflect my thinking and feelings. It is not necessarily the system or logic of my work I want to present, but the visual invention which results from it. My artistic goal is reached when a finished work can dissociate itself from its logical content and stand convincingly as an independent abstract entity. These algorithms can become very complex, that is to say, complicated and difficult to survey. In order to master this problem, the use of a computer is

Fig. 1 P-049/S: Plotter drawing ink/paper 1970 © Manfred Mohr

necessary in my work. Only in this way is it possible to overlay as many rules as necessary without losing control. It is inevitable that the results—that is, my images—are not readable at first glance. The information is deeply buried and a certain participation is demanded from the spectator, a readiness to interrogate this material (Fig. 1).

In principle, all my work can be verified and rationally understood. This does not mean that there is no room for associations and imagination. On the contrary, the rational part of my work is limited basically to its production. What one experiences, understands, learns, dreams … or interprets because of the presence of the artwork rests solely in the mind of the spectator. An artwork is only a starting point, a principle of order, an artist's statement, intended to provoke the spectator to continue his investigations. The steady increase of complexity in my work forced me to reconsider the use of the binary system black and white in order to find a more adequate visual expression. Adding colours to my work describe spatial relationships which are not based on colour theory. The colours should be seen as random elements, showing through their differentiation the complexity and spatial ambiguity essential to my work (Mohr 2001) (Fig. 2).

My colour work is shown as inkjet images, and also on a flat screen presenting a slow motion animation, so that time after time a different image appears. This work phase (as well as all my work since 1990) is based on the six-dimensional hyper-cube. This

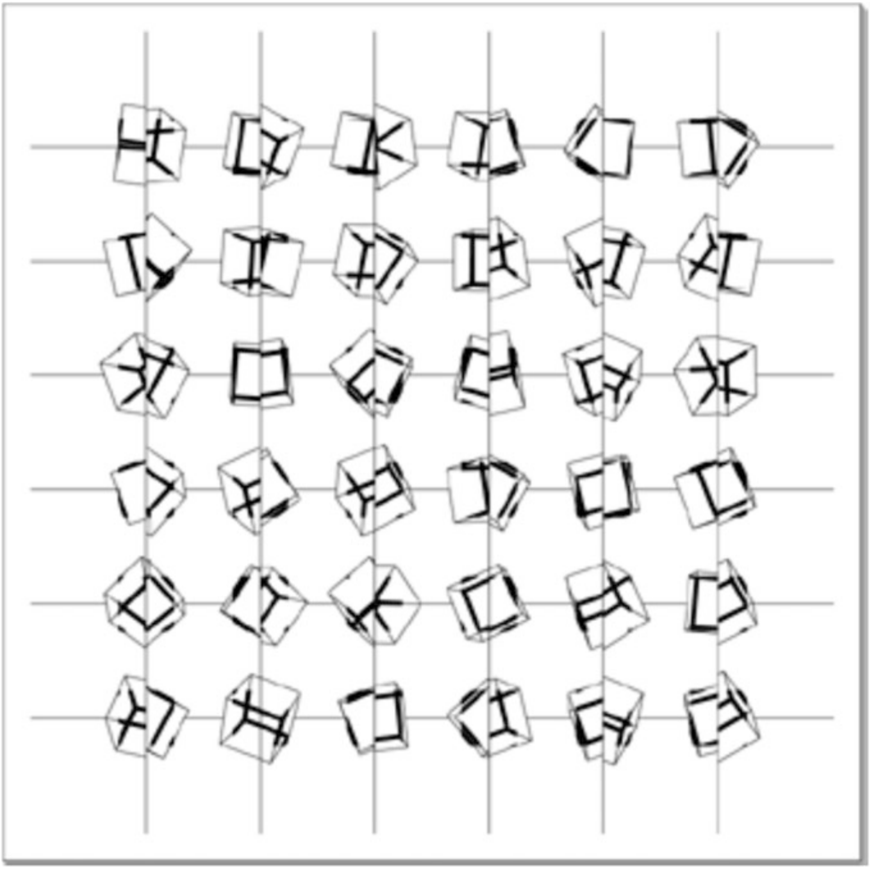


Fig. 2 P-197/S: Plotter drawing ink/paper 1977 © Manfred Mohr

geometrically defined structure has 32 diagonals. The endpoints of each diagonal lie diametrically opposite in the structure. A “diagonal-path” is the connection of two such diametric points through the network of edges of this complex structure. In a six-dimensional hyper-cube, each of these 32 diagonals have 720 different “diagonal-paths”. For each work a random selection of four “diagonal-paths” from this repertoire of 23,040 (32 * 720) possible paths is made (thick lines) and are ordered from 1 to 4. The corresponding vectors are connected with thin lines. Thus, vector pairs are created and together with the thin lines, form planar quadrilaterals or colour fields (Fig. 3).

In each work, two colour fields must stay white. The two outer “diagonal-paths” (one and four) are connected in the same way but without thin lines, wrapping the image around the outside of the bounding rectangle. The hypercube is rotated in six-dimensional space and then projected into two-dimensional space. The resulting image overlays the colour fields from front to back. Together with the “diagonal-paths”, the resulting image creates unimaginable constellations.

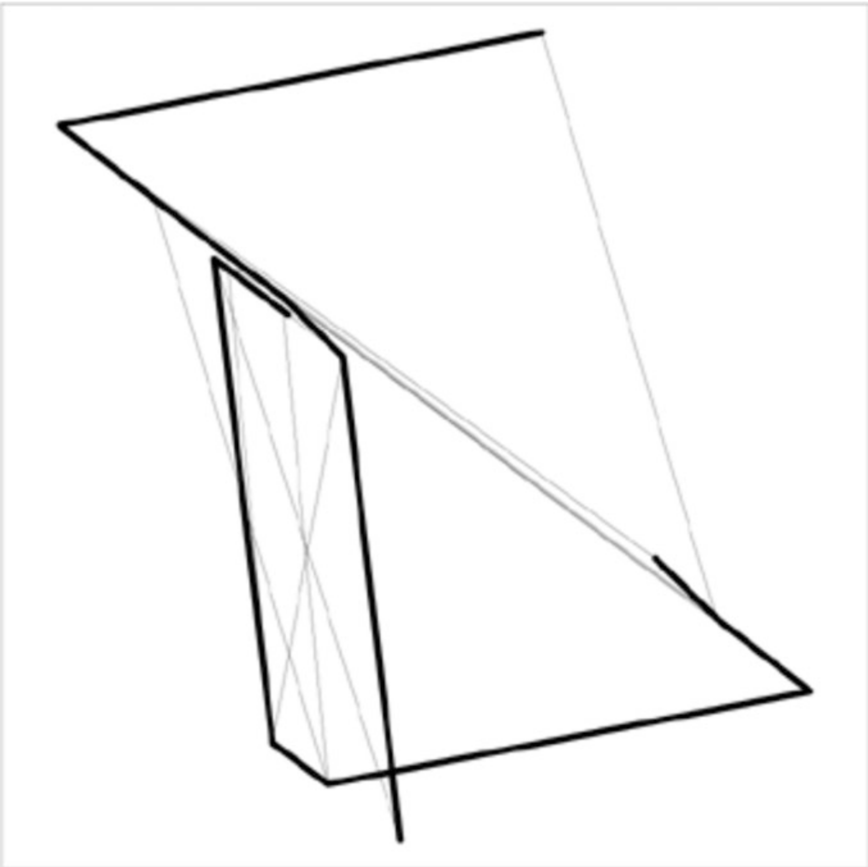


Fig. 3 P-503/U Plotter drawing ink/paper 1997 © Manfred Mohr

The Growth of Art and Technology

The term ‘Generative Art’ is still current within the relevant artistic community. Since 1998, a series of conferences have been held in Milan with that title (Generativeart.com), and Brian Eno has been influential in promoting and using generative art methods (Eno 1996). In both music and in visual art, the use of the term has now converged on work that has been produced both by the activation of a set of rules and where the artist lets a computer system take over at least some of the decision-making. The artist nevertheless determines the rules. Often contemporary generative art is time based, or even interactive, where the computer’s actions on the rules are seen to unfold as they are executed. See Boden and Edmonds (2009) for further details about the various attributes and manifestations of generative art.

In the last part of the 20th Century, there was a remarkable growth in generative art, in all its senses, and in the cross over between technology and art in other respects. Many organizations have been formed and the number of artists involved with digital technology has multiplied. By the 1980s, YLEM (Artists in Science and Technology) had been formed in Palo Alto, California (YLEM 2017); Electra, a large exhibition of electricity and electronics in the art of the 20th Century, was held in Paris (Popper 1983); and the artists’ initiative V2 (Lab for The Unstable Media), in Rotterdam, made the exploration of the impact of technology on society central to its work. In 1987, Ars Electronica in Linz, Austria, began the Prix Ars Electronica. Each year, juries of international experts award highly prestigious prizes to artists working in a wide range of digital media (Prix Ars Electronica 2017). Another important organization is ZKM in Karslruhe, Germany, which combines dedicated exhibiting space with research and library facilities, all dedicated to art and digital media (ZKM 1997). The NCC-ICC in Tokyo, is equally active in high-value and high standard exhibitions, competitions and meetings on art and technology (NTT-ICC 1998). The research in art and technology that was undertaken at the Advanced Telecommunications Research Institute International (ATR) laboratories in the Kansai region is particularly notable, because it was grounded in a technological world into which artists entered as full collaborators and, in some cases, as project leaders. At ATR, new technologies were developed with, and by artists, at the same time as new art forms are evolved (ATR 2017).

Organizations promoting digital art have arisen from a wide variety of backgrounds, including the visual arts, music, performance and film. Each of these starting points brings with it its own critical framework and orientation with respect to art and technology. The conceptual paths represented by performance and film, for example, have also embraced digital technology and offer their own perspective. In fact, computer generated films were made at Bell Laboratories from the early 1960s. Time, as employed in film and performance, as well as interaction and participation, are particularly significant in the context of the computer. These possibilities have come to the fore most strongly in the recent past now that the power of the computer is sufficient for many of the early dreams to be realized. Computers are important for art practice in many different ways and in relation to a wide range of media.

The media that are used in digital art apply to many art forms, including painting, performance, film and participation. Where the medium is static such as printing, the technology issues concerned with the output devices (e.g. printers, video projection) are well understood. However, the situation is quite complex when it comes to interactive art. Here, we are concerned with the way that the technology behaves, as well as, for example, how it looks.

There are many pathways to the development of innovation in art and technology and the organizations mentioned above have different agendas and frameworks that influence the particular approach adopted. The experiences in art and technology exploration that underpin this book spring from a field with a multi-disciplinary character. For example, Human-Computer Interaction (HCI) combines new developments in interactive digital technology with research into the associated human issues (Hewett et al. 1992) to contribute to art.

Interactive art is a particular form that has grown in importance specifically because of the invention of the computer. It is an important aspect of the context for this book, which we will now explore.

Interactive Art

Art becomes interactive when audience participation is an integral part of the artwork. Audience behaviour can cause the artwork itself to change. In making interactive art, the artist goes beyond considerations of how the work will look or sound to an observer. The way that it interacts with the audience is also a crucial part of its essence. The core of such art is in its behaviour more than in any other aspect. The creative practice of the artist is, therefore, quite different to that of a painter. A painting is static and so, in so far as a painter considers audience reaction, the perception of colour relationships, scale or figurative references is most important. In the case of interactive art, however, it is the audience's behavioural response to the artwork's activity that matters most. Audience engagement cannot be seen just in terms of how long they look at the work. It needs to be in terms of what they do, how they develop interactions with the piece and such questions as whether they experience pain or pleasure.

Interactive art is distinguished by its dynamic 'behaviour' in response to external stimuli, such as people moving and speaking. For artists, this means that observing people interact with their works provides a way of understanding exactly how the work ‘performs’, that is, how it responds to the gestures, sounds and other features of audience behaviour in the immediate environment. Observing the responses of an interactive work can reveal unexpected effects that may or may not be predictable from the artist’s point of view. Understanding how people feel about their experience with interactive artworks is an altogether different matter. It is impossible to directly observe the inner feelings of the audience but, for some artists, this is critical to the artwork. In that case, being able to explore the ‘interaction space’ involves some form of evaluation with audience cooperation. However, whatever the level of interest that the artist takes in the audience’s interaction with the work, they will typically see the physical artwork and the participating audience together as a unified system. It is impossible to understand an interactive artwork by just considering the art object unrelated to its audience and the audience actions and, hence, the artist’s focus will be on a combined artificial (art work) and human (audience) art system.

The aesthetics of interactive art include the nature of the behaviour of this total system. The aesthetic experiences of the audience include experiences of action and response as well as experiences of perception, as in a static work of art. The aesthetic decisions made by the artist include decisions about the fine details of the behaviour of the artwork as much as its appearance. The growth in interactive art as a form has, therefore, extended the range of aesthetic considerations being employed. This extension of artistic form, and extension of the scope of aesthetic decision-making, provides the underlying backdrop to this chapter.

Interaction and the Art System

An interactive artwork can be described in terms of its behaviour, the mechanism by which it operates and the means of its construction. As mentioned above, can be helpful to see the interactive artwork in systems terms. A system is a collection of elements, or objects, that relate one to another: a change in one implies changes in others according to the relevant relationships. A static system is one in which nothing changes. An artwork, such as a painting, is essentially a “static system”. We say “essentially” because, of course, the nature of light that falls on a painting, the colour of the wall on which it is hung, etc., certainly change how it looks. Physically, however, the painting does not change. By ‘Art System’, we mean an artwork that consists of a system that changes within itself and where that change is apparent to an observer. The physical art system itself can also be seen as an element of a larger system that includes the audience: this was referred to as ‘The Matrix’ in the Cornock and Edmonds 1970 conference paper, which was later published in Leonardo (Cornock and Edmonds 1973).

The distinction between an art system that has an internal rationale that alone determines how it responds or behaves and one that is affected or stimulated by external factors, such as the degree of light or the presence of a moving human being, is an important one. We can, then, define two kinds of art system in this context. The first is known as a 'closed' system and is one that is not subject to any external influence. It is like a clockwork mechanism that moves and changes within itself according to its own logic. The second is known as an 'open' system in which at least some of the elements can be changed by external forces, be they the wind or human intervention. We can further distinguish between open systems that are influenced by the general environment, such as wind or temperature, and those that are (or are also) influenced by the audience. 'Kinetic' works that respond to wind or temperature change, are at one end of a spectrum and interactive installations at the other. Gina Czarnecki's *Silvers Alter* interactive art system, for example, makes sense only with human participation. The installation takes the form of a large scale back-projection on which human forms 'live'. These figures are changed by the audience's presence and movement within the space. The interactivity encourages a social, physical and verbal interaction between people before the interaction with technology (Czarnecki 2002).

By 'interactive art system' we mean the category where human actions, or measurements from human bodies such as heart rate, affect the behaviour of the system. In this book, the term 'art system' is used to refer to this interactive case. Computer components are frequently used in the construction of interactive art systems because of the speed and flexibility with which they can control responsive devices. Computer technology is fundamentally general purpose and at the same time readily adaptable for whatever form of interaction is required. Today, almost any interactive system from a washing machine to a car to an art system is controlled by computers and realised through software. The use of the computer as a control device that handles interactions according to complex and possibly changing rules has transformed participative art. By programming the computer with the rules that define the artwork's behaviour, the artist is able to build significant dynamic interactive art systems that would otherwise have been impossible to construct and very difficult to conceive in the first place. However, the computer programs that act as controllers of interactive art can be quite complex. This means that considerable effort can be required to understand them and it is often difficult to be sure about the behaviours that can arise in all of the expected and unexpected circumstances. Thus, the artist often experiments as a work is made, in order to be clear about what its behaviour is. The alternative perspective is to treat the work as one full of surprise, even for the artist.

Early Interactive Art

It is possible to debate the origins of interactive art at great length but, for the purpose of this chapter, we can say that it started with Marcel Duchamp. In 1913, excited perhaps by the new technology in bicycle wheel hubs, he took a wheel, fixed it on a stool and placed it, upside down in his studio. Today it is seen as a significant work of art, but Duchamp said,

> Please note that I didn't want to make a work of art out of it. The word 'readymade' did not appear until 1915, when I went to the United States. It was an interesting word, but when I put a bicycle wheel on a stool, the fork down, there was no idea of a 'readymade' or anything else. It was just a distraction. (Cabanne 1971, p 47)

Part of the distraction was in spinning it, so, art or not, it was interactive in the simplest sense. When, later on, he made Rotary Glass Plates, this work was intended to be an artwork. It was also interactive in an extremely simple sense: the viewer had to turn it on, and hope not to be injured it seems! According to Duchamp, the first version "nearly killed Man Ray" when he started it and the glass shattered (Naumann and Obalk 2000).

Much later in the century, in 1952, John Cage composed 4.33, his famous 'silent' piano piece. Although not exactly interactive, this work was, like the Duchamp pieces, incomplete without the actions and attention of the audience. 4.33 encouraged the audience to listen to the ambient sounds around them. Then, in 1953, Yaacov Agam started making what he called Transformable Reliefs: artworks that could be rearranged by the audience. He also made other pieces that were play objects of a sort, that had to be stroked or touched in some other way for the audience to experience them as intended. His interest, according to Günter Metken was "… to release the creativity of the art public, to encourage people to enter into the spirit of his work and change it according to their tastes" (Metken 1977: 5). This interest, put this way, probably captures the intention of many artists who explored interaction in the early days. Akam went on, beyond the transformable works, to try many other ways in which the audience could participate in the creative act.

The kind of work that Duchamp, Cage, Agam and others were making became known widely as "open works" once Umberto Eco's 1962 essay on the subject became known in English (Eco 1989). Based largely on an analysis of modern music (but not mentioning Cage) this paper articulated a growing concern for "an open situation, in movement. A work in progress." Eco stresses that an open work is not one to which the audience can do what they like.

> The possibilities which the work's openness makes available always work within a given field of relations. As in the Einsteinian universe, in the 'work in movement' we may well deny that there is a single prescribed point of view. But this does not mean complete chaos in its internal relations. What it does imply is an organizing rule which governs these relations. (Eco 1989: 19)

Eco distinguished between a performer and a member of the audience, "an interpreter", but argues that, in the context of an open work, they are in much the same situation. Looking at, listening to or interacting with an artwork is in essence a performance in his terms. This point is relevant to the work of Andrew Johnston that is reported in the chapter 'Almost Tangible Musical Interfaces' (Johnson 2011). The "audience" for his virtual instruments consists of performing musicians but his consideration of their interaction with his systems is close to the other work in the book that considers members of the public as audience.

Involving the audience actively in the artwork had many advocates, such as GRAV and in the development of Happenings, where participation was also prevalent. Kirby described rather basic examples of participation in Allan Kaprow's Eat:

> Directly in front of the entrance, apples hung on rough strings from the ceiling. If the visitor wished, he could remove one of the apples and eat it or, if he was not very hungry, merely take a bite from it and leave it dangling. (Kirby 1965)

Participation in the artwork, by becoming part of the art system and interacting with whatever the artist provided, was becoming a familiar experience, whether it was typing at the keyboard or eating the apple.

Jack Burnham, an influential writer concerned with a systems theory perspective on art, saw the importance of understanding artworks in their environment and that all things "which processes art data, … are components of the work of art" (Burnham 1969). By that definition, the audience is part of the artwork. Stephen Willats has also worked from a systems' point of view. and on participation in art since the 1960s. He explains that the function of his work is,

> to transform peoples' perceptions of a deterministic culture of objects and monuments, into the possibilities inherent in the community between people, the richness of its complexity and self-organisation … the artwork having a dynamic, interactive social function. (Willats 2011)

In 1965, Willats published the first issue of Control Magazine, which has included many contributions on socially situated, participative, art and on interactive art systems. In the first issue he states that the artist provides a starting point for the observer and:

> The observer is
> given restrictions inside
> these restrictions are
> variables, with which he
> determines his own
> relationship. (Willats 1965)

This captures a significant aspect of many artists' attitude to their work at that time. The artist set up a system, with restrictions, that the participant could operate in a way that led to their own completion or resolution. For some, like Willats, going beyond those restrictions was also welcomed, so that the possibilities become "limitless", in Willats' term.

A significant pioneer in interactive art was Nicolas Schöffer, who developed the concept of cybernetic sculpture through a series of innovative works (Schöffer 1963). In 1956 he presented CYSP 1, a dynamic sculpture that interacted with a dancer and the environment, using photoelectric cells and a microphone as sensors. Another early innovator was Robert Rauschenberg who, in 1959, made the 'combine' painting Broadcast, which had three radios built into it that members of the audience were free to tune as they wished. It was not his only excursion into interaction. John Cage recounts:

> (I cannot remember the name of the device made of glass which has inside it a delicately balanced mechanism which revolves in response to infrared rays.) Rauchenberg made a painting combining in it two of these devices. The painting was excited when anybody came near it. Belonging to friends in the country, it was destroyed by a cat. (Cage 1961: 106)

Possibly the cat's reaction was an early example of behaviour in relation to interactive art that did not conform to the artist's expectation, although it might have pleased Cage.

As electronics developed, the opportunities for making interactive art increased. Edward Ihnatowicz, for example, showed his work, SAM, in Cybernetic Serendipity (Reichart 1968). SAM looked rather like a flower mounted on a short backbone. It used hydraulics to move its parts in response to sound detected by four microphones in the 'flower-like' head. SAM was more sophisticated in the way it interacted than most of the earlier work in that it not only responded to sound, but it restricted its response to sound of an 'acceptable' volume—not too quiet and not too loud. Cybernetic Serendipity was one of the defining exhibitions of early cybernetic and computer-based art. Another significant early interactive work in the exhibition was Gordon Pask's The Colloquy of Mobiles (Pask 1968). This was a work based on Pask's cybernetic principles in which a set of five mobiles that interacted with one another, communicating through light aiming to reach a stable state of satisfaction. Although it was primarily based on interactions between the mobiles, the public was able to use lights and mirrors to influence the behaviour of the work and so it was a very early example of interactive art.

After he showed SAM, Edward Ihnatowicz went on to build The Senster (Fig. 4), which was a very early, possibly the first, interactive sculpture driven by computer. It was a very large lobster-like arm construction that detected sound and movement in response to which it moved, rather in the same way that SAM did, but with a much more sophisticated appearance. In fact, as with SAM, it seems that the algorithms used to drive the behaviour were relatively simple. It was the complexity of change in the environment and certain rules within the algorithm (such as ignoring very loud noises) that led to this sophisticated appearance. In Ihnatowicz's work, it is clear that how the sculpture looked was of relatively little importance. What mattered was how it behaved and, in particular, how it responded to the audience.

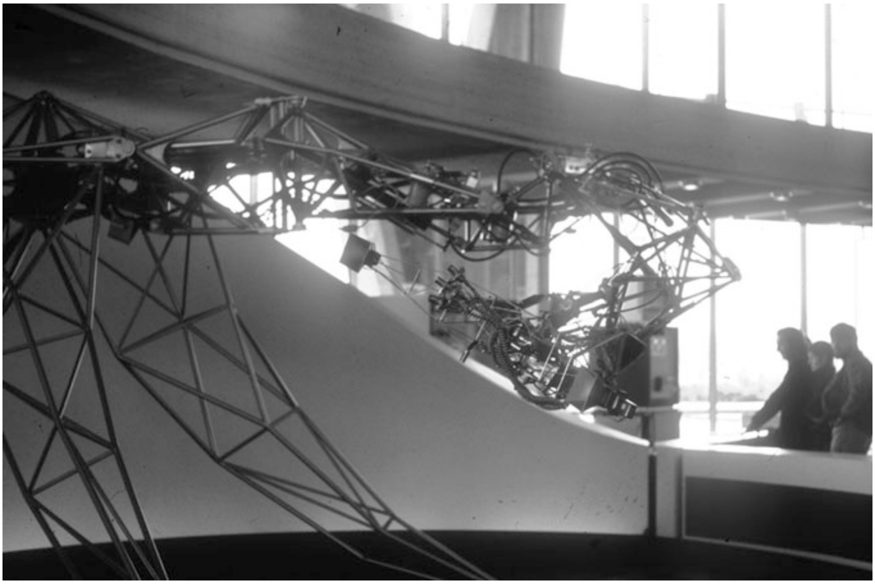


Fig. 4 The Senster. Photograph by Edward Ihnatovitz

At the same time that Ihnatowicz was developing The Senster, Stroud Cornock and Ernest Edmonds were using a computer to develop another interactive artwork, called *Datapack. Interestingly, but perhaps not surprisingly, they used a very similar machine to Ihnatowicz. They used a Honeywell DDP-516 and he used a Philips machine that was very similar and, possibly, a re-badged version of the same computer.

By 1966, Roy Ascott had developed a view in which participation and interaction between the audience and the artwork was central (Ascott 1966):

> In California in the 1970s, introduced to the computer conferencing system of Jacques Vallée, Informedia, I saw at once its potential as a medium for art and in 1979 abandoned painting entirely in order to devote myself wholly and exclusively to exploring telematics as a medium for art. (Ascott 1998)

Ascott has become one of the most active figures in the community, as a teacher, speaker, writer and conference organizer, as well as a practicing artist. Notwithstanding the fact that he “abandoned painting entirely” in the 1970s, he has continued to produce objects from time to time, as can be seen in his 2011 London exhibition, but all of them have addressed the issues of participation and the implications for art of the ideas of computing and communications.

The development of interactive art was a geographically wide phenomenon with significant activity, for example, in Australia. The Sydney collective ‘Optronic Kinetics’ were committed to ‘responsive artworks’ and they made such a work (unnamed) around 1969.

> It consisted of a dark room in which was placed a cathode ray screen controlled by a radio frequency device sensitive to movement. As one moved about the room a wave pattern changed form on the screen and a sound of varying pitch was emitted from a device called a Theremin. (Davis Smith, of Optronic Kinetics, quoted by Stephen Jones in his book on early art and technology in Australia. (Jones 2011: 164))

The Growth of Interactive Art

From the early days of experimental interactive art, it became apparent that the computer could have an important role in facilitating, or managing, interaction. This role is quite different to the computer as a means of producing graphic art images. By 'managing', was meant that the computer controls the way an artwork performs in relation to its environment including its human audience. Because the role of the computer was envisaged as critical to the experience, some speculated that such work could transform the artist from a maker of artworks to a catalyst for creativity. The role of the audience was seen as the important new element in the artwork.

Once the personal computer and the individual workstation appeared, the pace of change in interactive art accelerated significantly. Earlier mini-computers had been interactive and people had developed ideas about human-computer interaction before personal computers appeared, but the new availability of computer power brought access to interactivity out of specialist laboratories. Although artists did not necessarily restrict themselves to using personal computers, the availability of such machines certainly caused a significant growth in interest and activity. The history of these developments in interactive art still has to be told in full, but a number of authors have included partial histories as part of books that address the broader subject of digital, or information, art. Stephen Wilson devoted significant parts of his major book "Information Arts" to reviews of developments in art using artificial life, robotics, gesture and touch etc. (Wilson 2002) and covered an interesting selection of such art in a later publication (Wilson 2010). Another example is Wolf Lieser's book on "Digital Art", which includes a section devoted to selective artworks involving 'Interactive Objects and Art in Public Spaces' (Lieser 2009). There is no space to repeat or extend such histories in this book, but a few examples will help to present a background picture of the field and illustrate the context in which authors have conducted their work.

Karl Sims is an artist, with expert technical skills, who developed a strong line of work around the notion of evolution in artificial life-like systems, implemented in his case, as for many others, by the use of Cellular Automata (CA). A cellular automata system is a matrix of simple on/off elements (cells) that have an effect on their near neighbours at each step in a step by step process (each step being called a 'generation'). All kinds of rules may be invented to determine the effect, for example a cell might be set ‘on’ at the next step if it has two neighbours that are on. Artists, such as Sims, produce graphical representations of such evolving processes as time based artworks, sometimes using random variation in the rules and a selection algorithm that decides which alternative next generation to go with. Sims has made works where he has turned such systems into interactive artworks by replacing the selection algorithm by human choice, a process that he called ‘perceptual selection’ (Sims 1992). Sim’s work Galápagos, from 1997, exemplifies this approach. The work consists of twelve screens on stands driven by a network of twelve Silicon Graphics workstations. Pads on the floor are used for participant actions. They are used in two ways. When there is a set of displays on the screens a participant can stand in front of the one they ‘like best’ and so make the ‘perceptual selection’. Other pads are provided that will activate the development of the next generation of the system. As Sims put it:

> Twelve computers simulate the growth and behaviours of a population of abstract animated forms and display them on twelve screens arranged in an arc. The viewers participate in this exhibit by selecting which organisms they find most aesthetically interesting and standing on step sensors in front of those displays. The selected organisms survive, mate, mutate and reproduce… Although the aesthetics of the participants determine the results, the participants do not design in the traditional sense. They are rather using selective breeding to explore the hyperspace of possible organisms…. (Sims 1998: 68)

The interaction is simple, but the computational complexity that it drives is quite high. It is an example of interaction where relatively simple acts, when taken together and over time can lead to a wide range of outcomes and to complexities that may seem quite surprising in relation to those simple acts taken individually.

Christa Sommerer and Laurent Mignonneau have a substantial history of collaborating on interactive art works based on artificial life (Sommerer and Mignonneau 2009). Indeed, as early as 1992 they made a work, Interactive Plant Growing, that used real plants as the interface that participants touched or approached. A classic example of their work is Life Spacies (Fig. 5), which was created in 1997. Physically, the work consists of a laptop computer on a stand in front a large projection screen. Virtual creatures, appear, grow and move on the screen using artificial life concepts. Participants are invited to type text into the laptop and, as they do, the text is used by the computer to generate new virtual creatures that enter the space. Participants can also type in text that becomes food for the creatures to feed on.

> The creature’s lifetime is not predetermined, rather it is influenced by how much it eats… a creature will starve when it does not eat enough text characters and ultimately die and sink to the ground…
>
> Written text… is used as genetic code, and our text-to-form editor translates the written texts into three-dimensional autonomous creatures whose bodies, behaviours, interactions and survival are solely based on their genetic code and the users’ interactions. (Sommerer and Mignonneau 2009: 107–8)

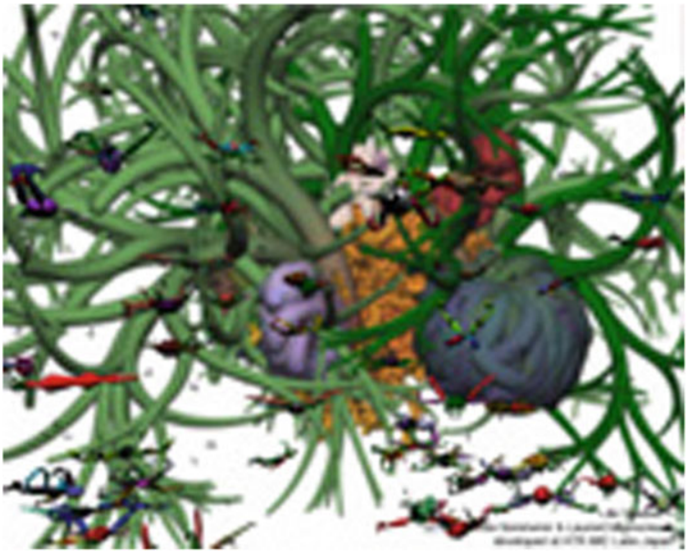


Fig. 5 Life Spacies, Screenshot © 1997, Christa Sommerer & Laurent Mignonneau, collection of NTT-ICC, Tokyo, Japan

Many artists have explored artificial life in various ways. Mitchell Whitelaw has talked with many of them and published a theoretical study of the field (Whitelaw 2004). In his article "Twenty years of artificial life", Simon Penny provides a brief survey of those developments (Penny 2011). He cautions us to remember the vast changes in technology when we look at early examples of this (and implicitly other) kind of art. As he says, however, "… there is still much grist for the mill in the application of these ideas in emerging cultural forms." In other words, despite the rapid growth in research and art in this area and the changes in technology that have gone with it, artificial life still has significant potential to inspire new work.

An interactive artwork that uses a direct relationship between the input and aspects of the output is Iamascope (Fig. 6). As the designers of this system describe it:

> The Iamascope is an interactive kaleidoscope, which uses computer video and graphics technology. In the Iamascope, the performer becomes the object inside the kaleidoscope and sees the kaleidoscopic image on a large screen (170") in real time. The Iamascope is an example of using computer technology to develop art forms. As such, the Iamascope does not enhance functionality of some device or in other words, "do any thing", rather, its intent is to provide a rich, aesthetic visual experience for the performer using it and for people watching the performance. (Fels and Mase 1999: 277)

The idea is that one member of the audience acts as 'performer'. An image processing system detects certain body movements that they make (typically, waving their arms) and uses that to generate both kaleidoscopic type image

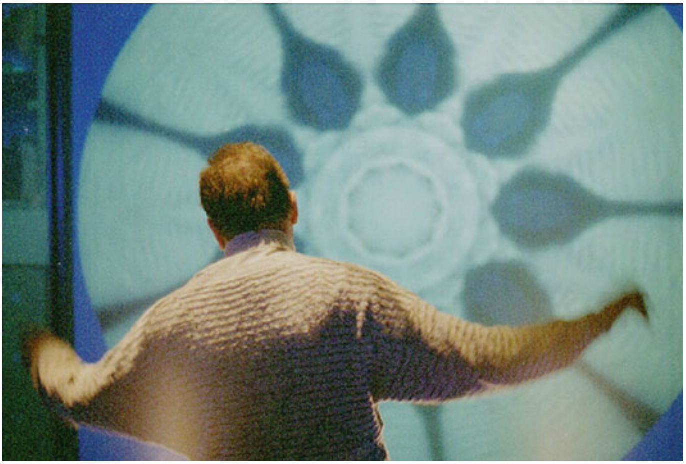


Fig. 6 Iamascope, Sidney Fels and Kenji Mase: photograph Linda Candy, Millenium Dome Play Zone, London, 2000

transformations of them and music. It is also intended to be interesting to other members of the audience who just watch the action—and it is!

Some artists have placed more emphasis on the object and the physical, one might say sculptural, qualities of their interactive art works than the interaction process. Jeffrey Shaw, for example, has made many such artworks where the interaction process is quite simple but the sculptural qualities are quite powerful. A well-known early work of his is The Legible City, 1988–91. In this work, a:

> … bicycle with a small monitor on the handlebars is mounted in front of a big projection screen. When the observer pedals, a projection is activated and he can move through three different simulated representations of cities (Manhattan, Amsterdam and Karlsruhe). The architectural landscape of streets is formed by letters and texts… Jeffrey Shaw presents a poetic image of the architecture of different cities, and leaves the discovery of the virtual information structure to the observer on the bicycle… The illusion is successful because riding, looking and reading compel the observer to dive into the picture. The rider loses himself in total immersion. (Schwarz 1997: 149)

Fostering Art and Technology Through Research

This book is specifically about digital technology and art but its focus also includes research in that context. One can argue that research has always been part of art practice and point to historical precedents, most obviously the work of Leonardo; but since the beginning of the 20th century, the explicit involvement of research might be seen to have begun in Russia following the 1917 revolution. In 1919 Malevich moved from Moscow to the small city of Vitedsk to join other important artists at the People's School of Art, which at that time was under the direction of Chagall. Although he never became Director, Malevich soon became informally known as the school's "leading official". Under that leadership studios became laboratories as he "sought the integration of art with technology band with scientific methods" (Zhadova 1982). At almost the same time, an explicit research agenda arose in the work of the Moscow Museum of Painterly Culture (NZhK), particularly under Rodchenko's leadership from 1921, with his explicit promotion of laboratory work, a scientific approach and technology (Kachurin 2013). An important later example of the explicit adoption of a research approach was the formation of Groupe de Recherche d'Art Visuel (GRAV), (Galimberti 2015). This book can be seen to be a development within this tradition.

The particular subject of this book arose from a series of initiatives that began with ideas raised in key meetings at the Creativity & Cognition conferences. The conference series fostered a community of interested practitioners and researchers and led to the formation of the Creativity & Cognition Research Studios. C&CRS was established in 1998 as a joint venture between the School of Art and Design and the Department of Computer Science at Loughborough University, England. In 2003, the C&CRS research moved to Sydney Australia and was re-imagined in an enhanced form at the University of Technology, Sydney as the *Creativity and Cognition Studios* (*CCS*). In its new form CCS continued the work initiated in C&CRS but with an enlarged and stronger PhD programme. The first ten years of CCS are best understood from a multi-authored book that describes and discusses much of the research and artistic practice (Candy and Edmonds 2011). Whatever level of computer expertise the artist might have, the issue of the influence of the use of the technological environment on creative practice is important. The characteristics of art and technology intersection and correspondence have implications for technological requirements and the environments in which new developments can take place as well as directly upon art practice. Research has an important part to play in understanding and developing these implications.

End Notes

1. Georg Nees, is thought to have gained the first Ph.D. in Computer Art in 1969.
2. Max Bense has been credited with founding the field of Visual Semiotics.
3. A. Michael Noll and Bela Julesz worked at AT&T Bell Labs in 1965 on visual research, communications and computer graphics.
4. Frieder Nake: see the biographical note.
5. More information about Bit International and New Tendencies can be found in Rosen 2011.

6. *Leonardo* was founded in Paris by kinetic artist and astro-nautical pioneer Frank Malina to serve as an international channel of communication among artists, with emphasis on the writings of artists who use science and developing technologies in their work. Today it is the leading organization for artists, scientists and others interested in the relationship of science and technology to the arts and music.
7. Billy Kluver: founded E.A.T., was an Assistant Professor of Electrical Engineering, at UC, Berkeley, and subsequently at Bell Telephone Laboratories in Murray Hill.
8. Garnet Hertz: Canadian artist who investigates technology and communication.
9. Constructivism: in its broad meaning, abstract geometric art with its origin in Russia in the early 20th century. It was an entirely new approach to making objects which sought to abolish the traditional artistic concern with composition, and replace it with 'construction'.

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Between Worshipers, Priests and the Nuke: An Introduction to the Cultural and Social History of Early Computer Art

German Alfonso Nunez

In 1964, sixteen years after the publication that has brought him fame, Norbert Wiener did not sound content. Over a quite short and anxious book, the father of cybernetics pondered over the implications of his creation. Voicing concerns over the "social consequences of cybernetics" (Wiener 1964, viii), Wiener questions the ethics of machine learning, its impact in the workplace, the job market, religion, the ontology of humanity and the dangers of misapplying his original work. All in all, Wiener's God and Golem, Inc. stresses the negative aspects of cybernetics that, in his opinion, were being overlooked by naïve or malicious individuals interested only in personal profit and power.

Let us move forward some years, to 1971. Over a publication created around some of his and other pioneering artworks, Frieder Nake publishes a provocative article damning computer art. In "There Should be no Computer Art" (Nake 1971), published in the Computer Art Society newsletter, PAGE, the computer art pioneer calls for—as its title suggest—the end of computer art. According to him computer art, apart from not offering something new in terms of aesthetic experiences, was being cooped up by the very artistic establishment that it ought to combat. Claiming that this practice should be concerned with investigation and research and not commerce or aesthetic mastery, Nake affirms that computer art should not be created for "the rich and the ruling" (Nake 1971).

Superficially, these two very public demonstrations of contempt seem to point to a simple case of two disgruntled creators losing sight of their product. After all, cybernetics and computer art were popularized, transformed and adopted by very different individuals over an extended period and context. Cybernetics, with its formalization of communication and information, and computer art, attempting to adapt art to its new material condition, were very powerful ideas that would see an afterlife that could not be predicted back then.

Yet, here we propose that their connection is more than just a mere possessive streak. These two examples point to a common ancestry that lies at the heart of these two projects: namely, the optimistic, quasi-utopian, rational formalistic intellectual and cultural mood of the long fifties and its eventual demise.

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_2

The Intellectual Culture of the Early Cold War

For those involved with the history of computer art, the very act of discussing it and cybernetics may seem banal. Since some very good texts have already touched the subject, one might argue that there is not much left to talk about it apart from very specific case studies. Moreover, as we know, not only cybernetics was influential over early computer art but it also predates it. We can see its influence, for example, in the works of Soviet artist Yuri Zlotnikov, who strove to reduce human expression from his paintings; over the universalist proposals of *Paulista* concrete poets that aimed to apply feedback loops as poetic devices; in the kinetic sculptures of Abraham Palatnik etc.[1]

One could argue that these examples posit many computer art pioneers within the tradition of rationalistic artistic practices of the post-war, with concrete art being the clearest example. Having said that, here I want to stress that both computer and cybernetics were part of a larger trend, seem both in intellectual and artistic circles. That artists, both traditional and technologists, were similarly influenced by cybernetics is just but the tip of the iceberg. As hinted so far, the complaints of both Nake and Wiener, as well as the very adoption of cybernetics by artists, result from changes occurring outside these specific examples. In other words, these *exogenous factors* (Baumann 2007) is what made possible both developments, computer art and cybernetics, as well as their eventual criticism. To illustrate this shared background we shall begin with the most obvious link between computer art and cybernetics: computers.

Digital computers, as we know, are a direct result of geopolitical concerns arising from the Cold War. Amongst the various authors that relate the origins of computing with the demands of armed conflicts and politics, it is Edwards (1996) who provides the most interesting insight to us. Following his research, we discover that both the computer and the emergent theories of information, such as systems theories or cybernetics, had a function other than the purely practical. These accounted as metaphors or frames on how to perceive and act within the new world order that emerged from the wastelands of WWII. Allow me to clarify this.

From the point of view of its biggest financiers and enthusiasts, the US government and its strategists, computers symbolized an opportunity that we could, given enough data (i.e. mathematically formalized information regarding the world and its agents) predict and consequentially control the conflict. Perhaps better exemplified by the controversial S.A.G.E. anti-air system (Edwards 1996, 108–110), computers were at the centre of this assumption of control and prediction. Yet, the problem with such an assumption is that it was exactly that, an assumption: one that disregarded “the traditional forms of practical reason and statecraft, which emphasized prudence, experience, deliberation, and consultation” (Erickson et al. 2013: 3).

[1]An in-depth discussion of these and other artists, in relation to both cybernetics and its social context, can be found in Nunez (2016).

The central tenets of this rationalization—ideally mathematically formalized, universal, procedural, generalist, mechanical and analytical—results in a "Cold War rationality" (Ibid.) that became normalized and unquestioned. Its by-product, a "formalistic language", which saw "war using categories of games, bargaining, production and management", reinforced the "view of war as a rational problem" (Edwards 1996, 143). So strong was the pull of such a thought that its adherents, a "new priesthood" (White in Erickson et al. 2013, 10), were the authoritative voice of reason and truth. Its influence, hence, could be seen everywhere.

Although not constituting a single field or theory, this general disposition was instead felt as a diffuse discourse in intellectual fields everywhere. We can see its presence being felt, for example, in the formalist economic theories of the time (Blaug 2003), which substituted national contexts and social relations for unrealistic models that assumed purely rational and all knowingly actors. Surprisingly, one may even recognize this impulse in the works of Noam Chomsky who, in his own words, in order to "determine and state the structure of natural languages without semantic reference", sought to "inquire seriously into the formality of linguistic method and the adequacy of whatever part of it can be made purely formal" (Chomsky 1953, 242). One might also add to this list game theory, rational choice theory, system theory and, of course, cybernetics itself. After all, what is cybernetics if not the theory that best capture the dissolving boundaries between an infinitude of systems, from physical to biological ones, via a mathematical formalization of information and its dynamics?

Yet, more important than these examples themselves, it is the allure of these theories, which can be summed up by the very 'priesthood' label. Despite having "no end of critics who disagreed, on technical, philosophical, or moral grounds" (Erickson et al. 2013, 49), including some of its own proponents, this rationality was the authoritative method of inquiry. Following on this same thread but discussing the development of US national policy in the Cold War, Amadae (2003, 158) offers a valuable summary: "The mathematical formalism structuring rational choice theory is impelled by the same academy-wide momentum propelling an increased emphasis on formal models as an indication of scientific standing". As in our aforementioned examples, the emphasis is not as much in the meaning of things but, instead, on its form and structure: all in the name of objectivity and truth.

Early Computer Art Discourse

Early computer art also partakes in this intellectual trend and no one was as engaged with this discourse as those pioneers that circulated around Max Bense. In fact, the German philosopher can be viewed as the ideal purveyor of rational formalism in the early computer art. Rather than attempting to criticize or explain his aesthetics, which is not at all my intention, we shall focus on Bense's goal: "to develop a theory that would allow one to measure the amount and quality of information in aesthetic objects, thus enabling an evaluation of art that goes beyond 'art historian chatter'" (Klütsch 2012, 67).

Attempting to objectify art and its interpretation, hence stripping any trace of subjectivity from its apprehension, Bense in effect aims to construct a "scientific art" via mathematics. Alongside Abraham Moles and others, this program, which favours a specific kind of art, rational and scientific, was first and foremost anchored over the assumption that in art, as in other disciplines at the time, objectivity, rigour, formalization and universality should be the aim. In other words, "just as Chomsky was looking for the laws of natural language, Bense was looking for the laws of aesthetics" (Klütsch 2007, 421). It was this new universal aesthetics—"oriented on objective rather than subjective problems" (Bense 2011, 296)—that lies at the heart of this first stage of German computer art.

On the other side of the Atlantic another pioneer, Michael Noll, would also play the same game. An American engineer that was employed by the legendary Bell Labs, Noll is a world apart from Bense and the first generation of German computer artists. Distant from both the art world and concretism specifically, Noll entered computer for "fun" (Noll 2016). Discussing his work mostly within the confines of technical journals and memorandums, Noll is nevertheless part of the second ever exhibition of computer art within an artistic context in 1965. Yet, it is in a memorandum that Noll best exemplify his understanding of art. Later republished in 1966, it attempted, similarly to Bense's previous efforts, a scientization of art. Its experiment was simple: to show participants two pictures, one produced by his program and the other a black and white photographic copy of a Mondrian. Three questions then followed: one regarding the subject background, one asking whether the picture was computer made and, finally, one inquiring the preference of the subject for either picture. Although claiming that the experiment "was designed solely to compare two patterns that differed in elements of order and randomness" (Noll 1966, 9), Noll concludes that not only the computer picture was elected as the preferred one because of its 'order' but that also, given enough time and effort, one could produce another picture that would be closer to that of the artist. Implicit in his experiment is an assumption that through formalization one might predict and, thus, recreate human behaviour—art included.

The Changing Cultural Landscape of the Late Sixties

While both German and American pioneers were successful in the sense of kick-starting a new genre, these failed to insert themselves into the larger art world. In other words, computer art was neither celebrated nor well discussed outside its own circles: a situation that, despite some advances, invariably persists to this day (Shanken 2016; Nunez 2016). If that faith described earlier was so pervasive, surely computer art should have been celebrated. Here the reactions of our first two characters, Nake and Wiener, come into play. Mirroring the concerns that were being raised outside of their domains, both public reactions are proxies of a changing culture. As computer art emerged from its previous space, in technical and trade journals such as *Computer and Automation*, the enthusiasm for its premises were quickly fading. Too little too late, we might say. The problem with rational formalism and its inherited optimism, towards a controllable and ever improving future, is that, in the end, nothing changed. In fact, as the sixties progressed, things got worse. The general goodwill towards the technocratic society planned in the aftermath of WWII had, finally, come to an end.

That view of the world was anchored by a deterministic belief in "exponential technological growth" (Krier and Gillette 1985, 405) that would, in turn, result in greater prosperity for all. For a while, that was indeed the case. In many ways, the economic miracles of the period were a testament to its success. It should come as no surprise that whilst that growth persisted, public "opinion generally viewed the transition to a society of abundance as a problem of engineering, not of politics" (Maier 1977, 615). On top of raising living standards and educational opportunities, unprecedented economic growth, new appliances and a closer, interconnected world, we even had a glamorous space race! What could possibly go wrong?

Retrospectively, the whole technological-optimism of the long fifties seems naïve. Neither control nor predictability, computerized or otherwise, could foresee what would come next: social unrest, weaker economies, bloody proxy wars, nuclear tension, raising oil prices, environmental concerns etc. Made clear by the counter-cultural hymns and its protesters, this cultural revolution and its humanistic turn was a pivotal event in the reception of early computer art. From the claims that it was a soulless enterprise (Taylor 2014) to the impression that certain exhibitions could face public protest (Usselmann 2003, 392), from computer artworks pointing to the Vietnam (as in Charles Csuri or Waldemar Cordeiro artworks) to computers being targeted as symbols of dehumanization, state control and the military-industrial complex (Turner 2006), from the worsening public attitudes towards science and technology (Pion and Lipsey 1981) to art and technology efforts being under suspicion for collaborating with the corporate and military sector (Goodyear 2008), the changing cultural climate of the sixties could not have been worse to these newly emerging artistic.

Returning to our first two characters we should note that, as the years passed by, both would change the tone of their discourse, towards a reflection and critique of their own fields. Although still citing Bense, Frieder Nake would ostensibly move towards an anti-art position, in the sense of criticizing art, its commerce and its system. The evolution of his discourse, towards a revolution of the artistic system, was a central element of his call against computer art (Nake 1971). We could also include here, albeit later in his career, an emphasis towards conceptual art and, as such, away from Bense's influence (Nake 2008). That stands in contrast to other German computer artists at the time. In the same year that Nake published his manifesto, Mohr (2015, 160), for example, equates "creative practice" to an "algorithm which represents a human behavior". It was this view of art making that led him to establish—in true rational formalistic fashion—a "syntax" which was later represented "through mathematical formalism" to "realize all possible representations of [his] algorithms"(Ibid.). This same change can also be seen in Norbert

Wiener. Although defending the study of automata in principle, Wiener criticizes what he sees as the "sin which consists of using the magic of modern automatization to further personal profit or let loose the apocalyptic terrors of nuclear warfare" (Wiener 1964, 52). It would not be fair, however, to claim that Wiener was a naïve utopian in the first place. As earlier as 1950, in *The Human Use Of Human Beings: Cybernetics And Society*, Wiener warns that "The simple faith in progress is not a conviction belonging to strength, but one belonging to acquiescence and hence to weakness" (Wiener [1950] 1989, 47). Yet, despite some previous warnings, it is in *God and Golem*, published in 1964, that Wiener's criticism becomes more vocal. After following the development of cybernetics over the course of fourteen years, he sees those that attempt to control or study automatization "beyond a legitimate curiosity" as "gadgets worshipers" who, "as devoted priests of power", regard with "impatience the limitations of mankind, and in particular the limitation consisting in man's undependability and unpredictability" (Wiener 1964, 53).

Conclusion

Fred Turner reminds us that, for the people involved in the art and technology scene, "cybernetics mapped the world as it was and should be: an information system that transcended the limits of biology and technology […]. It was in many ways an ideal technocracy watched over by engineers and managed through communication machines" (Turner 2014, 71). It was this same vision that kick-started computer art. Likewise, it was the criticism of this view that led us to the space which may label as the Art, Science and Technology art world (Nunez 2016): Incapable of finding a home within the contemporary art system, belonging always to the periphery and to footnotes, these artistic practices, would, in order to survive, develop its own space, its own world, with a whole system dedicated to it. Paradoxically, this could not have developed if not by way of the criticism directed at its relationship with technology and industry. It is this history and its conflict that has opened the way for both this very book and the careers of many of its characters.

Although a very different beast today, this art world and its products are intrinsically connected to these early days: one might only think of the centrality of a publication such as Leonardo or an institution as SIGGRAPH, which for more than fifty years have informed the way the field produces and think these artistic products, as an example of a clear and direct influence of that period.

To negate this history and its consequences is to blindly forget the conflict that generated our field. The recognition of its effects, however, opens a possibility to rethink both our current position and our pioneer's practice. The vitality offered by these artists, which for the past fifty years of so have rethought art and its position, cannot be lost to conformity. At the risk of losing our hard-earned space, and following the examples set by Wiener and Nake, perhaps technological art should leave its cosy corner and confront itself.

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A Million Millennial Medicis

Harold Cohen

A client visited my studio recently to see what new work I had. But instead of buying a painting, she invested about a quarter of what a painting would have cost on a new computer, a data projector and a license to run my computer program, AARON, from the output of which the paintings had been made. If you were to visit her apartment in New York now, you would find one wall of her living room serving as a screen on which you would catch AARON busily generating original images, a new one every two minutes or so.

AARON has been under continuous development since the early 1970s. It is still modest in size by today's standards, about 12 Mb including the code I've written myself and the LISP environment in which it runs. That is equivalent in size to ten rather fat novels. Given a cable modem on your computer, you could download it all from the World Wide Web in about four minutes. The program also needs around 32 Mb of internal memory to run in, which is also modest by today's standards; the machine I work on today has four times that much and could hold a good deal more.

Around the time AARON began nearly 30 years ago, the first computer I owned had only 8000 bytes of internal memory. So, in 30 years the internal memory I have had to work with has increased from 8000 bytes to 128 million; i.e. 16,000 times as much. My current machine's hard disk holds 20 Gb, enough to store about sixteen hundred copies of the program but there is really no way to calculate the increase in mass storage over the same period, because my first machine had only paper tape for storage. Punching the tape at ten characters per second, it would have taken almost two weeks to store the program, assuming you could get enough tape. That was not an issue at the time, though, since the first versions of the program ran to a couple of thousand bytes, not 12 million. My current machine, running at 866 MHz, is almost 20 times as fast as that cutting edge "minicomputer". The vice-president of the company that made it told me he did not think the price of minicomputers would ever fall below the $10,000 I paid him for mine, because it would never be worth anyone's while to make them for less.

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_3

Have you ever tried counting up to 12,000 million, or catching an eight-hundred-millionth of a second as it went by? How did our numbers get to be so far outside ordinary human experience? Moore's Law says that computer power per unit cost doubles every eighteen months. My five-year old daughter can count to eighteen and doubling is easy enough to understand; but think about what doubling every eighteen months actually means. This is the contemporary version of the old tale about the crafty advisor who bankrupted the king by requesting payment for services rendered with one grain of rice on the first square of a chess board, two grains on the second and so on—2^{64} grains of rice turned out to be a lot of rice. In AARON's thirty years I've seen twenty eighteen jumps, which means that the computing power per unit cost available to me today is greater than it was when AARON started by a factor of 2^{20} power, which is over a million. A million-fold increase in anything is pretty impressive, but since Moore's Law deals with raw computing power, it only scratches the surface of what these immense numbers imply. Just as computing power increases exponentially, the number and the range of applications computing makes possible proliferates exponentially also. Just as AARON in its present state would never have been possible 30 years ago, we did not then—*could* not then—have had global weather prediction, CAT scans, the mapping of the human genome, digital imaging, … the list goes on and on. Most important of all, we could never have had the revolution in communications that is going on right now: no email, no World Wide Web, no instant access to libraries full of information, no e-commerce, no way of receiving the equivalent of ten fat novels in minutes.

Every day, we see more and more indications of how different things are from what they were yesterday. Yet most of us still find it extremely difficult to grasp the fact that the process of technological change that brought us from yesterday to today is now sweeping us into tomorrow at ever increasing speed. Doubling every eighteen months means that the next eighteen months will see as much change as all the previous changes put together. And when our current silicon-based computing technology finally runs out of steam, its successor technology, molecular computing, quantum computing, whatever it turns out to be, will make Moore's Law seem like a masterpiece of understatement. A recent article in *Scientific American* described the next generation as follows: if you imagine the entire page of the magazine to represent one logical unit in a silicon-based computer, the same unit in a molecular computer would be as big as one period on the page.

And this is not merely a technological revolution. We are being swept forward in an accelerating cultural revolution of unprecedented scale. As an artist, I have always believed that art is a cultural undertaking much more than it is a personal one: that, inevitably, the health of art reflects its relationship to the culture it serves. It is not clear any longer what that relationship is to be in the decades ahead, because it is not clear any longer how the culture will evolve in the decades ahead. Traditionally—in Western cultures, at least—the arts have been supported for the services they provide, not directly to the culture at large, but in return for the luxury objects they provide to those relatively few patrons wealthy enough to afford them and willing to do so. Today, at the same time that the Internet is effecting truly global communications for the first time in history, it has also been manufacturing wealth at a rate unprecedented in history; at the height of the internet boom, reportedly sixty new millionaires a day!

That should mean that the arts can look to a rosy future with patronage for all, should it not? Rumour has it that in his multi-million dollar home, Bill Gates, Mr Microsoft, has some very large, custom-made computer screens upon which he displays reproductions of Rembrandt paintings, paintings he could afford to buy if they were on the market. If art-as-luxury-object is the name of the game one can understand that a Rembrandt painting is more of a luxury than a painting by Harold Cohen, but a *reproduction* of a Rembrandt? We owe the existence of the great luxury objects of Western art to the fact that the Medicis of the Renaissance supported *living* art. Clearly Bill Gates is no Medici and I think we should not assume too much about how many of those new millionaires will be. Yet the big question is not how many Internet millionaires will become art patrons, but whether it really matters.

Why is this so? Because even as this new wealth is being created, its cultural influence is being side-lined by the very communications revolution that is creating it. Let me explain. When I was exhibiting paintings fifty, forty, thirty years ago, an exhibition in one of London's leading galleries meant that perhaps two or three hundred people would see my work. A museum show might mean a thousand or two. Fifteen years ago, when I represented the USA in the World Fair in Japan, it was reported that a million people went through the US pavilion and saw one of my drawing machines at work over a six-month period. Five years ago, an exhibition at the Computer Museum in Boston was attended, physically, by the old-style numbers, a mere couple of thousand; yet my total audience, reached by television coverage, syndicated newspaper reports, magazine articles, the full range of media coverage made possible by an increasingly powerful and pervasive communication system, was estimated to be more than thirteen million. Since then, and while I may be the only artist remaining in the Western world who does not have a web site of his own, I am shocked to find my work referenced on almost a hundred other sites. I cannot even begin to guess how frequently those sites are accessed. To get some sense of the kinds of numbers we will have to consider in the years ahead, I heard recently from a curator at the Tate Gallery in London asking for permission to reproduce works of mine in their collection on their web site. Launched just last year, he told me, the site is now recording 170,000 hits a day!

One can hardly suppose that the arts will somehow avoid being impacted by rapidly changing patterns of patronage. It is hardly surprising that more and more artists today are looking to the World Wide Web, rather than to the hundred-year old gallery system, to provide a way of getting their work out to a potentially planet-sized audience. It is not clear, however, that the Web will actually pay off for them. According to Yahoo's Web reference book published last year, "there are more than fifty million websites residing on servers all over the world and the number is growing by thousands every day." The success of the gallery system rested upon a sophisticated marketing apparatus, and without an equivalent apparatus to support it, any work on the Web is likely to be lost in the sprawl, unlikely to be seen by anyone other than by accident. In any case, I do not believe that the point for the artist is to reach the largest possible audience at any cost, but to reach an audience capable of hearing what he has to say, without compromising what that is in the process. And it is prone to compromise. No matter how original and valuable his internal thoughts may be, there is simply nothing to disseminate if they stay inside his head. At the same time, there is nothing automatic and nothing neutral, about the business of getting them out of his head and into the external world. The external image has to be produced and what the individual is able to say is heavily mediated by whatever technology of production he can muster, just as it will then be mediated by the technologies of dissemination.

That has always been the case, of course, although for most of Western history, both the means of production and the means of dissemination stayed stable enough for long enough—I am oversimplifying a bit—that they could be largely ignored as active elements of art-making. The Industrial Revolution changed both, from painting in the studio with traditional earth colours to painting outdoors with factory-produced metal-oxide colours of unprecedented vividness; from traditional patronage to the beginnings of the dealer system. But those changes were marginal compared to what we are facing now. For the means of production and the means of dissemination—computing and communications—are not merely changing as rapidly and as radically as everything else, they are the central issues, the engines that are driving the technological revolution. I believe that from now on they will figure as active components of art-making, to a far greater degree than history and training have ever suggested.

It is 32 years since I met my first computer and by simple virtue of having been around for long enough in this revolution I am able now to discern with reasonable clarity the influence of these two components upon what has played out in my own work. Just a couple of weeks after arriving in San Diego on a one-year visiting professorship I met a graduate music student who seemed intent on teaching programming to anyone in the arts he could grab, and I simply allowed myself to be grabbed. To explain why I allowed myself to be grabbed I will need to say something about what I had been doing before it happened.

For most of the 1960s I had been preoccupied with what I still regard as the core mystery of image-making: the curious fact that we are able to use marks on flat surfaces as representations, surrogates, for events and objects in the real world. My paintings were driven by that preoccupation: they were *about* representation, without being representational in any obvious sense. But by the end of decade I was feeling that all I had succeeded in doing was cataloguing some of the ways in which marks serve as representations, without ever developing anything I could consider to be a broad theory of representation. I was feeling not only that I understood as little about the mystery as I had at the beginning, but that I evidently lacked the means to elucidate it further. In a state of frustration, it seemed to me that there were more interesting things happening outside my studio than inside it and, once the opportunity was presented to me, I thought that computing might conceivably be one of those things. The meeting was thus unintentional and, in the event, bewildering. If I pushed beyond the first encounter, it was not because I immediately saw the future in a great flash of light, it was simply that I found programming to be an exciting and invigorating intellectual exercise. No doubt Pascal was right and fortune does indeed favour the prepared mind, but the mind is not always well enough prepared to accept the favour as soon as it is offered. It took me about six months before I began to develop a suspicion that this new technology, this new means of production, would allow me to get back on course, and to examine what was in my head in a clearer way than I had ever been able to do by painting alone.

All this was several years before my own first minicomputer and computing was even more unlike the way we know it today. The interactive, Windows-like environments we take for granted did not exist. Programs were punched in IBM cards, a line to a card, and the entire deck of cards was submitted to an operator who fed them to the university's central computer, a room-sized machine with considerably less power than the cheapest PC has today, and which the user never saw. You went back the next day for the output and if you had misspelled something or left a semicolon off a line, as I always did, you re-punched that card and re-submitted your job, to come back the following day for another error and another re-submission. It could take days to do what it now takes minutes to do. Perhaps most trying of all for someone new to this new technology, there were no precedents that you could look to for justification, no one to say what computing might do for someone in the arts.

This may all sound very negative and certainly I would never want to go back to that primitive state. But it was not actually a negative experience. From my own perspective, the most significant difference between then and now is that today the user's biggest problem is to know which of the many programs being thrust at him by marketing moguls on the Web to buy. In 1969, there were no programs to buy and no Web, nor even computer stores, to sell them. If you wanted a program you wrote it. I have never thought there was anything negative about that. On the contrary, I cannot begin to express how fortunate I feel myself to be that I came to computing at that time, prepared to do it the hard way, and with a growing suspicion that it might provide me with a way of refocusing upon my core preoccupations, my concern with the nature of representation. I reasoned that if an artist's images could mean anything at all to people he had never met, it had to reflect some commonality much deeper than individual experience and probably had something to do with the fact that all human beings, regardless of their culture, use essentially the same cognitive system. I figured, then, that I might learn something about how human beings make images and how they read them if I could simulate, in a computer program, a few of the low-level cognitive functions we all share—the ability to differentiate between figure and ground, the ability to differentiate between closed forms and open forms, and so on. And since I didn't want to subvert any chance of acceptance by producing obviously mechanistic drawings I paid a good deal of attention to structuring the simulation in terms of the feedback mechanisms that pervade all human behaviour, whether in driving a car, steering a forkful of food to the mouth, or doing freehand drawing.

I thought that the test of the program's success as a simulation and an indication that I had learned anything in designing it, would be whether its output would be accepted on the same terms as, interchangeable with, human output. Obviously, it could not be interchangeable in the sense of including those agreed upon, specific meanings in paintings that belong to a single state of a single culture. I regard artworks as meaning generators that evoke meaning in the viewer rather than inform the viewer what someone else, some artist remote in time and culture, intended to communicate. So, when a woman at one of my exhibitions told me she knew I must live in San Francisco since the program had just drawn one of the city's landmarks, Twin Peaks, I felt I could claim that my program was functioning as an evocation machine, doing just what it was supposed to be doing; and not one jot less so because I was living in San Diego, not San Francisco, and AARON had no concept of Twin Peaks.

That phase of AARON's development took the better part of six years and I could probably write most of the code today in a couple of afternoons. The difference reflects the fact that I was working both at the limits of available computing resources for that period and also at the limits imposed upon my means of production by my own programming skills. During that same period, I was also trying to resolve questions about the third element—the means of dissemination—that had arisen because of the other changes. Thinking conventionally in terms of exhibitions, it was clear that the little ten-inch monochrome screen upon which I was doing my programming would not suffice for an exhibition; only one or two people could actually see it at any one time. By 1975, I had built my first device intended explicitly for exhibiting—a small computer-controlled turtle that rolled around on huge sheets of paper, leaving a trail of black ink behind it. Lots of people could see that at the same time. But the little turtle had so much 'personality', attracted so much attention to itself, that I became convinced that people could not actually see the drawings because they were focusing so completely on the turtle. I used it only twice—once at the international Documenta exhibition in Germany; and once at the San Francisco Museum of Modern Art. I abandoned it then in favour of more anonymous, conventional drawing machines, still big enough that at least a dozen or so people could stand around it and see what was being drawn.

I went on using machines of that same conventional sort for the next ten years. Yet it was clear even from my very first clumsy attempt at engineering that the nature of exhibitions- the means of dissemination, had changed for me as much as it had changed for the audience. As a painter, I recognized that my paintings had a public role, but I never thought I had one myself. However, I was not just showing paintings in the mid 1970s and information about the sort of thing I was doing was not widely available as it is today. The public seemed to be divided pretty evenly between un-sceptical believers and unbelieving sceptics. The believers were happy to believe that computers could do anything and consequently accepted the idea, with neither difficulty nor understanding, that mine was making art. The sceptics thought computers were just complicated adding machines and, consequently, experienced insurmountable difficulty and equally little understanding, in believing that mine was doing what I said it was doing. One gentleman in Germany even announced that, of course, I was only doing this turtle stuff to make money, which gave my two unpaid assistants and me the biggest laugh we had had in weeks. I was

Fig. 1 AARON drawing in black and white 1985 © Harold Cohen

presenting this two-sided public with something it had never seen happen before, forcing both sides to ask questions, and I felt I had some responsibility in trying to provide answers.

From that point on, my exhibitions became extended conversation events in which I had the central role to play. I was repaid for my loss of privacy with some remarkable conversations. During my exhibition at the Tate Gallery in London, for example, one visitor remarked that he thought it a bit sad that the program had to be limited to doing what *I* wanted instead of being able to do what *it* wanted; particularly so because it had not been taught to do its own colouring and needed me to do it.

I experienced no sudden flash of enlightenment; but looking back from much later I was able to see that even though the early stages of AARON's development were intended as a simulation of human behaviour, the idea of the program's *autonomous* behaviour had been implicit from the very beginning. In pointing to the possibility of an autonomous, self-determining program the man's remark rang a sort of advance warning bell for a change that did not complete itself until several years later (Fig. 1).

Before moving on to that change, and collapsing a long and complicated story into a couple of paragraphs, I should fill in briefly what had been happening to what I had in my head, what I wanted to say, along the way. When I started on the program—AARON as evocation machine—it had seemed to me that I could continue to develop it indefinitely by adding more and more cognitive 'primitives' to its repertoire. After a while, as it turned out, I could not identify any more primitives to add. I started to suspect that the human cognitive system is the way it is, not because of a huge array of primitives, but because a relatively small set of

Fig. 2 Drawing by Zana aged four years

primitives develop complex interactions in coming to terms with the external world. At that point, sometime around 1980, I started to look beyond what the textbooks told me about cognition to see how children's drawing behaviour actually develops. Having watched my own children when they were very young, I knew that drawing starts with scribbling, and that at some point a round-and-round scribble migrates outwards from the rest of the scribble to become a sort of container, an outline. It had also seemed to me that this was the point at which my children started to think of their drawings as representations for the familiar things of their world.[1]

I never had any great success in trying to simulate this key phase of children's drawing. However, the principle of generating a core figure and then drawing an outline around it turned out to be amazingly powerful. In applying it I found AARON's drawings becoming much more 'thing-like', so much more like representations of things in the world than anything it had done previously, that I concluded finally that I should really tell the program something about the real world. It took one final prod from a curator who wanted AARON to draw the Statue of Liberty for a bicentennial exhibition for me to add some rudimentary knowledge of how the human figure is constructed and how it moves and AARON crossed over into figuration, dragging me along with it. And the rest, as they say, is history (Fig. 2).

The things one has in one's head do not come in isolated packages, and they do not all operate on the same level of control. Important as the change from abstraction to figuration was for me, it was paralleled by an increasing preoccupation with the notion that AARON should be able to do its own colouring. The way both issues worked themselves out was being determined to a very large degree by the fact—on a higher level of control—that AARON had been built as a simulation of human behaviour. Providing enough knowledge to deal with the human figure was giving the program independent control over a larger range of performance and, to that degree, eroding its identity as a simulation; but without causing a total revision of that identity. In fact, it was the problem of giving AARON independent control over its own colouring that finally caused that fundamental re-evaluation; the realization that what I wanted to say, what I *needed* to say, had to do with autonomous program behaviour, not with the simulation of human behaviour.

But why colour? Why could colour force a change of direction in a way that the move to figuration had not done? The problem of independent colour control was proving to be the most difficult I had ever faced.

For about two years I experienced the same kind of frustration I had experienced at the end of the 1960s; the feeling that I lacked the intellectual means even to think about the problem, much less to do something about it. The first sign of a breakthrough came when I asked myself what elements of colour human artists had control over and realized that I had known the answer for as long as I had been painting and teaching. I still do not know why it took me so long to bring it into focus. The most important element of colour is, in fact, not colour at all, but brightness. If the artist has control over the brightness structure of his image he is half-way home with respect to colour. And when I showed the program how to control the brightness structure of its images, it was able very quickly to generate satisfactory colour schemes, some of which I could transpose directly onto the paintings I was making from AARON's output.

But that was, after all, only half-way: it was satisfactory but not masterful. And still linked too tightly to the simulation model to go the rest of the way. I had not yet fully grasped the fact that the simulation model could not solve the problem, for the simple reason that the program's strategies as a colourist could not possibly simulate the human colourist's strategies. But what *are* those strategies? How *does* the painter choose what colour to make some area of a painting? Colour is a sort of ultimate abstraction for human beings. We can use it, sometimes at a high level of expertise, but we cannot say how we do it. If I could not explain my own educated intuitions to myself, then how could I possibly write a program to simulate them?

As inexplicable as the human colourist's strategies are, what is clear is that they depend on the physical apparatus he has at his disposal. Human artists have eyes, and they know what colours they are mixing because they can see them. They mix colours in feedback mode as they do everything else in feedback mode, continuously adjusting the individual colours in a painting by eye until their educated intuitions tell them they have it right, without ever needing to say—without being able to say—what they think is right about it.

My program did not have eyes to provide a feedback path, so continuous adjustment was out of the question. What it did have was the ability to construct a complete colour scheme "in its head", so to speak, and that is an ability human beings lack completely: so completely, in fact, that we can hardly imagine any mode other than our own existing, much less construct one. So it required a major change in mental set to understand that, while programs can be designed to do many of the things only expert human beings can do, and to do them at an expert level, all performance is apparatus-dependent and they cannot go about doing them in the same way when they do not use the same apparatus. That, of course, is just another way of saying that externalizing what one has in one's head is mediated by the means of production, that is, the technology one uses to externalize it. AARON's strategies would have to be built on its own ability to construct a colour

Fig. 3 AARON painting 1999 © Harold Cohen

scheme in its entirety and it would have to have rules that would guarantee getting it right first time. If that sounded like a daunting proposition—and it certainly did—it looked less so to me than the alternative, because I knew that if AARON did have eyes, I would then be forced into trying to simulate precisely the behaviour I already knew I could not describe (Fig. 3).

Once I had set myself on the path to making AARON an autonomous colourist, I had also to figure out what I would do about the means of dissemination, given that I wanted to continue to show, not merely the results, but the process. Colour displays of quite high quality were available by this time, but they were still too small to be considered as exhibition devices. I suppose it was just a bit too obvious, having built several generations of drawing machines, to think I had to build a painting machine.

Notice that I referred to the human colourist as possessing, not simply intuition, but educated intuition. He may get by without a detailed knowledge of any of the standard theories of colour, but he does not paint with theories of abstractions, he paints with paint. Paint gets its colour from a wide range of physical materials, each of them having distinct physical and optical properties, and what we mean by expertise in this domain is, among other things, a detailed knowledge of how these materials interact with one another. The physical properties of paint are not an issue when you are working on a computer display, but they certainly are for computer programs designed to work in the real world. I needed to be able to develop the program on the display, but the program had to make decisions in terms of what would happen on the machine. That is precisely the opposite of what industry wants of its colour output devices, which is to reproduce, as faithfully as possible, what the user does on the screen. It took the better part of a year to provide adequate knowledge: deciding on a suitable range of water-based dyes and suitable papers, making over a thousand samples from carefully measured mixtures and measuring the colour composition and brightness of the results.

I built three machines in all. The first served to show me how little I knew about engineering and never made it out of my studio. The second served me for a single exhibition at the Computer Museum in Boston. The third has been filmed in my studio for several TV programs, including, most recently, *Scientific American Frontiers*, but it has never been used in a 'live' exhibition and it won't be. It will shortly join the historical collection of the Computer Resource Center in Silicon Valley. The truth is that my experience of exhibiting with this machine was uncomfortably like my earlier experience with the turtle: a complicated technology, extremely difficult to keep stable, garnering much more attention than the program it was supposed to be serving. I could not help noticing, for example, that what really turned on the audience was not so much what the machine was painting, but the fact that it washed out its own cups and cleaned its own brushes. The principal reason for abandoning the machine was different, however. I reached the conclusion that there's something fundamentally regressive about trying to drag nineteenth century moving-parts technology into the twenty-first century. I should be looking forward, not backward. But Where is Forward, Exactly?

I want to refer back to one of those museum conversations I mentioned earlier. This particular conversation took place during my exhibition at the Brooklyn Museum in New York. The show used four drawing machines, and a man had been standing watching one of them at work for some while, at first asking me questions, then engaging other people in conversation and trying to answer their questions, watching other people buying drawings for $25 each but never buying one for himself. Then, about fifteen minutes before closing time, as I was getting ready to do a last drawing, the man said suddenly "I want to buy the one it's starting now!" I pointed out that he had been watching the machine for hours and had already seen at least a couple of dozen finished drawings. Didn't he want to choose one of those, to see what he was buying? He frowned for a moment, then he said "The Medicis didn't know what they would get when they commissioned Michelangelo to do something, did they?" And I thought, Marvellous! For $25 this man has bought himself a place in history and won a new understanding of his relationship to art.

I suggested earlier that the enormous wealth being created by the Internet, rather than providing a new generation of Medicis in the old patronage model was actually being side-lined as a cultural force by the very communication system that generated the wealth. I was not thinking about the millions of individuals who access the Web every day, but more particularly about this self-appointed new-style Medici in the Brooklyn Museum and all the hundreds of others like him—not millions yet—who bought original drawings in this and in other museums for $25 each.

If one thinks of dissemination in terms of art museums and art galleries, then almost inevitably one thinks in terms of art objects. Even so, I started to see about a year ago that data projectors, widely available today, would make much better exhibition devices, providing a far better fit to what it is I want to disseminate, than low-level robotics technology that grabbed the viewer's attention away from what the program was doing. And if physical art-objects are still required—and I am sure they will be—I could use one of the large-format printing machines that can produce museum-quality originals directly from the program's digital output; in minutes, instead of the six hours my painting machine required. It occurred to me also to question the underlying assumption that dissemination has to involve galleries and museums. I have no doubt that they will evolve to serve changing public needs, as, indeed, they have been evolving, and continue to exist. At the same time, I started to see that the new communication media, the Internet and the World Wide Web, could enable me to make the entire art-making process, not just the art objects, available to this new breed of Medicis without needing the gallery context at all. I could make the program itself available, so that anyone could download it off the Web and watch it generate original images all day long if they wanted to. They could run it on their personal computers in exactly the way I see it running on mine, even making prints for themselves if they want physical art objects. The logic of my situation seemed obvious, but that did not make its implications one bit easier to accept for someone who has spent half a century in the "official" art world. What if these new Medicis were in reality no more than a figment of my imagination? And if they did actually exist, what if they would not want what I have to offer? There are always a million reasons for not doing something. Finally, I was able to stop myself asking "what if?" and arranged with a distributor, who can provide a Web-based equivalent to the marketing machinery of the orthodox dealer to market licences to the AARON program.

Today, anyone with enough interest, a computer with a modem and not much more than my Medici paid for his drawing fifteen years ago, can download a copy of AARON, doing just what I see it doing in my own studio. And, like the client with whom I opened this story, they can do what Bill Gates never understood that he could do. Why exhibit static reproductions of Rembrandts on your living room wall when you can not only display an infinite number of new, original images, you can have the privilege of being present while the artist is making them? Will it work? Technologically, of course, it will work: it is working now. But, I believe that the health of art rests upon its relationship with the culture it serves. We may view the future that is rushing towards us as exciting or terrifying, infinitely desirable or infinitely depressing. We cannot have any very clear idea what it is going to be like and there is no way back. Whether AARON will help to establish a viable relationship with the culture as the future reconfigures it, I cannot possibly know. But, while I wait for the results to come in at least I have the feeling that, without being able to see more than a very little way down the road, I do have my head pointing in the right direction. That is a feeling every artist needs.

End Note

1. See A Self Defining Game for One player for a discussion of creativity, drawing and AARON available on the website and in a short version in Leonardo, 35 (1) (2002)

Structure in Art Practice

Ernest Edmonds

My personal development in the use of digital technology in my art practice began more than fifty years ago when I used a computer for the first time to perform an art task for the construction of a work (Edmonds 2002). I was making a wall hanging relief consisting of twenty separate pieces, but I was struggling with what seemed an intractable problem. I had many bits and pieces and I wanted to arrange them according to certain rules. I found it very hard. Whenever I made an arrangement, it broke one of the rules I wanted to satisfy. It was as if I was setting out a chess game but at least one of the pieces was always in an illegal place. Luckily, I was able to gain access to three hours of computer time, which was almost enough to solve the problem for me. I had to switch the computer program off after three hours because someone else needed it but I still had not quite solved the problem. However, my program had reduced it into something I could solve myself. I finished solving the problem by noticing that I could make a small change to the computer's partial solution and complete the task. Thus, with a little help from me, the program then solved the problem.

That was a good beginning but I did not find this way of using computers very exciting. Later it became clear that many of the structural issues that had concerned me, such as the co-existence of two colours in the same space, could be tackled by moving from static to time-based work. By this time, such work was made possible by the fact that computing technology had moved on and could support it in a unique way.

The use of computers in abstract, constructivist,[1] art has mostly been in the production of static objects or series of objects and yet an important property of the computer is that it can handle complex activity developing in time. Indeed, computer technology has had an important impact in music from the specialized research at IRCAM[2] to extensive exploitation in Rock music. It is true that computer-generated images and videos are widespread, and, in so far as they aspire to art, they are often classified as "computer art", which is often understood to refer

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_4

to work that has a strong technological feel about it. Recent developments in computer art have often placed a strong emphasis on constructing abstract models of three-dimensional worlds from which views are selected to make the final work. That may be too simple a description, but it certainly is the case that most of that work is not constructivist. More often, it might be more related to surrealist art. The use of the computer to represent imagined realities has been dominant.

The use of computers for constructing and manipulating images has received considerable attention and there is no doubt that most of us are quite amazed at what can be achieved technically. The exploitation of these possibilities in art practice, so far, has been largely influenced by one type of computer graphics, known as geometric graphics. In this approach, the basic elements, manipulated in order to produce images, are either geometric abstractions such as lines, circles and polygons, or three-dimensional entities such as spheres, cuboids and surface patches of one sort or another. We are so used to these notions that often, we forget that they are abstract. The abstract concept of a line, for example, is of something of no thickness and yet when we actually draw a line, it unavoidably has one. Of course, the physical line has many other qualities not attributable to the abstract one. Why else would we care about the difference between a 3B and a 2H pencil? Therefore, in using geometric computer graphics, careful attention has to be given to how the abstract descriptions of images constructed in this way are realized as perceivable images.

The technology itself encourages a view that the realization of the image is only an approximation to the perfectly formed abstraction. In the early days of the use of computer in the visual arts, this approach was used in order to generate drawings produced by automatic drawing machines called graph plotters. Inevitably, when it came to producing the drawing, one of the key concerns was the particular pen to be used and the speed that it was moved over the paper. Computer-generated video images, or sequences, showing views of imagined worlds constructed within the computer, are typical of modern work of this type. The concrete reality of the work is somewhat subsidiary to the abstract notion of it.

Video Constructs

The work that I am concerned with now is what I have come to call “video constructs” (Edmonds 1988, 1989). A video construct is a work that is specified in a program. The structure of the work consists of visual elements comprising shapes and colours each with a set of physical or geometric relationships and time-based ordering relationships. The pieces are time-based, in that they exist in time just as music and film do. The concrete and final destination of the images is a video monitor. In no sense are the images seen on the screen a view of some other reality. They do not represent paintings or drawings any more than they relate to images seen in television news programmes. The work is concerned with precisely what exists on the monitor.

The fact that an artwork is generated through a computer system allows considerable attention to be paid to the generating structures that underlie both the images, and their movement in time. However, the image is not a view of an abstract world hidden behind the screen. The image on the screen is the concrete and only reality of the work.

To take a specific example, the video construct, Jasper (Fig. 1) is based upon a number of overlapping squares of reducing dimensions, each of a different gray tone. The work starts with the gray levels stepping evenly from black to white, starting with the largest square and ending with the smallest. This order is disrupted at the beginning and the work proceeds in a search for a new resolution. The search itself is the basis of the work. The image pulsates as the tones shift between the static squares in a way that is, perhaps, closer to the so-called minimalist music than normal video material. It changes with a regular persistent rhythm and has a sense of continual repetition, even though in reality it never quite repeats itself.

In a later example, Fragments ver5,[3] a matrix of squares is explored in a similar way, except in colour. Here, the piece moves through a portion of the colour space. Whilst the local rate of change can be fast, with some specific images only lasting for a fraction of a second, the general shift of colour is slow enough for the work to be quite different in the mid-afternoon from its mid-morning state. This work cannot be understood satisfactorily in the context of, for example, film. Rather, it is a changing exhibit having, perhaps, more in common with light dappling on water as the sun slowly rises and eventually sets than with the simple geometry that is, at first sight, its basis.

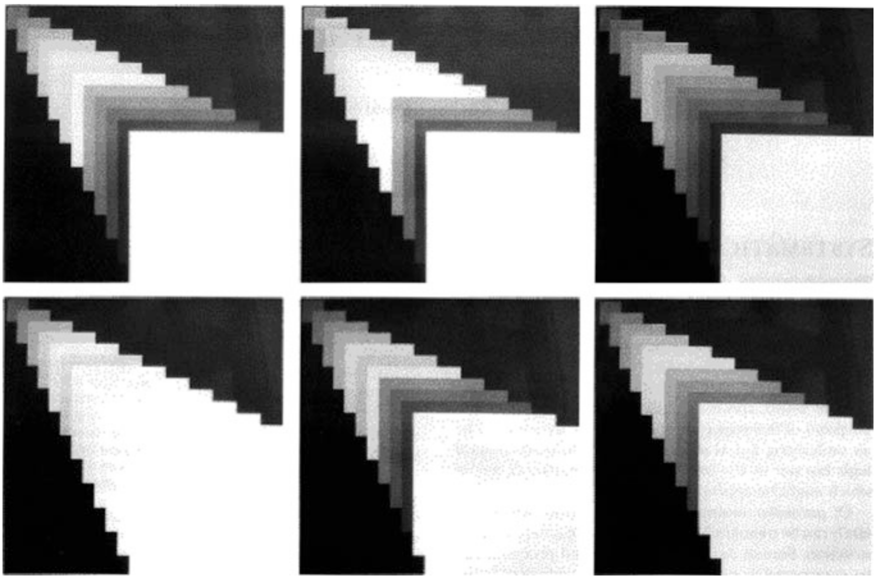

Fig. 1 Six stills from *Jasper,* video construct, 1988 ©Ernest Edmonds

Control and Structure

It has become clear that a detailed technical control of the computer system for producing video constructs is as important to me as having control over oil paint were I currently painting in oils. Having control is largely a matter of the availability of specification methods that are clear and brief enough to be understood. For me, the most exciting element of the video construct is the careful and very terse way in which a specification of what occurs in time is possible. The brevity of the specification is extremely important in the development of my ideas. The inevitable exploration is so strongly supported by this aspect of computer use that new thinking about works emerges during my creative process (Edmonds 1993)

The exploration of time-based constructive work made possible by modern computer technology is more than a new way of doing something. The conceptual development that goes along with the art practice is something new that has implications beyond video constructs. The new thinking and evolving concepts that come from the digital work will inevitably influence drawing, painting and construction as much as they are influencing the video. My use of colour, for example, was changed significantly by the opportunity to codify and control it within algorithms, as in the early use of such systems shown in Fig. 2.

Thus the computer enabled me to express, at a much higher level than I was used to, what I wanted to achieve. I was able to write computer programs that specified the structures and the internal relationships and correspondences of the time-based work. The structures that I provided to the system specified the time-based development of the images as well as the colour and physical relationships that can be used in any single still, the transformations that can be used between stills and the strategy for progressing through time. The system has built-in knowledge that can be used to move from these structures to the actual realization of a work.

The system enabled the structure I had specified in my program to be generated in visual form. I could then look at that visual form, reflect on it and evaluate it. This meant that I could start to think about the implications of the structures in ways that were not possible before. Generating time-based work of this kind was transformed by the computer. It was not just a matter of a speeded-up process but one that was changed in kind, in the sense that the way that thinking about the work was enhanced was entirely new. This work developed into a specific approach to the use of computing to augment creativity in which the expression of knowledge in the system and the interactive development of that knowledge was very important to my creative process.

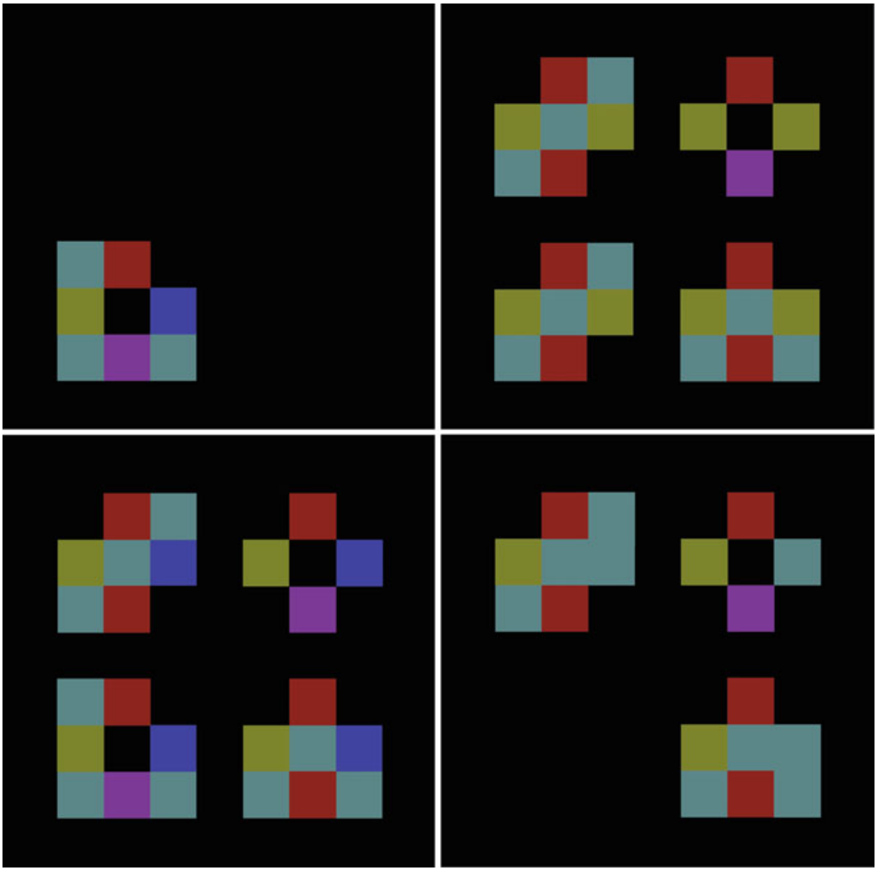

Fig. 2 Four stills from *Sydney*, video construct, 1989 ©Ernest Edmonds

Interactive Video Constructs

Recently (*as written in 2002*), I have returned to my interest in the development of interaction techniques within artworks, first announced in 1970 (Cornock and Edmonds 1973). Today, it is possible to use image-processing technology in order to build interactive works (Fels and Mase 1998). In my case, the time-based video constructs have become *interactive* video constructs (Edmonds and Dixon 2001) Structures in time can be constructed so as to react to events detected by sensor systems. In the example of Kyoto (2001),[4] a real-time image analysis facility is incorporated into the generation of the work. The system includes a digital video camera that points towards the space in front of the work: it looks at the audience. The system uses motion analysis designed to detect human activity and so reports to the video construct computer about the presence of people and about the degree of motion (e.g. fast waving of a left arm). The behaviour of the piece then reacts to participant behaviour. The generative system at the heart of the work has a real-time correspondence with the participant's movement and, in turn, a visualized correspondence with the images displayed.

Kyoto, and similar work, incorporate a human motion recognition system designed to operate with a single person in front of a camera. A video stream from the camera is taken as input and processed in real time. Continuous interpretation of motion is provided from the images in the video stream. The system builds a model of human movement in front of the work and analyses it, in real time, to the computer controlling the images. The model can represent the following:

- presence/absence of a person
- distance from the camera
- quantity of motion
- general direction of motion
- number of separate motions
- which body part caused each motion
- position of each motion
- recognition of specific motions (e.g. waving).

Conclusion

I have described some of the thinking behind my time-based and interactive art up to the work employing image recognition. The work allows me to reflect on the implications of the organizing principles and the compositional elements that comprise the structure underlying my artworks. Generating time-based and interactive work was transformed by using the computer because it enables the effective construction of inter-relationships that provide computational models for building correspondences between forms and systems. The point is that the computer enabled me to express my ideas for the artworks in a way that gave me access to general strategies for constructing and evaluating the outcomes. I can specify rules and relationships between objects in a computer program, which then generates visual sequences. From this I can see the how this realization reveals the effects of the underlying structure. This means that I can explore and evaluate different structures for their effects and make changes in the rules that govern the structure according to personal criteria. It makes it possible to concentrate on the essential features of the work, such as how an interactive piece behaves rather than just how to build it. The comparative ease with which interactive artworks can now be created is helping me make a much fuller use of the conceptual advances that the computer has offered in terms of understanding structures in time and for interaction.

End Notes

1. Constructivism is a movement characterized by geometric abstract forms with its origin in early twentieth century Russian art.
2. The Institut de Reserche et de Coordination Acoustque/Musique, Paris, founded in 1977 under the leadership of Pierre Boulez. It is devoted to advancing the techniques of music, particularly in electronics and computing.
3. Fragments, Kyoto: more information on my work is available on my website: http://www.ernestedmonds.com.
4. As note 2.

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From Zombies to Cyborg Bodies: Extra Ear, Exoskeleton and Avatars

Stelarc

This article is about what is seen to be meaningful in performances and the ideas that are generated by the actions in them. Sometimes, existing available instruments and technology are used. For example, in the body amplification performances with the Third Hand, medical instruments to monitor and pre-amplify body signals were used. The Third Hand was based on prosthetic devices and research at the time, but as a constructed object, it is unique. However, it is not always possible to simply access technology. The Stomach Sculpture that was inserted inside the body for the Fifth Australian Sculpture Triennale was an object constructed from scratch. To achieve it, the assistance of a jeweller and a micro-surgery instrument maker were needed. The team used an endoscope to track the insertion and to document it on video. Also with the Exoskeleton, there has been research and construction of small walking robots. A new contribution was the design of the six-legged spider-like robots large enough to support a human body. The control system is unique too. The leg motions are controlled by arm gestures; magnetic sensors on the segments of the jointed exoskeleton, which wraps around the upper body, indicate to the computer which mode of locomotion and the robot's direction is selected.

Zombies and Cyborgs

The body is an evolutionary architecture that operates and becomes aware in the world. To alter its architecture is to adjust its awareness. The body has always been a prosthetic body, one augmented by its instruments and machines. There has always been a danger of the body behaving involuntarily and of being conditioned automatically. A zombie is a body that performs involuntarily, that does not have a mind of its own. A cyborg is a human-machine system. There has always been a fear of the involuntary and the automated. Of the zombie and the cyborg: we fear what we have always been and what we have already become.

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_5

Issues of identity and alternate, intimate and involuntary experiences of the body, as well as the telematic scaling of experience, are explored in accounts of recent performances. Technology is inserted and attached. The body is invaded, augmented and extended. Virtual–actual interfaces enable the body to perform in electronic spaces. What becomes important is not merely the body's identity, but its connectivity, not its mobility or location, but its interface. The Stomach Sculpture is an object inserted into the stomach cavity. It is actuated by a servo-motor and a logic circuit tethered to a flexi-drive cable. It opens and closes, extends and retracts and has a flashing light and a beeping sound. The Stimbod software makes possible the remote choreography of the body using a touch-screen interfaced muscle stimulation system. In the Fractal Flesh performance, people at the Pompidou Centre in Paris, the Media Lab in Helsinki and the Doors of Perception Conference in Amsterdam, were able to access and actuate the artist in Luxembourg. Exoskeleton is a pneumatically powered six-legged walking machine actuated by arm gestures. Hexapod is a more compliant and flexible six-legged walking robot and although it looks like an insect, it will walk like a dog. Movatar is an inverse motion-capture system—an intelligent avatar that will be able to perform in the real world by accessing and actuating a body, whereas in previous performances the artist has attached prosthetic devices to augment the body. Now the body itself becomes a prosthesis, possessed by an avatar to perform in the physical world. The Extra Ear is a proposed project to surgically construct an ear that, connected to a modem and wearable computer, becomes an Internet antenna able to hear real audio sounds to augment the local sounds it hears with its actual ears.

Surface and Self: The Shedding of Skin

As surface, skin was once the beginning of the world and simultaneously the boundary of the self. But now stretched, pierced and penetrated by technology, the skin is no longer the smooth and sensuous surface of a site or a screen. Skin no longer signifies closure. The rupture of surface and skin means the erasure of inner and outer. An artwork has been inserted inside the body. The Stomach Sculpture, constructed for the Fifth Australian Sculpture Triennale in Melbourne, whose theme was site-specific work, was inserted 40 cm into the stomach cavity, not as a prosthetic implant, but as an aesthetic addition. The body becomes hollow, not the Body Without Organs, but rather a Body with Art. The body is experienced as hollow with no meaningful distinctions between public, private and physiological spaces. The hollow body becomes a host, not for a self but simply for a sculpture. As an interface, the skin is obsolete. The significance of the cyber may well reside in the act of the body shedding its skin. The clothing of the body with membranes embedded with alternate sensory and input/output devices creates the possibility of more intimate and enhanced interactivity. Subjectively, the body experiences itself as a more extruded system, rather than an enclosed structure. The self becomes situated beyond the skin. It is partly through this extrusion that the body becomes

Fig. 1 Extended arm; Melbourne/Hamburg. Photo T. Figallo © Stelarc

empty. But this emptiness is not through a lack but from the extrusion and extension of its capabilities, its new sensory antennae and its increasingly remote functioning (Fig. 1).

Fractal Flesh

Consider a body that can extrude is awareness and action into other bodies or bits of bodies in other places. An alternate operational entity that is spatially distributed but electronically connected. A movement that you initiate in Melbourne would be displaced and manifested in another body in Rotterdam. A shifting, sliding awareness that is neither "all-here" in this body nor "all-there" in those bodies. This is not about a fragmented body but a multiplicity of bodies and parts of bodies prompting and remotely guiding each other. This is not about master-slave control mechanisms but feedback-loops of alternate awareness, agency and of split physiology. Imagine one side of your body being remotely guided whilst the other side could collaborate with local agency. You watch a part of your body move but you have neither initiated it, nor are you contracting your muscles to produce it. Imagine the consequences and advantages of being a split body with voltage-in, inducing the behaviour of a remote agent and voltage-out of your body to control peripheral devices. This would be a more complex and interesting body, not simply a single entity with one agency but one that would be a host for a multiplicity of remote and alien agents.

Of Different Physiology and in Varying Locations

There may be justification, in some situations and, for particular actions, to tele-operate a human arm rather than a robot manipulator. If the task is to be performed in a non-hazardous location, then it might be an advantage to use a remote human arm, as it would be attached to another arm and a mobile, intelligent body. Consider a task begun by a body in one place, completed by another body in another place, or the transmission and conditioning of a skill. Consider the body not as a site of inscription, but as a medium for the manifestation of remote agents. This physically split body may have one arm gesturing involuntarily which is remotely actuated by an unknown agent, whilst the other arm is enhanced by an exoskeleton prosthesis to perform with exquisite skill and with extreme speed. A body capable of incorporating movement that from moment to moment would be a pure machine motion performed with neither memory nor desire.

Stimbod

The Stimbod is made possible by a touch-screen muscle stimulation system. A method has been developed that enables the body's movements to be programmed by touching the muscle sites on the computer model. Orange flesh maps the possible stimulation sites whilst red flesh indicates the actuated muscle(s). The sequence of motions can be replayed continuously with its loop function. As well as choreography by pressing, it is possible to paste sequences together from a library of gesture icons. The system allows stimulation of the programmed movement for analysis and evaluation before transmission to actuate the body. At a lower stimulation level it is a body prompting system. At a higher stimulation level it is a body actuation system. This is not about remote control of the body, but rather of constructing bodies with split physiology, operating with multiple agency. Was it Wittgenstein who asked if in raising your arm you could remove the intention of raising it what would remain? Ordinarily, you would associate intention with action (except, perhaps in an instinctual motion, or if you have a pathological condition like Parkinson's disease). With Stimbod, though, that intention would be transmitted from another body elsewhere. There would be actions without expectations. A two-way tele-Stimbod system would create a possessed and possessing body—a split physiology to collaborate and perform tasks remotely initiated and locally completed—at the same time in the one physiology.

Extreme Absence and the Experience of the Alien

Such a Stimbod would be a hollow body, a host body for the projection and performance of remote agents. Glove Anaethesia and Alien Hand are pathological conditions in which the patient experiences parts of their body as not there, as not their own, as not under their own control—an absence of physiology on the one hand and an absence of agency on the other. In a Stimbod not only would it possess a split physiology but it would experience parts of itself as automated, absent and alien. The problem would no longer be possessing a split personality, but rather a split physicality. In our Platonic, Cartesian and Freudian pasts these might have been considered pathological and in our Foucauldian present we focus on inscription and control of the body. But in the terrain of cyber complexity that we now inhabit the inadequacy and the obsolescence of the ego-agent driven biological body cannot be more apparent. A transition from psycho-body to cyber-system becomes necessary to function effectively and intuitively in remote spaces, speeded-up situations and complex technological terrains. There are also cyber-sexual implications with Stimbod. If I was in Melbourne and my remote lover was in Rotterdam, touching my chest would prompt her to caress her breast. Someone observing her there would see it as an act of self-gratification, as a masturbatory act. She would know though that her hand was remotely guided. Given tactile and force-feedback, I would feel my touch via another person from another place as a secondary and additional sensation. Or, by feeling my chest I can also feel her breast. An intimacy through interface, an intimacy without proximity. Remember that Stimbod is not merely a sensation of touch but an actuation system. Can a body cope with experiences of extreme absence and alien action without becoming overcome by outmoded metaphysical fears and obsessions of individuality and free agency? A Stimbod would thus need to experience its actuality neither all-present-in-this-body, nor all-present-in-that-body, but partly-here and projected-partly-there. An operational system of spatially distributed but electronically interfaced clusters of bodies ebbing and flowing in awareness, augmented by alternate and alien agency.

Parasite: Event for Invaded and Involuntary Body

A customized search engine has been constructed that scans, selects and displays images to the body, which functions in an interactive video field. Analyses of the files provide data that is mapped to the body via the muscle stimulation system. There is optical and electrical input into the body. The images that you see are the images that move you (Fig. 2).

Consider the body's vision, augmented and adjusted to a parallel virtuality which increases in intensity to compensate for the twilight of the real world. Imagine the search engine selecting images of the body off the World Wide Web,

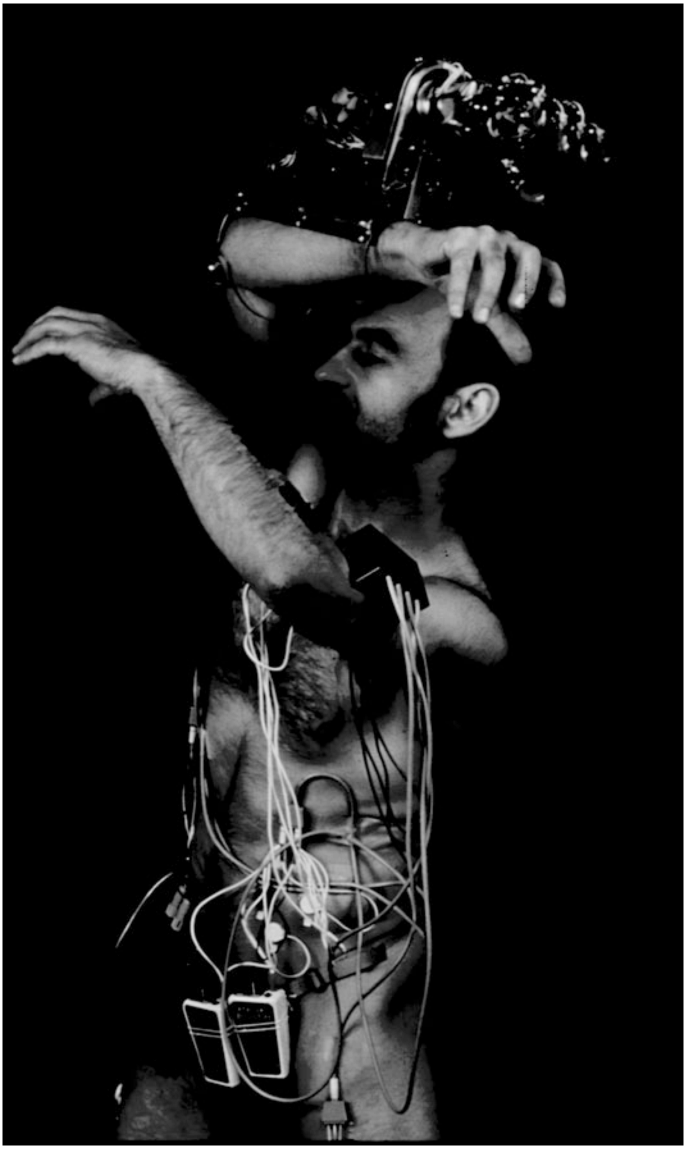

Fig. 2 The third hand: Japan. Photo S. Hunter © Stelarc

constructing a metabody that in turn moves the physical body. Representations of the body actuate the body's physiology. The resulting motion is mirrored in a VRML (Virtual Reality Markup Language) space at the performance site and also uploaded to a Website as potential and recursive source images for body reactivation. Real-Audio sound is inserted into sampled body signals and sounds generated by pressure, proximity, flexion and accelerometer sensors. The body's physicality provides feedback loops of interactive neurons, nerve endings, muscles, transducers and Third Hand mechanism. The system electronically extends the body's optical and operational parameters beyond its cyborg augmentation of its Third Hand and other peripheral devices. The prosthesis of the Third Hand is counter-pointed by the prosthesis of the search engine software code. Plugged-in, the body becomes a parasite sustained by an extended, external and virtual nervous system.

Exoskeleton

A six-legged, pneumatically powered walking machine has been constructed for the body. The loco-motor, with either ripple or tripod gait moves forwards, backwards, sideways and turns on the spot. It can also squat and lift by splaying or contracting its legs. The body is positioned on a turn-table, enabling it to rotate about its axis. It has an exoskeleton on its upper body and arms. The left arm is an extended arm with pneumatic manipulator having eleven degrees of freedom. It is human-like in form but with additional functions. The fingers open and close, becoming multiple grippers. There is individual flexion of the fingers, with thumb and wrist rotation. The body actuates the walking machine by moving its arms. Different gestures make different motions—a translation of limb to leg motions. The body's arms guide the choreography of the locomotor's movements and thus compose the cacophony of pneumatic and mechanical and sensor modulated sounds.

Hexapod

What is explored is a walking architecture that exploits gravity and the intrinsic dynamics of the machine to generate dynamic locomotion. By shifting body weight and twisting and turning the torso, it is possible to initiate walking, change the mode of locomotion, modulate the speed and rhythm and change its direction. The body becomes the body of the machine. The machine legs become the extended legs of the body. It is a more intuitive and interactive system that does not function through intelligence but rather because of its architecture. It is a more compliant and flexible mechanism. It looks like an insect but walks like a dog. Hopefully, this hybrid human-machine operation will initiate alternate kinds of choreography. It is five metres in diameter and weighs about 250 kg. It was first presented at the NOW Festival in Nottingham, England (Fig. 3).

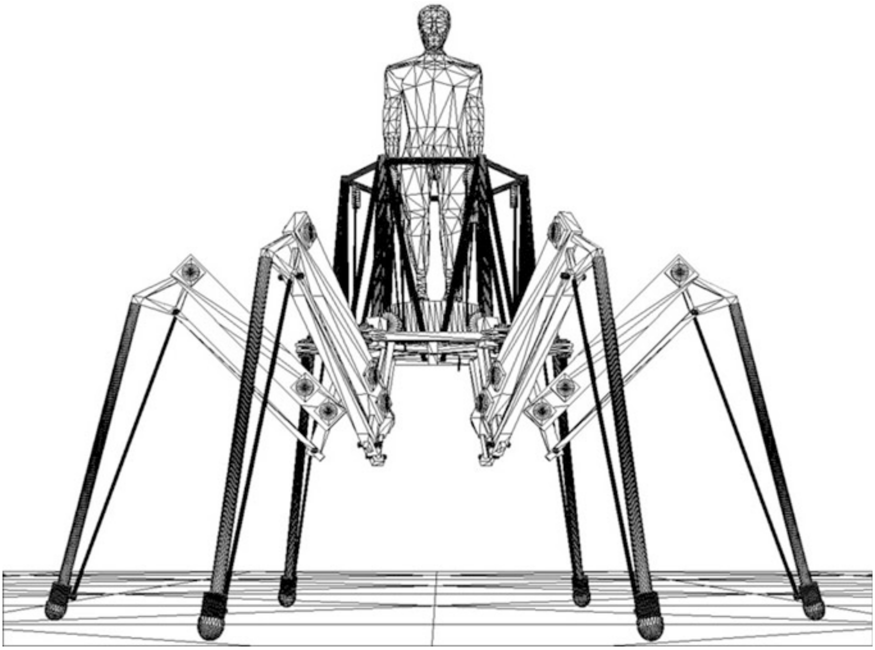

Fig. 3 3D modelling of the HEXAPOD robot. © Stelarc

Movatar: An Inverse Motion Capture System

Motion capture allows a body to animate a three-dimensional computer-generated model. This is usually done by either markers on the body tracked by cameras, analyzed by a computer and the motion mapped onto the virtual actor. Alternatively, it can be done using electromagnetic sensors, like Polhemus or Flock-of-Birds, that indicate position and orientation of limbs and head. Consider though, a computer entity, a virtual body or an avatar that can access a physical body, actuating it to perform in the real world. If the avatar is imbued with an artificial intelligence, becoming increasingly autonomous and unpredictable, then it would be an AL (Artificial Life) form performing with a human body in physical space. With an appropriate visual software interface and muscle stimulation system this would be possible. The avatar would become a Movatar. And with appropriate feedback loops from the real world it would be able to respond and perform in more complex and compelling ways. The Movatar would be able not only to act, but also to express its emotions by appropriating the facial muscles of its physical body. As a VRML entity it could be logged into from anywhere, to allow your body to be accessed and acted upon. Or, from its perspective, the Movatar could perform anywhere in the real world, at any time with a multiplicity of physical bodies in diverse situations and remote locations.

Extra Ear

Having developed a Third Hand, consider the possibility of constructing an extra ear, positioned next to the real ear. A laser scan was done to create a 3D simulation of the Extra Ear in place. Although the chosen position is in front of and beside the right ear, this may not be the surest and safest place anatomically to position it. An inflating prosthesis would be inserted under the skin and then gradually inflated over a period of months until a bubble of stretched skin is formed. It is then removed and the cartilage ear structure is inserted and pinned beneath the stretched skin. A cosmetic surgeon would then need to cut and sew the skin over the cartilage structure. Alternatively, the ear could be constructed on the forearm and reposition later. But this would also require microsurgery to guarantee blood flow. Rather than the hardware prosthesis of a mechanical hand, the Extra Ear would be a soft augmentation, mimicking the actual ear in shape and structure, but having different functions. Imagine an ear that cannot hear but rather can emit noises. Implanted with a sound chip and a proximity sensor, the ear would speak to anyone who would get close to it. Perhaps, the ultimate aim would be for the Extra Ear to whisper sweet nothings to the other ear. Or imagine the Extra Ear as an Internet antennae able to amplify Real-Audio sounds to augment the local sounds heard by the actual ears. The ear is not only an organ of hearing but also an organ of balance. To have an extra ear points to more than visual and anatomical excess. It also points to a re-orientation of the body.

Where Next?

The future is what you're constructing now—the Extra Ear project is being pursued at the moment but it is unrealized as yet. The ethical and surgical problems about constructing it are particularly important. It might have to be constructed on an arm and then relocated beside an actual ear. But that would require some orthopaedic surgery (to pin the ear to the cranium) and micro-surgery (to guarantee blood-flow). This creates the necessity to have even more specialist practitioners involved. It is hard enough to get cosmetic and reconstructive surgeons involved. If the project is not physically realized, it is not important. The idea does not suffice in itself as interesting or meaningful art. The computer modelling and animated gif on the website was not meant to be an image for itself, but rather an indication and exploration of the positioning and appearance.

Residencies have been undertaken at the Advanced Computer Graphics Centre, RMIT, Melbourne University, Kansas City Art School, Carnegie Mellon University, Ohio State University and Flinders University. They have provided specific facilities not found elsewhere. For example, the Virtual Arm project would not have been possible without the expertise and computer facilities at RMIT. The Studio for Creative Inquiry at Carnegie Mellon provided free access to the Biology,

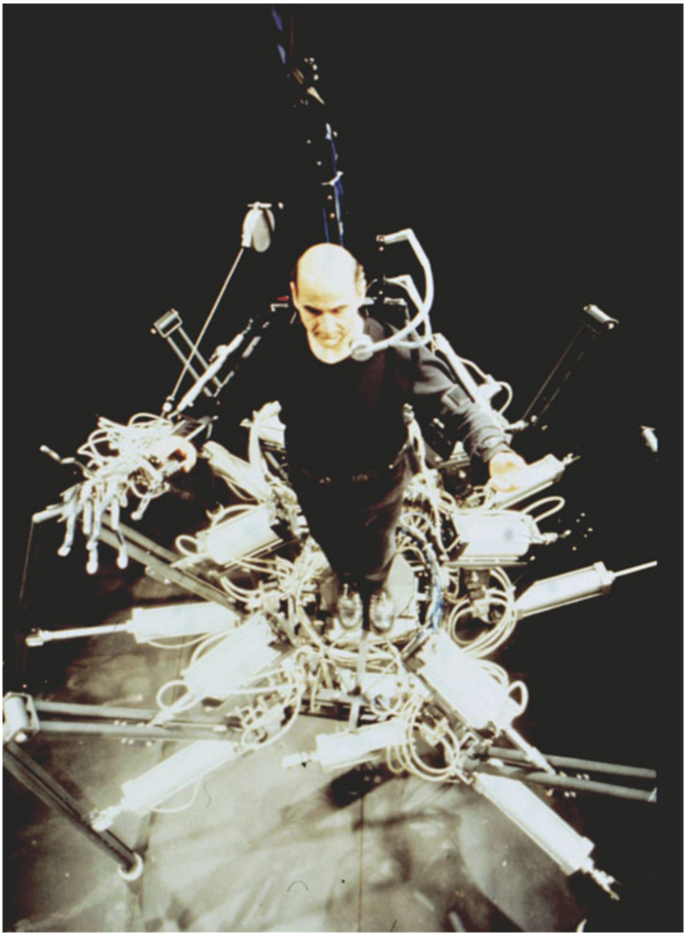

Fig. 4 Exoskeleton cyborg frictions, Dampfzentrale-Bern 1999. Photograph by Dominik Landwehr, robot construction and programming: F18, Hamburg

Robotics and Computer Science areas. At Ohio State University, it was possible to access and experiment with a state-of-the-art Motion Capture System. Exoskeleton was funded by a performance space in Hamburg, Kampnagel, with all the pneumatic actuators supplied by SMC. It was constructed with the assistance of F18, a group of artists/engineers. This was a project completed as part of a residency for Hamburg City. The current position held is Principal Research Fellow in the Digital Research Unit, Department of Visual and Performing Arts at the Nottingham Trent University. The new walking robot, a project jointly done by The Nottingham Trent University and Sussex University is even more unique. Designed by Inman Harvey from the Evolutionary and Adaptive Systems Group, this robot will not be tethered and its locomotion, speed and direction will be controlled by shifting the body's weight, twisting its torso and turning the body. It is a more compliant and flexible structure that is a more dynamic loco-motor. It is a large robot approximately five metres in leg-spread. None of the collaborations have been artistic, rather they have been technical. The artist has to be opportunistic as the projects are not easy to realize. As these projects have involved specialist medical, computer and engineering skills, technical assistance is always needed (Fig. 4).

Acknowledgements The Muscle Stimulation System circuitry was designed by Bio-Electronics, Logitronics and Rainer Linz in Melbourne with the box fabricated with the assistance of Jason Patterson. The Stomach Sculpture was constructed by Jason Patterson in Melbourne. The Fractal Flesh and Parasite software were developed by Gary Zebington and Dmitri Aronov in Sydney. Exoskeleton was completed by F18 as part of a residency in Hamburg, coordinated by Eva Diegritz from Kampnagel. Hexapod is a collaboration between the Digital Reseach Unit, Nottingham Trent University and the Evolutionary and Adaptive Systems Group at Sussex University with funding from the Wellcome Trust. The project team includes Barry Smith (Project Coordinator), Inman Harvey (Robot Designer), John Luxton (Engineer) and Sophia Lycouris (Choreographer).

Tears in the Connective Tissue

Joan Truckenbrod

As cyberspace races towards the future, there is a cry for the hand in this virtual ecology. Linking to cyberspace, where is the touch, the tactility, the physicality of experience? The reach out and touch of telephone mythology has become the banner of the World Wide Web. Email and the Internet provide a long distance touch with an immediacy, simultaneity and multiplicity of connection. But the behaviour and feel of linking to and through computers is flat, a projected world connected through a flat light screen. In this mono-dimensionality, the visual dominates other perceptual senses. Computing is superimposed upon our physical world with little or no attempt to integrate the sensory perceptions into the digital experience. Computing should be constructed with sensory experiences like touch, rather than the language of the machine. The connective tissue linking the natural world with the virtual world through the body and mind is disjoint.

Experiences are kinaesthetic in which there is a synthesis of hearing, seeing, tasting, smelling and touching. The fragmentation of sensory experiences occurring in the cyber-world began with the invention of the printing press. According to McLuhan the invention of print and the printing press is responsible for segmenting sensory experiences. Our ability to think and feel kin-aesthetically, in such a way as to bring hearing, seeing, tasting and touching together, has diminished with the development of print. Words became divorced from related modes of expression, such as voice, gesture, dance, song and animated behaviours such as ritual and storytelling. When an individual perceptual sense like vision, becomes locked in a technology, it becomes separated from the other senses. This portion of one's self closes, as if it were locked in steel, whereas prior to such separation, there is complete interplay among the senses (McLuhan 1988).

Computing is obsessed with creating virtual experiences that simulate forms, materials and behaviours from nature. Virtual experience "overthrows the sensorial and organic architecture of the human body by disembodying and reformatting its sensorium in powerful, computer generated, digitized spaces" (Tomas 1994). Cyberspace disengages from physical reality. Sensory experience is reduced to a mono-medium of digital coding. Digital imaging mediates between these different

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_6

realms of experience. The screen, the digital print, digital fibre creates portals to electronic worlds, spiritual dimensions and personal realms. The computer imaging cosmos is multi-planar, not in the three-dimensional nature of Cartesian space, but with multiple planes of imagery from different realms of experience existing simultaneously. The physicality of real space is imaged photographically, and carries the social and emotional baggage of reality. Imaginary spaces are created by hand using digital drawing and painting tools. Subterranean, invisible, interstitial happenings are sculpted with the light of the digital media. I create multiple planes of simultaneous existence in the social world, the emotional realm, the spiritual world, the natural world, and the virtual world. Some of these planes of experience have a clarity, like looking into a deep clear lake, while others are oblique, circuitous, nebulous, and intimate.

This intermingling is similar to looking through a car window on a rainy night. The world outside is transformed through the streaks of rain. As a shadowy reflection on that distorted image, I see my own face, and I feel that I am looking at the inside of the mask. The facial image is torn by shreds of the outside world flowing down the windshield with the pouring rain. This is not a crisp, bright image in a mirror, but hints of an image that pulsates with the sheets of rain. It appears to be the animating force peering out from behind the shadows of the streetlights, even more variegated with the strikes of lightning. The image as spirit has been summoned up by the ritual pounding of the rain under the cover of the darkness.

Was the image on the inside of the car window a real reflection or a virtual image? And how did the image connect to the distorted image of the real world viewed through the rain? The simultaneity of these disjunctive images connects them and creates overlapping experiences. I use the indigenous nature of computing to evoke symbolic multiple connections between layers of images, mediating between these real and virtual worlds and between spirit and matter. This synthesis embraces the idea of convergence mythologies in African art in which the differences between worlds are linked. Each African culture has a specific explanation for the convergence of spirit and matter. For example, people of Yoruba conceived the cosmos in terms of two distinct yet inseparable components. Aye is the visible, tangible world of the living while Orun is the invisible, spiritual realm of the ancestors, gods, and spirits. In some societies, a dream and the dreaming person are the point of intersection between the human and the spirit realms (Nooter and Roberts 1996). The dreaming person is the intermediary of communication. Headrests are important agents in this process and are usually carved with mirror images of animal heads because these two realms are viewed as mirror images.

To bridge the experiential world and the imaginary world, I use different modes of digital representation simultaneously. Pictures that are photographic in origin refer to the experiential world while painted or sketched images refer to the world of imagination. Each mode of representation carries with it an intent which is injected into and becomes part of the image. A photo is a framed image that accurately represents the people, place or event on the other side of the lens. Photos, until the era of digital manipulation, have usually implied reality, a realistic view with a true narrative of an event or situation. There is, however, the photographer's perspective superimposed on the image as a result of the framing of the scene through the lens of the camera. Scanners and digital cameras are the photographic agents for computer imaging. The real world component of my artwork is created using digital photographic techniques. Here, the manipulation is extended to every grain (pixel).

Digital painting, on the other hand, projects a view from the imagination. There is a dream, a perspective, an opinion, or a personal experience of the subject. Paintings are infused with moods and emotive gestures. The process of painting by hand brings to the surface a probe of experiences not normally visible. Painting becomes a performative and ritualistic activity. Body painting in the Aboriginal culture exaggerates this because of the physicality of painting in conjunction with spirituality. Body painting is a sensuous, tactile form of social interchange in which stories are shared as the body is painted. The combination of touch and hearing increases the empathetic power and intensity of this form of communication. In the Aboriginal view, the meaning of symbolic experience is fully understood when it is absorbed through languages that affect both body and mind.

Computer imagery bridges the physical and the virtual worlds by using languages of both body and mind. The gesture of the hand with the stroke of a digital brush is an agent of the inside world, a portal between worlds. The hand is a vehicle for uncovering the layers of one's consciousness. In African mythology, the hand is a source of action and an instrument of creativity. It is the vehicle that transforms the ineffable, invisible abstractions of thought into objects of tangible, material reality. The hand is a way in which the unseen image can be conveyed visually through a dialogue of presence and absence that stretch meaning across the boundaries of experience and envisioning. According to African mythology, the hand dreams to visualize the invisible and bring extraordinary aspects of existence into human reach.

Body world experiences in 1998 jarred my way of being in the world. The social world, the natural world and more so the intimate world warped like the chaotic molecules in the stretch of a rubber band. Words were silenced simultaneously with an explosion of connections to the intimate dimensions of nature. Intensified in my everyday experience, wind brings tears as it patterns the sunshine with shadows of trees and undulating leaves. Colours embody light molecules themselves. Charging molecules, reshaped with light as my patterns, patterns of my body, of my soul are reshaped with blasts of light. Winds move the water, continuously reforming the pattern of one's life, translucent layers move spontaneously to reveal and conceal simultaneously. These images are a fluid synthesis of photographic and scanned images. They confront the viewer with their scale, ranging in size from 50 in. high by 38 in. wide to 58 in. high by 40 in. wide. The viewer is engulfed: it is analogous to the tide moving in, swirling around and capturing the vision as if caught in a tide pool, a microcosm. With the tension of the undulating tide on the threshold of revealing secrets that again become concealed. The ritual transformation in these prints creates a threshold into unsettling worlds. A radical transfiguration embodies the conflict of optimism with trauma. Chemicals applied to farmlands and foods, hormones and antibiotics in animal feed create an artificial mantle of wellbeing while playing havoc with our bodies. These substances mimic hormones and disrupt endocrine systems, causing cancerous tumours. The dichotomy of the view of beauty on the surface subverts the reality of invisible poisons underneath.

In my current artwork, the images embody transformation and rebirth. Water is the conduit as narratives ride on the surface of undulating waves. Directed by the moon, the tides in their circadian rhythm reveal the mythology of the underwater world, and then reverse direction conceal its secrets. Waves move in opposite directions creating strong undercurrents that are masked by the light patterns on the surface. The magic of light captures my imagination as it fills the surface of water with image, a synthesis of the place of the tides and the story beneath.

I work digitally to create a recombinant montage of these realms: the world of light and the underwater world. I create digital prints and digital fibre artworks using the dye sublimation process. Silk as water, embodies the mythical spirit of its creation. This vitality resonates through the silk fibre, engaging with the imagery. The printed tapestry resonates a powerful synthesis. My intrigue with silk fibre was peaked during a visit to the famous fabric shop in Como, Italy. In this shop, unlike American fabric shops, the walls were lined with tall, stately, dark wood shelves stacked high with bolts of elegant fabrics. In the middle of the shop were very long dark wood tables, a bit wider than the width of fabric. Upon inquiring about a particular silk fabric, I was treated to an incredible experience that I still see in my mind's eye. The fabric was taken off the shelf, unrolled off the bolt and propelled down the long table in elegant rushing waves. There in my mind were my images riding on the surface of that wave. Silk fibre and the sea share the same language (Fig. 1).

My images are digitally printed on fibre which is, for me, analogous to the tide. The silk fibre originating from nature has a resonance with one's life spirit. It maps onto the undulations of air currents, echoing waves in the ocean (Fig. 2).

Images are continually juxtaposed in a virtual sketchbook, floating in my consciousness and periodically erupting through the surface. Tension emerges as unlike or conflicting images are woven together in a non-linear digital montage. Images I create are layered to expose different sections of each original image.

Analogous to the ocean with strong currents pushing and pulling on the sea life, images swell to the crest of the wave, leaving traces on the surface of the image. I am influenced by the turbulence of the sea and its connection to our own personal jarring transformation and renewal.

My working palette includes the underwater world and the reverberations of the spirits that dwell there. This is represented by the light patterns on the water that project themselves onto objects that I place in the water. These worlds that I create become womb-like, evoking transformation and renewal. I place bodice tissue patterns from women's clothing in the water because they capture the twisting and

Fig. 1 Thresholding, (Firelight in a ceremonial dance protecting the secrecy of symbolic forms painted on the body. Limited Edition Roland Print on Capri Paper, 56 h × 40 w (1999)) 1999 © Joan Truckenbrod

transformation of the ocean's current. Sunlight carried on the surface of the waves is projected onto these patterns. These undulating patterns of light make me think of ceremonial symbols that are painted by the Aborigines on their bodies in the secrecy of night only to be revealed by firelight as they perform ceremonial dances around the fire.

Fig. 2 Contrapuntal, grasping blasts of light that warp the plane of experience, 1999, Ltd. Edition Roland Print on Capri Paper. 56″H × 40″W © Joan Truckenbrod

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Algorithmic Fine Art: Composing a Visual Arts Score

Roman Verostko

I was born in the year of the great depression, 1929, in the coal fields of eastern United States. Sixty years ago, at the age of 12, I made my first painting using a paint set I bought from a Montgomery Ward catalogue. Later I worked my way through art school, then attended college and spent some years in monastic life. By 1960 I found myself in the milieu of the abstract expressionists in New York.

Beginning in the late 1950s my interest turned to several faces of pure visual form: geometry, spontaneous brush strokes and automatic writing. I became an avid purist seeking an art of pure form that transcended the material world. For over 40 years I have worked with pure visual forms ranging from controlled constructions with highly studied colour behaviour to spontaneous brush strokes and automatic drawing. Various terms for this art include 'abstract', 'concrete', and 'non-objective'.[1] In its purest form such art does not *re-present* other reality. Rather it *is* the reality. One contemplates a pure form similar to the way one might contemplate a fine vase or a seashell. For me, at its best, this art evokes a transcending cosmic experience. My study of Mondrian provided my first awareness of this experience.

A New Frontier

Radically new procedures for creating such art emerged in the last quarter of the twentieth century. With the advent of computers, I began composing original detailed instructions for generating forms that are accessible only through extensive computing.[2] These instructions, called algorithms, opened a vast array of pure form, an uncharted frontier of unseen worlds waiting to be discovered and concretized. Those drawn to view culture with neo-Darwinian spectacles will relish the evolution of this art. Writing on the new biology of machines Kevin Kelly identified The Library of Form, a frontier hyperspace of form pioneered by Karl Simms (Kelly 1994). My on-going work concentrates on developing my program of procedures,

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_7

the ‘score’, for visualizing these forms. By joining these procedures with fine arts practice I create aesthetic objects to be contemplated much as we contemplate the wondrous forms of nature.

Algorithmic Form Generators

When I was a child a ‘computer’ was a human person hired to do computation. Algorithms for computation in accounting and engineering were carried out by humans, as were those for the tessellations in Islamic art. In recent times, we have come to apply the term “algorithm” more broadly to the detailed instructions for carrying out any task whatsoever. The algorithm driving the bread making machine embodies a recipe (the detailed instruction) for making bread.

From prehistoric times human craft has been algorithmic. The procedures for weaving baskets, fashioning hunting tools gradually evolved and passed from one generation to the next. A better algorithm meant a better product! From a broad perspective, algorithms in the arts would include the composer’s score, the architect’s plan and the choreographer’s dance notation. Given sufficient detail and an adequate computer language, any procedure for executing a task can be translated into an instruction (algorithm) for executing the task. A computer, connected to appropriate machinery, can execute instructions for playing music, drawing a form, or displaying a figure moving in space.

The greater part of my creative work in the past fifteen years has been developing art form generators (software) that I integrate into my exploration of “unseen form”. These are original detailed procedures, for initiating and improvising form ideas. The detailed procedures are designed to be executed specifically as pen drawn lines, and sometimes as brush strokes, using pen plotters driven by a PC. Such form generators may be likened to biological genotypes since they contain the code for generating forms. The procedure for executing the code, somewhat analogous to biological epigenesis, grows the form.[3] The creation and control of these instructions provides an awesome means for an artist to employ form-growing concepts as an integral part of the creative process. Such routines provide access to a new frontier for the artist (Fig. 1).

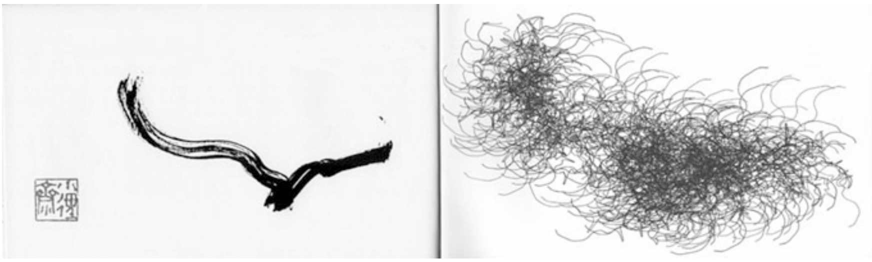

Fig. 1 Frontispiece with plotted brushstroke[4] 1990 © Roman Verostko

The Work

Works are executed with a multi-pen plotter (drawing machine) coupled to a PC driven by my software. The plotter, choosing from an array of pens loaded with pigmented inks, draws each individual line. Most works require thousands of lines with software controlled pen changes.[5] An optional brush routine allows the occasional substitution of a brush for a pen. Brush strokes are plotted with brushes adapted to the machine's drawing arm. One series of illuminated digital scripts is reminiscent of medieval manuscripts. Many of these works are enhanced with a touch of gold or silver leaf applied by hand. However, the design elements illuminated with gold are always code generated and machine plotted (Fig. 2).

Fig. 2 Epigenesis: the growth of form,[6] 1997 6ft × 3 ft © Roman Verostko

Content and Meaning

Over the years the software has evolved by stages yielding a series of works for each stage—*Pathway, Gaia, Glyph, Scarab, Apocalypse*, *Ezekiel and Cyberflower.* Each of these series has distinctive formal qualities associated with its form generators. None of the works are made with intentional representations in mind. Rather, each work presents one more adventure into an uncharted world of forms. This art does not re-present some sort of subject or object. Just as a botanist might label a newly discovered flower so I label this or that newly made visual form or series of forms. Titles are arbitrary and often derived from evocative qualities associated with the work. The art works are visual manifestations of the dynamic procedures by which they grew. The finished works invite us to savour the mystery of their coded procedures whose stark logic yields a surprising grace and beauty. These procedures provide a window on those unseen processes from which they are grown. By doing so they serve as icons illuminating the mysterious nature of our evolving selves.

Creativity and Cognition, Loughborough

In 1996, Creativity and Cognition[7] at Loughborough provided an opportunity for me to reflect on my work and measure some of my ideas in a foreign context. The experience allowed interaction within a milieu of artists specifically interested in coded procedure. This allowed me to assess my algorithmic procedures alongside those of colleagues whose work was new to me. This led to questions as well as affirmations relative to my work. I learned that pen plotted work on paper could hold its own in varying contexts and the direction I had taken continued to be worthwhile even in the face of seductive newer technologies.

As an active artist for over 40 years, I always placed a great deal of value on mastering a tradition and a technology. As a painter, I did not change paintbrushes every two or three years! One of the problems with the digital revolution is that the technology undergoes continuous change rapidly. Must we artists keep changing our technology or can we settle on a specific technology for a long term in order to become a master of that technology? When I exhibited my first algorithmic work in 1985 I realized the technology could occupy me for a lifetime. My practice today employs the same DOS environment, the same ink pens and plotters, and the same command language. My refinements concentrate on algorithmic invention and the quality of the pen plot. My concerns become more and more tuned to the nuances of various rag papers, ink viscosities, the limits and character of pen plotted lines, and the unique form properties derived from intense algorithmic procedure. My Loughborough experience helped confirm my direction. Since then I have acquired even more of the old equipment and have continued my commitment to work with this technology into the future.

Reflections: From the 20th into the 21st Century

Reflecting on the past forty years, I find myself on the same search that I began in the late 1950s, namely, the search for pure visual form that evokes transcendent experience. Close to twenty years ago I had my first glimpse of a new frontier of form made accessible with computing power. Since then I have gained a glimpse of this awesome array—too vast to hold—infinities of form. As the twenty-first century unfolds I envision a return to pure form. With algorithmic procedure forms will grow beyond the dreams of first generation twentieth century abstractionists who will emerge as pioneers of twenty-first century formal art. I recall visiting Michel Seuphor in Paris back in 1963. He glowed with his vision of a visual world that could lead us beyond mundane social conflict. Clearly the artists who pioneered the new reality saw it as a springboard to a greater cosmic consciousness. They envisioned a visual art somewhat like a symphony of sound. Note how the symphony transcends political conflict and invites us to be in our bodies with a total sense of hearing and simultaneously leads us beyond the material world. Diverse audiences can share the same symphony without respect to their social and political differences.

This phenomenon was very clear to Kandinsky who wanted his art to embody pure form free of political and social conflict (Kandinsky 1947). His art stood on its own visual form without describing some "other" object or ideology. Following this path, I have sought a similar goal. The project, Epigenesis: The Growth of Form, exemplifies a procedure that I believe will emerge very strongly in the visual arts of the twenty-first century. In this instance, the procedure grows a series of improvisations based on the visual relationship of an arbitrary set of coordinates. The procedure, somewhat like a composer's musical score, generates a series of improvisations based on the initiating visual form. In effect, there are eleven variations on a visual theme achieved through thousands of lines. Each pen line, distributed and shaped by the score, builds an intricate network of variations within a self-similar visual structure. By analogy to a 'sym-phony', the harmony of sounds, these visual improvisations become a 'syn-graphy', a harmony of visual forms. Today, one can create a score for harmonic graphic generation in many ways similar to the way composers score for sound (Verostko 1990).

The vision I have held for the past twenty years has been gradually emerging as the new reality. With the emergence of the genetic algorithm and the growth of the software industry, artists, without laborious programming, will eventually grow algorithmic generators for their form preferences. The algorist programs of my time will then fade into an archaic past and our code will look quaint. I hope I live long enough to savour the rebirth of this neo-formalist art as it springs forth with vibrant life in the twenty-first century. All will marvel in a wondrous world of form as in a newly found Garden of Eden—an arcadia of great delight (Fig. 3).

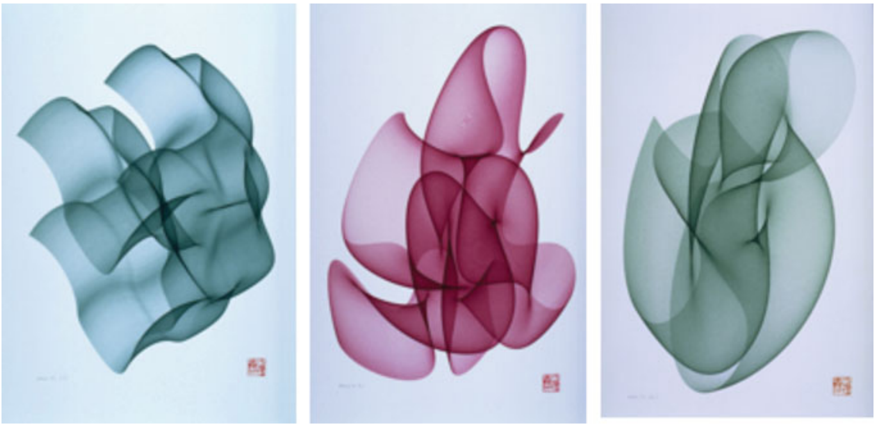

Fig. 3 Cyberflowers, 2000, Algorithmic pen and ink drawings © Roman Verostko

There are moments when one wishes that someone, the likes of a Mondrian, could appear for a brief moment in our historic time … and be able to experience his own "Broadway Boogie Woogie" in today's New York—ecstasy revisited!

End Notes

1. First generation pioneers whose work opened this new reality for me included Mondrian, Kandinsky, Malevich, Hepworth, Kupka, Gabo and Pevsner. The "non-objective" and "new reality" artists included Mondrian, Barbara Hepworth, Max Bill, Ozenfant, Malevich, Gabo, and Pevsner. The "New Reality" for them was the art object they created; their forms did not represent other objects.
2. Other *algorists* following a similar path were unknown to each other at the beginning. Pen plotter artists who had achieved a mature body of work by 1990 included Harold Cohen, Mark Wilson, Vera Molnar, Jean Pierre Hebert, Manfred Mohr and Hans Dehlinger: see www.solo.com/studio/algorists.html.
3. The term "epigenesis" borrowed from biology, refers to the process whereby a mature plant (phenotype) is grown from a seed or genotype (DNA). By analogy, the artwork (phenotype) is grown from the algorithm (genotype). The procedures for growing the work may be viewed as epigenetic. The algorithm (genotype) for each series of works is capable of generating a family of forms with each being one of a kind.
4. Fig. 1 shows one of 125 different brush strokes plotted for a Limited edition of Chapter "A Million Millennial Medicis" of "An Investigation of the Laws of Thought…" by George Boole, L.L.D. Macmillan 1854. Chapter III. "Derivation of the laws of the symbols of logic from the laws of the operation of the human mind. Limited edition of Chapter "A Million Millennial Medicis" with illustrations by Roman Verostko, St. Sebastian Press, Minneapolis, MN, USA, 1990.

5. See Art and Algorithm (www.verostko.com/alg-isea94.html), which addresses procedures and issues related to an artist's use of algorithms.
6. Fig. 2 shows one of 11 pen plotted units spanning 40 feet at Frey Science and Engineering Centre, University of St. Thomas, St. Paul Minnesota, USA see verostko.com/st/mural.html.
7. Creativity and Cogition http://creativityandcognition.com.

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The Computer: An Intrusive Influence

Michael Kidner

I am writing the following article from the point of view of a painter with no training in the fields of science or technology. Nevertheless, in the course of a long career, I have come to realize the inescapable value that the computer has to offer. As it is, I rely on the research of others for the raw materials of my own project which, in short, concerns patterns of space in the mind.

I began life as a painter in the 1950s. Painterly gestures, made from the stomach while denying the head, were typical of the strategy adopted by the avant-garde at the time. "A painting was finished if it worked" was a popular but unsatisfactory measure by which to proceed. It was not that I was scared to make intuitive gestures, I tried, but the intuitive gesture offers no satisfactory ground for dialogue—only inspiration via imitation. I chose instead to explore the interaction of colour where there was a clear measure by which to judge the effect of the experiments I was making.

I felt vindicated in following this independent approach when the Tate Gallery, London bought one of my paintings in 1962. However, colour needs form to articulate it (how big is red?) and I soon found myself more interested in form than in colour. I took a piece of bent wire and rotated it ten degrees at a time. As the form changed I noted the points where the wire profile crossed a vertical line held behind it and in this way produced a topographical map of the bent wire.

As the 1960s rolled on, cybernetics became a topic of hot debate among painters much as photography had been in the previous century. I took the view that the computer was an unwelcome competitor and I tried to imagine problems that would confound what I then regarded as an inhuman and unwieldy monster. I took a strip of paper and folded it at an angle of forty degrees but left the end sticking up at an angle of eighty degrees then repeated the operation several times keeping the sides equal in length. I aimed to come back to the starting point but for me it was a trial and error situation which made me wonder whether the computer would offer a better solution. I was afraid it could.

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_8

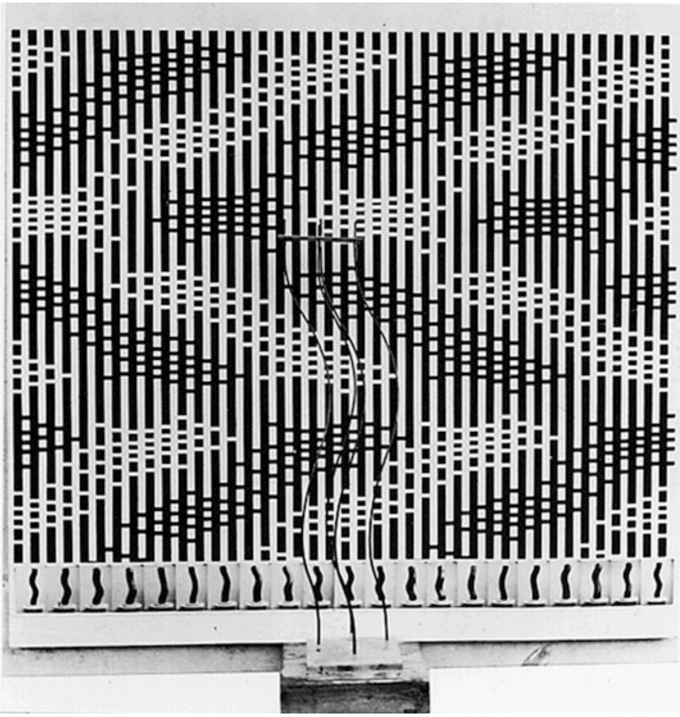

Fig. 1 Column No. 1 in front of its own image, 1970 © Michael Kidner

So then I tried to by-pass the computer altogether by stretching elasticized cloth between two wooden battens. By moving the battens I could distort an image drawn on the elastic through several repetitive stages and I devised top-down programs accordingly. However, the process was limited by the fact that the elasticized cloth would stretch in only one direction at a time (Figs. 1 and 2).

Residencies

I was still trying to extend the application of this analogue device when I received an invitation to take part in the 1996 Creativity and Cognition Conference in Loughborough, England.

What amazed me here was the incredible range and diversity of the problems which engaged the other participants at the conference as though the horizon of their imagination had suddenly been exploded. At the same time, I found it hard to relate to the results of their work partly no doubt because I was unfamiliar with the technology.

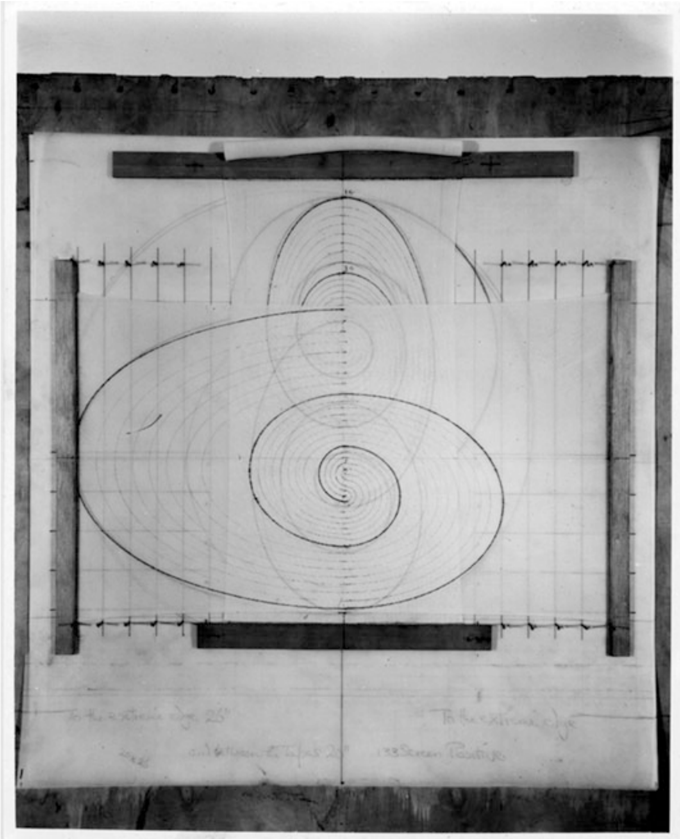

Fig. 2 Looped circle, 1978 © Michael Kidner

Shortly after this Professor Ernest Edmonds invited four of us to Loughborough to pursue whatever interests were uppermost in our minds. We were offered the assistance of experts from the university faculty which Professor Edmonds arranged to suit our different needs. It was such a generous offer that it proved difficult to make an adequate response.

Boolean nets was my problem but despite several patient sessions with a mathematician the mathematics defeated me. In the end, my advisor produced a video of Conway's The Game of Life, a fascinating programme, but because it was time-based I felt, as a painter, that it was not for me. Happily, this was not all the week had to offer since we all four benefited from each other's experience. See extracts from a conversation with Ernest Edmonds at the end of this article.

A visiting artist from Germany brought a drawing which she wanted to realize in print. I was surprised since her problem did not seem to relate to the computer until I realized that transposing a drawing on the monitor into a finished product was not as straightforward as I had assumed and a vital extension of the technology.

Another visitor from Holland wanted to experience 'virtual reality' and we were all offered a brief but astonishing turn with the helmet. Back home this visitor made impressive paintings based on his experience of 'virtual reality'.

Reflections

I was still suspicious. I did not want answers that might show up on the monitor seemingly by magic. The computer could be a seductive toy offering only a superficial understanding but the prospect of going deeper into the technology was disconcerting. It was not only that I begrudged the time but more that I was afraid of losing sight of the purpose while acquiring the necessary skills. There had to be another way.

Fortunately, I came across an a-periodic pattern by Roger Penrose (1991). It was a highly sophisticated computer-generated drawing that seemed to answer my problem. What I saw in Penrose's pattern was a tiny fraction of space like a seed that grows in time. It reminded me of water broken by whirlpools which disappear only to reform elsewhere in an expanding space, or again like a Mondrian painting without the neo-Platonic ideal which inspired it. Indeed it was a pattern with many contending centres and no certain outcome, like the evolution of life itself.

But what in particular caught my attention was the pentagonal organization of space instead of the rectangular convention which is the more generally accepted. The latter, adopted by Mondrian with his finely balanced verticals and horizontals, reflects stability whereas the former is more like the space I experience in an expanding/contracting world view.

However, my response had nothing to do with the problem that confronted Penrose. His concern was to tile the plane with the fewest possible number of shapes, a well-defined mathematical problem. Whereas my concern is to define the many associations his pattern inspired. If I could reduce the number of associations to one I thought the computer would quickly resolve the problem but because I have not been able to do this I believe the computer will offer as many, if not more solutions than I have associations. I foresee that it could divert me from my present objective by suggesting new ones, and ones that would be better aligned to its own way of operating. On the other hand I recently saw, in the exhibition, Apocalypse, at the Royal Academy, London, a sculpture of the Pope being knocked down by a meteorite. It seemed obliquely close to the kind of expression I was myself seeking but I could find no logical way to connect it to my own project. In fact, I wondered what sort of logical explanation could possibly account for it?

I do not pretend to understand the mathematics behind Penrose's argument against artificial intelligence, but feel satisfied that he can make it. I like a world in which the personification of the truth we believe in transforms itself as we approach. Instead of imposing reason on feeling, I try, as a painter, to impose my feeling on reason.

Michael Kidner: From a Conversation with Ernest Edmonds

E: I would like to start by asking you to say some things about your work.

M: Around about 1970 I read a book by Dancy called the number of the language of science and it was really the history of the number theory. I was so impressed with the way number was describing or the way Dancy described number as describing life, and it made a lot of sense to me and since then I have always felt that number did account for existence, if you like, in a way that enormously impressed me. So that, number has been very important in my thinking, and when it comes to numbers like imaginary numbers or complex numbers of things like that, I am very interested to try and understand what that means just as the interval between one and two means something that is easy to understand.

One of the things about the book that impressed me was the interval between numbers was crude as long we only had one to two, three four and gradually that interval, the interval you could say in time has been shortened to the point where it becomes continuous, and what I was feeling was that experience is continuous but our description of it is always cutting it up into pieces, so that it does not correspond to experience, but number has constantly tried to fill in that gap.

E: So just to take that a step further if number is at the centre, or number systems perhaps is at the centre, that presumably implies that the work is quite concerned with structure.

M: Yes … with measurement … Is structure synonymous with measurement?

E: No not exactly, so by structure I mean relationships between elements. So that, for example, a measurement can be a single entity, I could say this is eight centimetres long … but there is no structure … so it might be that the relationship between the length and the height of this is something like a golden mean, now we are talking about structure. But there are all kinds of structure that could be (say), there are two curves that are related to one another in some way, like different segments of the same.

M: Yes that's right. You see if you are talking about the proportion of the table or door or room being right, it is a little like talking about composition. I have never had a lot of time for composition really and so I suppose, in a sense, if you are not composing you are structuring. I mean that structure becomes the nature of the composition. There was a lot of discussion I think with the Russian constructivists around 1920 as to the difference between composition and construction. And they were all trying to do structures and criticizing composition. I would side very much with this.

E: I wonder if you could try to summarize what you have done in relation to things that are valuable to your work or your thinking…

M: (Referring to problems solved) I think both of them have been resolved to my satisfaction and they didn't actually get on to computers, we resolved it mathematically. The first, the one with folding the pentagon from a strip of paper, Helmut resolved it beautifully, not even mathematically, he just folded it with the paper strip then he just pulled out the paper and found the angle that way which thrilled me greatly.

It was a very nice solution … I suppose I could have resolved that cube one, if I had had a bit more skill. but—one of the problems with the model I brought was it was a millimetre or two out in terms of making a physical square so that's not very good … and certainly the computer does it very precisely. We did that in another department, we used a different bit of software. I didn't realize it would be so difficult to find the right software…

And I would say another thing which is almost as valuable, is for example, Helmut was able to get hold of the whole list of reading that I could browse through, which I wouldn't have been able to do at home. The thing that most interested me was that this was made possible by accessing articles, then going to the library, being able to get them out and read them.

E: Because the access was through computers.

M: It was entirely through computers, absolutely, and I mean there was a whole list that long, I only just selected one. It was really quite a basic article on how to construct the Boolean net. And then going through it with Helmut after that yesterday afternoon it became something I could in fact envisage doing with an exercise book at home.

E: Have you made an advance in that respect?

M: Very definite advance and I think if I see you this afternoon I will clear up some of the points, I went through it last night in my head, what we have done and then I realized some of the missing bits.

E: So how did it seem working with an expert like Helmut?

M: When I gave him this optical like a cube in three planes intercepting, he seemed to take a long time to realize the problem, but he was approaching it not very visually at all, I mean he was measuring proportions, what's the measure of that, what's this, he reduced the whole thing to a series of numbers and then quite quickly he resolved it, but, in order to get it to that point I don't think he would have noticed the problem at all if I hadn't asked him to prove it to me, because I don't think he thinks in that visual way.

E: You said to me earlier, the other day, that number is the essence.

M: It is. That's more to do with the thinking process, yes I don't know how number and the eye relate. In the artworld, it's more to do with anyone who uses number isn't being emotional or something…

E: So, have you been able to think at all how this might move on in your work? Have you had any concrete ideas?

M: Concrete ideas really mean going home in my exercise book, experimenting with what I now can do with Booleness because there are lots of games you can play given the structure.

I can just see that it's going to be absolutely essential and that working without a computer is going to be impossible but until that, at the moment I can do quite a lot in an exercise book to satisfy myself.

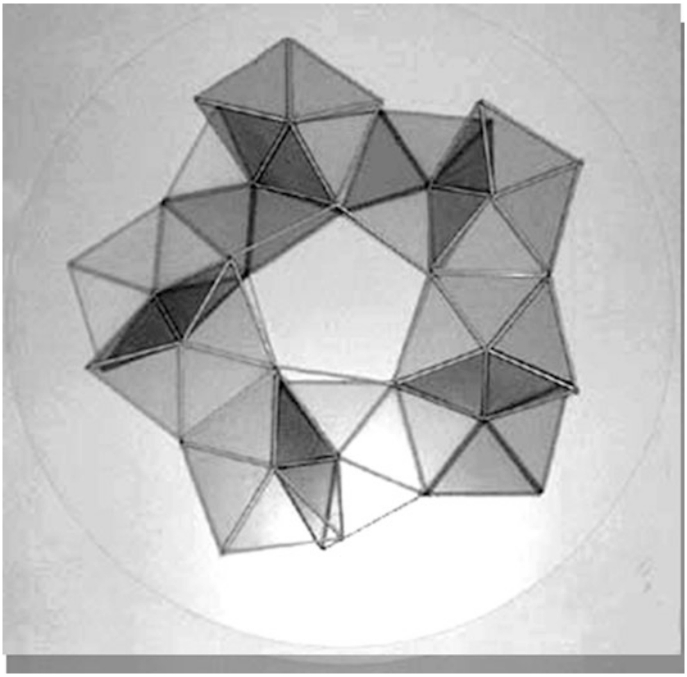

Fig. 3 Wall Net, 1998 © Michael Kidner

E: But you can see that to progress this as far as you would like, some software would be a positive help. Do you have a computer?

M: No, I don't. I've never even invented in the computer. But after this week I am not so concerned about the computer I am much more concerned about the software (Fig. 3).

Date of Interview January 1996

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Digital Art in Brazil

Priscila Arantes

This article draws a cartography of digital art in Brazil by focusing on the dialogue between pioneer productions of media art and some recent ones. We ask the question, what changed in the exhibition circuits and curatorial strategies of this production if we compare it with the beginnings of art and technology in Brazil? Curating as an important component for the formation, production and dissemination of an exhibit begins to appear more prominently in the art systems starting in the 1960s (Obrist 2008). In the 1980s, following the explosion of the market accompanied by the growth of temporary exhibitions and contemporary art museums, the activity of the curator indeed expanded. It is important to note that the expansion of curatorial practices brought about the creation of new formats and exhibition circuits, often in dialogue with parameters that exist in the production of art itself: curatorial projects based on process, curatorial practices that manifest themselves in circuits beyond the institutional exhibition space; curatorships that occur in urban space and cities, for example, collaborative and networked curatorial projects, are among the examples we could list (Arantes 2005).

Within this perspective, to think about the history of supposed history of art and technology exhibitions in Brazil, leads us to at least two questions: what exhibitions and what history of the exhibitions do we want to talk about? What point of view do we want to build, since history is always a discourse and as such is not neutral? I shall deal with two aspects which I consider to be essential:

(a) Historical exhibitions in art and technology: pioneering exhibitions in Brazil in art and technology
(b) Contemporary exhibitions that problematize or that sheds light on the issues brought about by contemporary culture.

Understanding that in concrete art we find the antecedents of digital and computer language, Waldemar Cordeiro, a pioneer in art and technology in Brazil, introduced, the computer into his creative process in the late 1960s. The *Derivadas de uma imagem* [Derivatives of an image] (1969) made in partnership with Giorgio Moscati, on an IBM 360 in the Physics Department of the University of São Paulo,

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_9

inaugurated computer art in Brazil. The objective of Cordeiro was to transform what was a photographic image, into computer language. In *A Mulher Que Não É BB* [The Woman Who Is Not BB] (1971), Cordeiro starts with the photograph of the face of a Vietnamese girl, burned by napalm—one of the greatest symbols of the destruction and irrationality of war—transforming it into thousands of pixels. It is interesting to note that, at the height of the Brazilian military dictatorship, Cordeiro adds to the images of computer art, social and political commentary, therefore differentiating his work from the computer art developed in the international arena which focused on highly abstract and metalinguistic forms, as in Vera Molnár's and Georg Nees's works.

Attributing to art the function of "communication of communication", Cordeiro (2010) understood the computer as an instrument for social transformation: for him, the modern artist was the one who was able to create new techniques of and for communication. In 1971, in parallel with other exhibitions in the field of art and technology, such as the first exhibition of video art in Brazil organized by Walter Zanini, Cordeiro organized the international exhibition *Arteônica* at FAAP (Armando Álvares Penteado Foundation). In the exhibition catalogue he highlighted the democratizing aspect of telematic arts and the possibility of access that the interface between art and communication could provide.

Another important name in the history of art and technology exhibitions in Brazil is Walter Zanini. In *JAC's—Jovem Arte Contemporânea* (1972), for example, besides the fact that Zanini opened the space for the production of new media he raffled off spaces in the museum for artists to produce their work while asking artists to give a greater emphasis to the artistic process over the finished object. *Prospective 74* was further ground breaking, in the sense of creating a network of known artists, in which each one would invite another one. This network of 'friends' resulted in an exhibition with over 150 artists who produced works that exceeded the limits of conventional media, such as video art and mail art. In addition, *Poéticas Visuais* (1977) were ever more innovating by giving the public the chance to select artworks, which they would like to take home with them. This exhibition provided the public with photocopies of the documents and artworks displayed, thus setting up the spontaneous participation of the viewers who were able to create many potential 'portable exhibitions'. It is noticeable, therefore, that Zanini valued a curatorial format that gave space to the idea of network collaboration, as well as access and information sharing between artists.

It is important to emphasize that the turn of the 1960s to the 1970s in Brazil corresponded to the worst period of the oppressive military dictatorship, with its mechanisms of censorship and repression. As a reaction to the dynamics of artworks which were acceptable to the dictatorship, experimental artists in art and technology took on, at this time, the challenge to not only work with languages outside the canons, which were traditionally legitimized in museum spaces, but embrace artworks that functioned as guerrilla tactics, as shown in the artworks developed by Hudinilson Junior's and 3NOS3 group against the conservative art of the period. In other words, what seemed to be important to emphasize at that time, in these first propositions, is that they not only incorporated new media within the circuit of art, but have potentialized a curatorial thought in tune with the cultural and contextual issues of the time.

Contemporary Curatorship: Archive and Database

If the popularization of the Internet allowed us to imagine a world where information could be more accessible, as Cordeiro thought at the time, on the other hand, we cannot ignore the intrinsic relationships between archiving, surveillance and monitoring of users' data by large companies and corporations within the current context. In this sense, it seems to me that, more than focusing on exhibitions that work with the specificities of languages, or to ask ourselves about the particularities of the curatorial activity in the exhibitions involving art and technology, perhaps the main interest is to verify which projects can contribute to thinking and reflecting upon the discussions that permeate digital culture. In this context we could not fail to make reference to the essay "*Database as symbolic form*" by Lev Manovich (1999) which, in the light of Panofsky's (1999) well-known *Perspective as symbolic form,* first appeared in 1927, defends the idea that the database would be the predominant cultural form of contemporary culture. From the old family albums, we witnessed a fever of producing digital files-on Google, Facebook, YouTube, Instagram; Mobile phone files, digital cameras and computer files. The web, in fact, appears as an endless source of resources, making cyberspace a vast territory for the exploitation of documents, information and collectibles.

Instead of doing a survey of more recent curatorial projects that dialogue with these questions, I would like to call attention to a trilogy about the archive and the database that I have been developing since 2010 in the Paço das Artes. Created in 1970, the Paço das Artes is an institution that belongs to the São Paulo State Secretariat of Culture. In addition to exhibitions, Paço das Artes promotes courses, lectures, symposiums, workshops, publications and artistic exchanges, and has been established as one of the leading institutions devoted to young Brazilian contemporary art scene. Through actions such as the Temporada de Projetos (Project Season), which received more than 5.000 portfolios and held about 250 exhibitions, the Paço das Artes has been a meeting point and one of the main platforms for the emergency of new artists, critics and curators. By not being a museum in the strict sense of the word and, therefore not having a collection—and by acting in the promotion and dissemination of young Brazilian contemporary art—makes its registration work and archive the fundamental axis of its 'collection'. We could say that the Paço das Arts actions constitute a kind of Imaginary Museum as defined by André Malraux (Malraux 2015): the Paço das Artes collection are the artists, the activities, curators, critics, educators and the public that had been there.

Livro-Acervo

The exhibitions *Livro-Acervo*, *MaPa* and *Arquivo Vivo*, in addition to being isolated projects, are part of a curatorial thinking process, which started as an investigation of the relationship between contemporary art, archive, and database.

The first project, *Livro-Acervo,* was designed by me in 2010 for the commemoration of the 40th anniversary of the Paço das Artes. The initial idea of the project was to develop a "big" curatorship that could not only rescue the memory of the Paço das Artes—the actors and agents who were part of its history—but also offer the public the opportunity to have access to a curatorial example beyond the traditional exhibition space. It was in this perspective that a new idea was born: to develop not only a curatorship in book form, portable and of easy circulation, but to also develop a curatorial concept based upon the concepts of the "archive" and "collection" of the institution, thus rescuing one of its most important projects: *A Temporada de Projetos* [an annual open call for projects].[1] This large project was composed of three main parts.[2] In the first part, the thirty artists who went through the annual *Temporada de Projetos,* were invited to develop a new work on paper (such as the flip book *Shipwreck*, developed by the artist Laura Belém). These works were printed as hard copies for distribution and inserted together with the other items comprising the project. In the same folder of notebooks worked on by the artists, we have the Encyclopaedia, the second part of the project, with information about each of the artists, curators and jury who participated in the *Temporada de Projetos* from the very beginning. The third part of the project consisted of a sound work of up to one minute long, recorded on a CD-ROM, developed by artists and curators, who participated in the *Temporada de Projetos* since its first edition. It is noteworthy to mention that the project parts were given in the form of a box alluding to the idea that the device contains an important part of the history of the *Paço das Artes* and its share of emerging Brazilian art.

Giving continuity to the project, *Livro-Acervo* was implemented in November of 2014, *MaPA: Memória Paço das* Art*es* [MaPA Memory of the Paço das Artes], a digital platform for contemporary art, brings together all the artists, critics, curators and members of the jury who have participated in the Temporada de Projetos since its inception in 1996. The platform consists of a database with more than 870 images of works exhibited in the *Temporada de Projetos,* and approximately 270 critical texts and video-interviews that have been especially developed since 2014 for this project. Bringing together more than 240 artists, 14 curatorial projects, 70 art critics and 43 jurors, the platform was built as a relational device and a *work-in-progress*, offering the researcher the opportunity to access information and existing relationships within the *Temporada de Projetos*.

On the *MaPA* home page, the public is presented through a random system, to a number of names (of artists, critics, curators and jury members who went through the *Temporada*). By hovering the mouse over any of these names-links, the map highlights in bold the other names involved in that particular year of the *open call for projects*. That is how one starts the research on the *MaPA* platform: as a relational device that allows one to know the trajectory of each artist alongside those of the critics who evaluated him/her, and the jury that selected him/her. The emphasis given to this "relational" history is explained in the dialogue with the *Temporada de Projetos* proposals, which in selecting artists, curators and critics early on in their careers and serves to validate new talent into the art scene. It is for this reason that the organization of information and references on the platform are made through the names of the artists, curators and critics. It documents their trajectories and the creative development of all those involved in the production and circulation of contemporary art, therefore validating the trajectories and creative development of all those involved in the production of contemporary art system.

Finally, the *MaPA* could be seen not only as a recovery device for the trajectory of the *Paço das Artes* and the institution's archives, but also as a research device for all those interested in the trajectories of the young Brazilian contemporary artists. Last but not least, the map is a trigger vehicle for developing other narratives on the history of Brazilian art, the young Brazilian art, which quite often has no opportunity, or does not appear in the official discourses of art history.

Arquivo Vivo [Living Archive]

The latest project of the trilogy is the curated *Arquivo Vivo*, of my own creation, presented in the Paço das Artes in October of 2013. Unlike the two previous projects, *Arquivo Vivo* did not only focus on the artists who passed through the Paço das Artes but expanded the debate to questions that permeate the archive within the context of contemporaneity. Drawing on the concept of *Archive Fever* proposed by the philosopher Jacques Derrida, who understood the archive as an incomplete device, and therefore always open to new and constant rewriting, *Arquivo Vivo* has presented twenty-two works by national and international artists which, in a different way, incorporated themes and procedures that relate to the archive and the database in its relation to history, memory and forgetting, based on the articulation of three main vectors:

(a) Archive and appropriation of history's and artArt history's documents and works
(b) Archive in the Body, and the Body as Archive
(c) Artist's Archives, Institutional Archives, and Databases.

In the first vector, we find artistic projects that often appropriated historical documents of history or re-enacted emblematic works/documents of the history of art. By appropriating these files, the artist deconstructs and modifies the 'original' meaning by pointing to the idea that the archive is always open to further readings and interpretations. This was the case, for example, of the Project *As Pérolas como te escrevi* by the Brazilian artist Regina Parra. The project is a three channel video installation. Each projection is composed of images of immigrants who entered Brazil clandestinely, and now live in São Paulo. The immigrants read excerpts from the letter Novo Mundo [*New World*] written by Américo Vespúcio in 1503. The projection on multiple screens, in addition to the counterpoint of the diverse accents of the immigrants who read the document of the history of the discovery of the Americas, not only alludes to a fragmentary and multiple narrative, which is built upon a relationship with the viewer, but also refers to the power relationships and the processes of colonization that have marked our history.

Within the vector *Archive in the Body and Body as Archive*, we find projects that consider the body as a kind of archive and/or incorporate the archive into the body tissue itself. The body here can be understood as a kind of writing that incorporates marks, erasures, and significant traces of a body/message in a constant process of construction of meaning. *Made in Brazil* by Letícia Parente as well as *Time Capsule* by Eduardo Kac, integrated this second vector of the exhibition. In *Time Capsule*, for example, Kac implanted a microchip for animal identification under the skin on his ankle, registering himself through the internet into a database. The project raises questions not only about digital memory, but also about current surveillance and information control devices. Whereas inside the third vector *Artist Archives, Institutional Archives and Databases* we found not only projects that put into play personal and/or institutional archives, but also proposals that create complex classification systems and databases in various media.

Rejane Cantoni and Leonardo Crescenti present in this vector *Fala* [Speech] (Fig. 1): an autonomous and interactive speech machine based on a database

Fig. 1 Fala (Speech), Rejane Cantoni and Leonardo Crescenti, 2012, microphone and 40 mobiles

composed of the 20 most commonly spoken words from 40 different languages. In the installation, a microphone connects a chorus of forty cell phones. All the cell phones are in listening mode in order to capture voices and other sounds in the exhibition space. The talking machine analyzes the information and establishes equivalences within its database generating an audiovisual result with a semantic meaning similar to, the captured sound; as a sort of “cordless phone” conversation. That is to say, it speaks and displays on the screens of the cell phones a word identical to, or similar to the word heard, pointing to the fact that the database is a device open to a multiplicity of possible meanings and relations. In contrast, *Expiração 09* gathers material from more than ten years of archived audiovisual material of the artist Pablo Lobato.

For the project, Lobato creates a software in order to define versions over time of certain sections of this archive, which are first selected, then copied to computers, and then have their respective originals deleted. Like a roll of the dice at the beginning of this art exhibition, the lifetime of each video is randomly defined by the software from 01 to 10 days (10 = being the maximum time of the exhibition). At the end of this period, all videos/files are permanently deleted, leaving only their first frame on a white screen at low opacity. In spite of the differences between the exhibitions, the idea was to not only to save important projects of the history of Paço das Artes and of contemporary Brazilian art, but to give visibility to issues related to the archive and the database so important to the museological collections. What we archive, how we archive, and how we give the information to the public were some questions that were part of these projects.

To end, we can say that the exercise of thinking about the histories of the exhibitions focusing on art and technology is not only an important exercise in the sense of rescuing a part of a story that often does not occupy the legitimate circuits of art, but also of rescuing discussions that are fruitful in order to understand some key issues of our time.

End Notes

1. The experimental vocation of the Paço das Artes is detected mainly through its Temporada de Projetos, which was created in order to make room for the production, promotion and dissemination of young artists. Conceived in 1996 by technical director Ricardo Ribenboim and the then curator of the institution Daniela Bousso. The Temporada de Projetos had its first exhibition held in 1997 and became over the years, a rich incubator for the young Brazilian contemporary art scene.
2. From the initial idea of the project, we invited the artists Artur Lescher and Lenora de Barros as curators overseeing the development and design of the first edition of of the *Livro/Acervo*.

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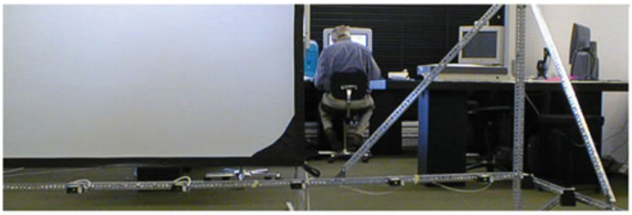
Part II
Environments



Environments

Most artists probably need access to new technology 'doctors' or 'surgeries'...we need residencies with technical support to get projects started and then regular check ups. Joan Ashworth

I would rank people skills as paramount closely followed by technical resources and know-how. The intelligence, good will and sensitivity of the support team are vital. Peter Lowe

Whilst the conceptual developments are the key issues, the role of the technology in encouraging, enabling and inspiring them has been central. Ernest Edmonds

The ideal way is a network of resources offering a variety of opportunities, software and hardware. Beverley Hood

Developing a broad horizontal framework covering logistics like access, permissions, bookings, getting hold of the right people, basic software support and general standard software. Dave Everitt

Theme: Environments

Ernest Edmonds, Linda Candy
and Fabrizio Poltronieri

To be able to push the boundaries of digital art forms, it is often necessary to do the same for the technology. Systematic approaches that bring together the various disciplines, practices and resource suppliers are required. This implies creating environments in which digital artwork can be developed. But what kind of environment is appropriate for digital art? In art and technology, we need environments for building the technical environments needed for specific projects. The chapter reviews these issues, covering digital technologies for thinking, making, marking and controlling from the late 1990s to the present day. Two particular developments are described: first the studio viewed as a research space and second living laboratories in public places, such as museums, where people can beta test interactive artworks. This chapter is followed by seven articles by artists, technologists and researchers: some from the 2002 edition are joined by more recent contributions.

Introduction

The challenge in creating a strategy designed to explore the nature of the relationship between artists and scientists is to create circumstances that engender the kind of communication that leads to a successful exchange of knowledge and perspectives and to an opportunity to explore new territory. The symbiotic merging establishes a pattern of exploration, development, and innovation, as each participant responds to the other's viewpoints and areas of expertise (Harris 1999). Intersection between art and technology in the 1960s was led by artists and computer specialists whose commitment was essential for the survival of those early ventures. It was also a time when academic equipment proved a useful resource for experimentation. From the 1980s onwards, the rapid changes in technologies presented new opportunities and demanded different approaches. Inter-disciplinary research, such as the early Xerox PARC work on user interfaces, was to have a profound effect on the take up of digital technology in the wider community.

L. Candy et al., *Explorations in Art and Technology*, Springer Series
on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_10

The invention of new metaphors for interaction made available in the Xerox Star (Smith and Johnson 1989), Apple Lisa (Redhead 1984) and Apple Macintosh user interfaces (Markoff and Shapiro 1984) and later, as Windows on PCs, were to open access to widespread computer use that would have been unimaginable twenty years before.

Accessible personal computing on a large scale resulted in the arrival of a new kind of participant in the digital art world. Art and design colleges began to introduce courses on digital technologies that provided artists with new media opportunities. Ironically, it could be said that the very accessibility of the new “easy to use” technology reduced the scope for innovation because there was less emphasis on learning programming languages which allowed the user to design and develop personalized systems. Software applications for image manipulation, such as Photoshop, gave artists tools that provided quick and easy methods for presentation of digital work. However, at the same time, they imposed a conformity of appearance that many struggled to overcome.

To be able to push the boundaries of digital art forms, it is often necessary to do the same for the technology. However, digital technology is a field over which few people have complete mastery. To overcome this problem, systematic approaches that bring together the various disciplines, practices and resource suppliers are required. This implies creating environments in which digital artwork can be developed, supported by access to appropriate human expertise as well as technological facilities and physical spaces.

Technology changes quickly, of-course, but this chapter retains most of the discussion from the first edition. Whilst the technology has advanced, many of the conceptual issues remain unchanged, so that part of the chapter that is now an historical review is still important in a contemporary context.

The Nature of Environments

Just as a potter needs a studio with a wheel, kiln, running water and other tools, digital artists need an environment with the means to produce their works. But what kind of environment is appropriate for digital art?

Defining what makes an appropriate environment for making digital art is less easy than it might be for the potter with thousands of years of history behind him. For one thing, the digital world of today is still very new and continuously evolving. As any experienced practitioner will testify, pottery and painting are complex enough activities, taking many years to master, even for the gifted. In the digital domain of today, however, the huge variety of choices and standards, as well as the inherent difficulty of using some kinds of hardware and software, makes it particularly complex. At this time, it is hard to arrive at a stable, all-purpose environment that meets the requirements of every user.

In computing, the term environment is often used to refer to a set of software facilities for assisting the development of a digital system. Computer programmers need an editor to compose and modify the program, a compiler or interpreter to translate the program into a form that the computer can execute, and a “de-bugger” to help them search for errors in what they have done, and so on. A collection of facilities is known as a software development environment, and its precise nature critically influences the ease with which the programmer can work. Software developers argue endlessly about which environment is best and what features must, or must not, be included.

Environments in computing may incorporate hardware as well as software because, in certain cases, new hardware, or new inter-linking of existing hardware, such as robot arms, has to be achieved. This is important in relation to the artists’ needs when, in particular, interactive art systems are being constructed. As well as the computer processor and the computer screen, more conventional things, such as books and whiteboards, are important parts of the artist’s working environment. Behind the screen lies the Internet, an important part of the development environment for the software designers of today. Searching the World Wide Web for help is a normal part of day-to-day practice for both artists and technologists. Even when working on a solitary activity, the Internet links them to other people, making these contacts, with various skills and knowledge, also part of the working environment.

A development environment for art and technology exploration was established at the Creativity and Cognition Research Studios with the express intention of assessing its role and identifying requirements for creativity support. The discussion that follows was informed by art and technology developments that took place over a number of years.

Co-evolution in Environments

A fundamental requirement of an environment for creative practice is that it supports and enables the development of new forms in art and the new knowledge that is required to achieve such outcomes. The point is that creativity in art and technology requires circumstances that enhance development possibilities. The question is how do we ensure that both the art and the technology development is fostered by the environment? This question raises a number of issues about how appropriate environments are formed and we will consider them below.

In order to shape the kind of environment needed for digital art, it is necessary to begin by defining the ethos and approach required. An obvious starting point is to define the potential user requirements by addressing the artists’ needs and expectations. As anyone involved in this kind of exercise knows, the apparently straightforward activity of identifying client requirements and scope of the tasks to be carried out, and then matching them with facilities and tools, is often a moving target. Nowhere is this more so than in creative digital work. The requirements gathering exercise for art-technology environments must be a highly responsive, iterative process. Only in this way is it possible to inform and shape the environment in the light of the experiences of digital art under development. This co-evolutionary process is a form of practice-based action research where the existing technology is subject to new perspectives from which technology research derives new answers. In turn, the use of new digital technology may lead to transformation of existing art forms and art practice.

Co-evolution requires evidence on which to base judgements and decisions. This involves the gathering of first-hand accounts of creative practice by the participants as well as records of observations of the processes involved by researchers. Based on these accounts of events and an analysis of the issues arising from them, different audiences may draw a variety of lessons. For the organizers of environments for art and technology, the issues range from software usability and fitness for purpose to physical space requirements beyond the computer laboratory.

Technology Environments: The Creativity & Cognition Studios Case

The creation of a fully integrated system of facilities comprising equipment, devices, software and networks must be a key objective of an art and technology environment strategy. The resources available to the artists-in-residence need to include a range of expertise, accessible at short notice and a repertoire of software and hardware acquired for the specific requirements of the participants. In the case of C&CRS, in the 1990s, considerable preparation was carried out before artist residencies took place in order to make sure that each artist had a realistic opportunity to achieve their goals. They were also intended to help contributors learn about what is needed to make art and technology collaborations successful and, in that respect, they served the purpose well. For, although considerable effort was spent in identifying the technological infrastructure and the human skills required for each participating artist, this was never sufficient for predicting everything that would be needed in advance for all situations. It could also not anticipate unforeseen events and unexpected failures in those things we thought had been addressed. However, it was possible, by observing and monitoring closely the work in progress, to add to the knowledge needed to make art-technology collaboration a realistic prospect and, most important, to develop responsive strategies for addressing change. In the short-term, tasks needed to be carried out in order to optimize the existing technology without incurring additional costs. At a broader level, there were important lessons to be learned about the physical and technological environments that are needed for this kind of activity and that do not necessarily come within the normal remit for computer science laboratories, art college facilities and gallery and exhibition spaces. This is new art and new technology and, in venturing into the area, new and imaginative architectures are likely to be required.

Given that an appropriate technology infrastructure is an essential basis for digital art practice, it is important to address the limitations of what is currently available. When C&CRS was first set up in the mid 1990s, the facilities and resources available at that time imposed their own constraints. A significant aspect of the response strategy was to draw upon the full resources of the university including the knowledge base of the personnel across many disciplines. Much equipment was available that had not been acquired for artistic purposes, such as virtual reality (VR) laboratories and computer aided engineering design systems. These proved useful for some digital art projects. However, most of the C&CRS artists began and finished their work in the studios where the facilities existed for use primarily in art practice. It was an important strategic decision to ensure that artists were not placed in a position of begging or borrowing from scientists and technologists with other pressing needs for the facilities. The primary reason for this was to ensure that the responsiveness to changes required by artists in the environment could be undertaken without creating conflicts in existing hardware or software configurations.

In setting up the studios, the facilities had to be heterogeneous, connected and of high quality. The computers used a variety of operating systems, including Unix, Windows NT and Apple Operating Systems. Some software could run on just one of these systems and some were cross platform. Consequently, it was sometimes necessary to move work from one type of machine to another in order to make full use of them. Naturally, everything was fully networked and connected to the Internet. The specific computers included Apple Macs, various PC models, Silicon Graphics machines, including an Onyx 2 and Origin server with 600Gbytes of disc space. The Apple Mac G4, for example, was well suited to extensive image manipulation and graphics design work and the SG Onyx could handle complex 3D graphics in real time. It must be said, though, that the power of an Onyx came at a non-financial cost, in that non-specialists can find it quite hard to use to full advantage. For that reason, the importance of human technical experts in C&CRS was helpful in some cases and vital in others. It is also important to note that complexity and sophistication is not always desirable. Very often, artists, like mathematicians, value simplicity and elegance in what they do. Therefore, it is also necessary to ensure that basic facilities are included. A simple system may not have every conceivable function available within it, but for creative purposes the constraints that it imposes may be a positive stimulus to new ideas. That principle continues to apply in todays' technology environments.

C&CRS technology included high quality CRT displays, a 42-inch plasma display, smaller flat panel screens, and video projection. Artists could also use a variety of printers and connections to video and sound equipment. In retrospect, neither sound nor video was as flexible or extensive as was desirable, but otherwise the basic provision held up well when used in real practice. The software repertoire, on the other hand, was not extensive enough. Buying new packages or downloading new patches to enable the software provision to match each individual's needs was continually needed. The diversity of specific computer package skills is a continuing problem. It is clearly an advantage to capitalize on an artist's acquired skill with a particular system, but it may not be the best system and, more significantly, the technical experts may not have sufficient knowledge of it. Hence the requirement for a broad base of expertise in various software applications outside the core support that can be drawn upon as needed.

Beyond the provision of a standard range of systems and output devices, digital artists often wanted the computer to control or affect something not normally attached to it, such as a light bulb, a slide projector or, perhaps, a waving flag. Equally, they wanted the computer's behaviour to be modified by a sensor of some kind, such as a blood pressure read-out. Interactive art systems often require new input/output devices or new interfaces to otherwise well-known devices. At one level, building computer-based interactive systems like this is not a problem as computers come with the raw ability to communicate with other electronic devices. However, arranging for a computer to communicate with a new device is far from easy. It requires professional programming skills, working at quite a deep level in the computer system.

In the C&CRS environment, it was quite common to enable the construction of new interactive systems, such as a sensor space in which a person's position can be tracked by the computer. Up to now, this has only been achieved by teams that include the relevant technical experts. This is an area in need of significant software support development. There are useful facilities to manipulate images on screens or in print, and facilities for editing and producing music. These systems allow people to work with image or sound without first having to become computer science experts. However, the building of interactive art is not well supported by standard tools and requires the expertise of programmers and hardware specialists.

Technology Opportunities and Constraints

JustTechnology (opportunities and constraints) as Opportunities the softness of a pencil affects an artist's drawing, the nature of the digital technology used influences the product generated. The computer and its associated equipment constitutes an exceptionally broad spectrum of options and opportunities. However, by the same token, this diversity represents an exceptionally wide range of pitfalls to encounter. The core of computing is the symbol processor that operates according to given instructions and, most important of all, can accept and process any set of instructions that can be specified. This sounds very impressive, but it brings with it a problem. The very generality of the computer makes it hard to use because it implies that there are very many options to choose from. It can do anything that we can instruct it to do, but formulating those instructions is a challenge to most people.

Instructing the Computer

In recent years, many new software applications have been invented that are relatively easy to use and that automatically generate the instructions that a computer needs. Today, millions of people use word processors, email systems and web browsers without having to even think about directly instructing computers. Unfortunately, this does not mean computer use is problem free. Creative people often require the computer to do things that are hard or almost impossible to specify, even though they are theoretically possible. This is where the main problem lies. How can we specify what we want without spending years doing it?

For the artist, there is often a specific aspect of this problem to be concerned about when creating interactive artworks where the computer controls special devices. Controlling displays, printers and other output devices requires both a detailed understanding of the device and an understanding of how the computer interacts with it. Controlling customized or new devices is often even harder. For the digital artist, some basic technical matters can pose a problem or, alternatively, can be used as an opportunity. In printing, for example, the rate of dots per inch (dpi) is important when it comes to the printing of smooth lines as against showing *jaggies* (i.e. stair-like lines that appear where there should be smooth straight lines or curves).

At least three strategies are used by artists. The first, and most common one, is to make the selected dpi sufficient, given the size of the print, to ensure that normal viewing would not lead to the jaggies being perceived. A second approach is used by artists who see the jaggie as an integral part of inkjet printing technology. To them, it does not make aesthetic sense to try to hide it. This could be seen as an example of being true to the material. Just as a carver might choose to bring out the grain, so a digital printer might choose to show the jaggies, in order to be true to the material. A third approach to the existence of the jaggie is to only allow vertical and horizontal lines as acceptable in such a medium and so avoid them all together.

The key point to note is that the artist must be able to decide on the issue rather than have it decided by the technology. The example of jaggies is one of many. Similar thinking must go into colour, display luminance, and refresh rates. In relation to three-dimensional (3D) graphics and virtual reality systems, the things to consider multiply even further. For example, displaying information in virtual or augmented reality, and representing and experiencing motion in space, must all be subject to explicit decision-making on the part of the artist. For the technologist, it may seem that we need to be as close to "reality" as possible, but the artist will wish to consider the nature and "truth" of the medium. These two contrasting views may lead to very different decisions about how to use the features of digital technology. Another example where there are many challenges is art made for mobile devices in which the context of use may not be knowable or where location-based sensing can add another dimension.

Interactive Art

A considerable amount of the work by artists involves interaction between art systems and the viewer. There is also interest in the relationships that exist, or can be developed, between the physical world and virtual ones or between physical movement and symbolic representation. One of the C&CRS artists uses swimming to help understand the nature of the water to be modelled in computer animations. Another artist is concerned with the precise nature of the relationships her audience forms with her work. Another artist uses movement in a space as an integral part of his interactive works, so that performance and visual art are brought together. Dynamic systems of one sort or another are often at the core of the artworks produced. The digital computer system manages interactions with or representations of physical behaviour.

Implementing artworks of this kind often involves the construction or selection of sensor and control systems. These are ways in which the computer can learn about its environment and affect what happens next. In general, the applications and programming languages available to build and use these systems are much less advanced and easy to use than the software we are used to, although the technology in smartphones and game controllers has enhanced the possibilities significantly. Artists working in this area often need to work at a detailed level with programming or work in collaboration with a software developer. The problems of instructing the computer in these situations are quite unlike using a well -supported device, such as a printer, although it was not so many years ago when basic computer graphics were as hard to work with as interactive position sensor systems are now. The artists' needs are always advancing and so seem to outstrip the application developer's progress, in that, by the time a requirement has been met, the artist has formulated a new need.

Art Practice and Technology Environments

Art practice is closely influenced by the tools of the trade used by the artist. The introduction of acrylic in painting or welding in sculpture led to new forms and new kinds of artwork. By the same token, the introduction of computers and digital media has changed what artists do. Computers are very special tools, however. We do not only use them to shape or construct objects. We also use them to shape or construct ideas. Using them can help us to think more clearly or, sometimes, more imaginatively. Of course, computers drive printers and screens, are connected to any number of devices that interact with the world and, even carve objects. However, before a computer can be used to produce work, we have to somehow provide it with the necessary instructions.

Before we can fully instruct a computer to produce something, we have to formulate the idea of what is to be created with precision. This formulation of instructions is a form of creation and shaping of ideas. Because of this, computers help us to think as well as make. Hence, they can be expected to change the way that artists think about their work as well as changing the form of the work. Every artist knows that holding the pencil and drawing with it is, in reality, as much about thinking as doing. Specifying a computer program takes this aspect further by engaging the artist in determining very precisely how the work will appear or behave.

Many questions and difficulties are associated with any tool or medium, but it is particularly so with the computer. These issues formed part of what was considered during the C&CRS artist-in-residencies. The innovations that we saw were at times conceptual, at times in the form of artifacts, and at times purely technological. Much of this innovation was related to interchanges between artists and technologists as much as between artists and technology. Consequently, the impact of the technology on the creative process often depended on the relationship between artist and technologist. We see that the impact of the digital world on the artist falls into two areas: on thinking about art (development) and making art (delivery). There is also an impact on the world of technology in generating or, at least, directing technical innovation.

Digital Technology and Thinking

It is a familiar experience to most people who work with computers that, as they work and struggle to persuade the machine to do what they want, they come up with new questions and new ideas. We say that teaching is the best way to learn, and teaching such a demanding student as the computer certainly requires us to make up our minds quite precisely about what is required. However, it goes further than that.

Art practice is an evolving creative process. By the same token, art practice using digital technology is also creative. Therefore, it is not surprising to find that, whilst working with the computer, artists often come up with new ideas and approaches that have no direct derivation from what they were originally trying to do. For example, one artist used a computer system to create performances in which changing images were projected coordinated with music. This led to the invention of a set of correspondences between the music and visual forms and then to artworks that represented music purely visually. The new ideas came to him only because of his work with the computer system. Although the new artworks had nothing directly to do with digital technology they would not have been created if he had not made his digital exploration with music and visual correspondences.

Digital Technology and Making

What follows is a description of the digital technology available at the time of the COSTART project in the late 1990s.

The use of digital media for creating a work of art has certain kinds of technical issues associated with it, such as the particular visual quality of an image. To take a simple example, how many pixels per inch should be used for an image? For a high-quality print, we might choose 600 and use as much as 500 Mb of data to store the image. On the other hand, if the image is to be shown on a Web page, we would normally use just 72 pixels per inch and hold its size down to much less than 1 Mb. At another level, digital media enables new forms of art making, for example, where interaction between the artwork and the audience is part of the work or part of the process of making it. With the help of digital technology, we can create new kinds of art, but how does the technology influence the art-making process?

The nature of the work is embodied not just in how it looks or what images are used, but in the way that it behaves when people interact with it. The problem of working with and defining interaction is a key one. From a practical perspective, there are many problems that most people working with interactive art systems encounter. It is not a simple task to write software to drive an interactive artwork that uses data such as position information from infra-red sensors. There are no high-level tools to do this, and only by creating computer programs from scratch can interactive systems of this kind be made to work to an artist's specification. When this takes place, it is not simply a matter of an artist passing the problem over to a technologist. Many of the detailed decisions made during such programming have an impact on the outcomes of the interaction, and it is these very outcomes that the artist is particularly interested in. An example from the early programming of computer drawing packages illustrates this point. When the ideas were first being developed for using a mouse to draw with, the question of sensitivity was identified as being significant for good interaction. For example, we can measure even a few microseconds of letting go of a button, but how does that help us decide on what should count as *really* releasing it? What should count as a clear enough signal that an item has been selected? These time intervals, built deep into the software, can be critical in defining the interactive experience that the user has. They can also be significant in defining the nature of the experience of an interactive artwork.

Making Electronic Marks

The Soft-board is a whiteboard connected to a computer and is designed to support business meetings.[1] Marks made on the whiteboard using pens of different colours are immediately represented in a computer window. A page is one workspace displayed on the monitor and a set of pages forms a sequence. When any mark is made it is recorded as a set of points for the current page. Both pen marks and eraser marks are recorded. At any time, a new page can be generated as a new blank canvas or inclusive of the previous pages marks. The controls for starting and stopping the recording and entering new pages are situated both at the whiteboard and on the computer screen. This enables the user to complete a whole sequence with pen in hand and without having to touch the computer keyboard or mouse.

The Soft-board does not use a computer-specific input device, such as a graphics tablet or mouse, and therefore complete freedom of movement is possible for the artist. This freedom allows the work to evolve in a way that overcomes some of the constraints usually associated with electronic media and the need to make allowances for them. One artist began his experimental drawings using such a device. He found that it was a very interesting method for making time-based work. The work with the Soft-board transformed his thinking about his drawing activity into one that involved time and movement. This change of thinking was at least as important as the drawings produced by using the technology.

A number of artists have deployed the Soft-board for different artistic purposes. One set out to use it as an open-ended exploratory tool to see what would happen in his personal drawing process. Another began by adopting an exploratory approach also, but with a difference. By meditating before each session, he aimed to remove all conscious thought during the execution of the drawings. He wanted to see how far he was able to achieve this and to do this he used the particular facilities of this medium for capturing and replaying the act of drawing. The replay in real-time proved to be a particular attraction for a number of artists: this was something that they had not seen in any other medium.

Controlling the Technology

A standard question for designers of interactive computer systems interaction design is how to determine if and how the user, rather than the computer, is in control of the interaction. Sometimes, the computer takes control, for example, in a car breaking system, but mostly users want to be in control themselves. When teams of people are involved in the interaction with the technology as, for example, in computer supported meetings, the nature of the meeting will affect how the system is designed. For example, if the situation is a democratic one where everyone has an equal say, how can the interaction be mediated? Is there a leader, a moderator or a chairperson?

Artists tend to be very particular about who or what is in control. They will wish to be the author of the creative concept and its progress, if not the actual physical realization of the artifact, where it exists. In this situation, developing new kinds of digital technology can provide a problem of control and, hence, ownership. When a software developer collaborating with an artist, writes a program for an interactive artwork which only they understand, who controls the artistic decisions then? Some technologies are easier for the artist to control than others. Some artists insist on learning how to stay in control. If they cannot control the process fully, they do not go in that technological direction.

Issues of control are closely related to the level of complexity the computer has. The more different things that a computer can do, the more complex its instruction language has to be and so the harder it is to control. The harder it is to control, the more has to be learnt in order to master it. This is often the dilemma. An application program may be quite easy to use and quick to learn. It might enable many things to be done beautifully. But, almost inevitably, it will restrict what can be done by the user. Often, it will impose too many limitations for the creative mind. Faced with these dilemmas, it is too easy to conclude that technology should stay as it is and artists should restrict their ambitions in order to accommodate it. However, for new ideas and art forms to be created, it is more helpful to view the limitations in the current technology as the requirements for new technological initiatives. Taking this line, by opening up the horizons of the software developers, artists might be the driving force behind the development of the next generation of technology. Likewise, by initiating new ideas and carrying them through themselves, artists can become the drivers of innovative digital art forms. This can be seen, for example, in the way that many artists are using credit card size computers and "PC sticks" as components in their works. These artists are quite like "hackers" bending the technology in new ways and taking advantage of the latest low-cost flexibility on offer.

Moving Technology Forward

The activities of artists who seek to break new ground in art are fruitful areas for discovering innovative technology. During collaborative art and technology projects, opportunities for new developments in technology often arise. The experiences and lessons from the C&CRS artist residencies about technology provision helped the participants to define new requirements for creative technology environments. In many cases, solutions to meet the requirements were relatively easy to find, but often they raised more questions that are not so easy to answer. For example: what impact do different kinds of media and technology used in art practice have on one another? Do artists re-conceptualize one medium when they use it in relation to another? Technologists are often taken by surprise to find that their world can be looked at in unfamiliar terms.

Re-Conceptualizing Technology

The way that artists have deployed the Soft-board is an example of the creative use of a business meeting support device. It is intended to help brainstorming and the organization of ideas, particularly in meetings, by keeping an electronic record of all that is done. In effect, the meeting can be played back through a dynamic record of what was written on (and removed from) the Soft-board. When it was explored as a way of supporting drawing, or as a drawing tool, its role was quite different. Not only was it useful to be able to record and play back the drawing process in a way that was parallel to the use in meetings, it also became a way of making dynamic art—the playback of the process could become an artwork in itself. In effect, both the process of drawing as well as the result achieved, became the work of art. Such a view of the device brought revised requirements. Fine details about how it played back and how the timing and control work became vital whereas, in the original use, this was a secondary issue and small delays were acceptable limitations of the system behaviour.

Environments for Building Environments

A fundamental question that we have been considering is, what kind of environments best support the development of digital art? There is one answer to this question which, although it may sound a little strange, is, nevertheless, appropriate. In art and technology, we need to have *environments for building environments*. This approach is analogous to having a store which stocks all of the components that one might need in order to build a carpenter's workbench. The store is an environment that has all of the components that one might need, such as vices, bench tops, tool racks etc. By selecting from them and assembling the items in our own workroom, we can build a specific environment suitable for our particular carpentry needs. The store provides an environment for building the particular environments that its customers need.

One artist, concerned with developing environments for her particular needs, makes works in which music and images are closely related in an interactive system. To build such systems from scratch, every time a new work is created, is a difficult undertaking. She has sought to find a more general method that can be used to help make a whole class of artworks using the same technology. In her solution, the Color Organ, she uses a set of building blocks with which she can improve the flexibility of the instrument. This is still hard to construct, as it requires skilled programming. What is needed is support for building the Color Organ in the first place: that is, a software environment in which systems such as the Color Organ can be developed. In other words, what is needed is an environment to support the development of environments such as the Color Organ.

Flexibility and Exploration

When we are not sure what we want or what we *might* want when we start a task or project, we need flexible tools and methods that allow us freedom. We need to be able to change our minds and to bend the rules or develop new rules as we go along. In this sense, we need the technology in digital art environments to be flexible. A natural consequence of the flexibility required in the technology was a requirement for multi-platform work. An artist might begin with material developed on one type of machine, e.g. a PC, but with a need to process it that could only be satisfied on a second type, e.g. a Silicon Graphics machine. Sometimes, even a third type was needed before completion of the task. This kind of process requires an environment in which it is easy to switch between one machine and another and in which an artist can move their data with them as they move from one machine to another. Thus, it is important to provide multi-platform, multiple format systems for creative work.

If the technology is to play any part in extending the boundaries of human thought and actions, then a critical issue is the design of technical systems for fostering creativity. In the light of what we know about creativity in action in the real world, how can personalization in new technology contribute to enhancing creativity? In order to design for the enhancement of creativity, we need to look beyond the surface issues of the human-computer interface. This means that we need to go further than designing customizable interfaces or configuring better programming environments.

A technical issue that is not always directly identified by artists as computer users is the flexibility that the computer system has in adapting to the specific needs of a project. It may often seem that computers are hard to use when, in fact, the software is simply difficult to configure in appropriate ways. Ways need to be found to provide this flexibility beyond programming from scratch using a basic computer language, such as C or Lisp.

Responsive Strategies

We need computing resources and software to enable the kind of guided or playful exploration of possibilities in which artists engage. At the very least, we must ask, if it is impossible to anticipate all the technology and support needs in advance, what basic provision will suffice? More deeply, we need to understand just how the technology can allow the required degrees of flexibility. How can we ensure that the environment is responsive to the evolving artists' needs? One solution might be the creation of more artists' software tools that allow the artist access to deeper levels of the computer's programming system, as distinct from software applications that have been developed for specific tasks such as image manipulation. Such tools could provide a bridge between the use of an environment that requires programming knowledge and the 'closed' application, which does not provide sufficient flexibility. Perhaps it points us to the methods of the earliest digital artists, who learnt the computing trade and became programmers in order to advance their art. The artist may or may not be a professional coder, but they certainly might be very competent operators in a "hack space" environment.

A co-evolutionary process, in which practice-based action research is used to understand and develop the technology and that art practice in parallel, is the method that can help to answer these questions. In particular, this approach can aid the development of strategies for the provision of responsive environments for digital art practice.

Several issues have been identified about strategies for providing creative technology environments which concern the network infrastructure, the hardware and software platforms and the tools and applications. In particular, the concept of flexibility is important in all of them: for example, the environment must be heterogeneous and support communication and data exchange between the different systems. Equally, it must be relatively easy to extend or add to the facilities. Often, we found that what existed did not match what was eventually needed. Producing art is a kind of exploration that needs flexible support. There is no exploration if everything has to be defined and fixed before you set off.

Our experience suggests that even today, with all the advances in software, the degree of programming and systems expertise is critical to having more artistic control over the developing process. Those artists who had such knowledge were in a position to make more interim decisions during the exploratory process that guided the next course of action. Those artists who depended on a technologist often felt uncertain as to how much control they might have to relinquish to achieve their goals.

There is no one solution to designing environments for creative use. Conflicting requirements, such as accessibility and ease of learning on the one hand, and a high degree of control by the artist on the other, may not be mutually achievable. Ways forward combine new technology, new ways of working and new collaborations. Each artist will choose a personal approach and the intersection of art and technology will lead along different paths in each case. Nevertheless, it is important to understand as much as possible about what is general in art and technology creative processes and how applicable different technologies are. The research studies discussed in the following chapters are an attempt to meet this need.

Studio and Living Laboratories

For creative practitioners in the interactive arts, the limitations of standard laboratory research have led them to adopt different kinds of settings based upon models from art studio practice and public museum experience. The realization of the studio-based environment extended to the 'living laboratory' has provided opportunities for practitioners to carry out research that enhances creative practice at the same time as developing methodologies for generating and communicating new kinds of knowledge.

A fundamental requirement of a research environment for creative practice is that it supports and enables the development of new forms of art as well as producing the knowledge that is required to achieve such outcomes. An environment for creative practice with digital technologies must be a highly responsive, supporting iterative process where new insights are fed back quickly into the development process. This co-evolutionary process is fundamental to practice-based research where the existing technology is used in a new way and from which research derives new answers: in turn, the use of new digital technology may lead to transformation of existing forms and traditional practices in art. The continual iteration of the practice-based process in interactive digital arts is not unfamiliar in other technology fields such as interaction design and, similarly, it can lead to innovative outcomes.

A key aspect of the interactive art practice described in this book is an organisational model that brings together studio based and public museum and gallery research. Many of the contributing practitioners began by making prototypes of their works in a university studio setting, which was a place to make works and then test them to a point of sufficient robustness for wider exposure. Once this had been achieved, they were then in a position to install the interactive works in a public setting where they were exposed to public scrutiny. The studio setting used by several contributors was the Creativity and Cognition Studios (CCS), a space within the University of Technology Sydney that performed the role of a studio laboratory, equipped with specialist equipment and facilities that enabled observation and recording of interactive situations. The same artists sometimes used a public exhibition space in Sydney's Powerhouse Museum, that was called Beta_Space, a site for exhibiting experimental work-in progress, and for working in partnership with audiences founded in 2004. This combination proved vital for success. Further details and examples can be found in Candy and Edmonds (2011).

In the creative arts, the studio is a 'natural' working environment where the artist dreams, explores, experiments and creates. It is usually a closely guarded personal space in which the works in progress are brought into being, assessed and made ready for exhibition or sometimes discarded. The main purpose of the studio is that it is an experimental or a development space, as distinct from an exhibition space. The existence of studios of whatever kind, are as essential to the artist as the laboratory is to the scientist. In the 1990s, the origins of our organizational framework, dedicated to facilitating and investigating creative practice in the area of art and technology, was the Creativity and Cognition Research Studios (C&CRS) based at Loughborough University, England. The Studios provided an environment where artists and technologists could work in collaboration on art projects and was partially funded by major research grants from the EPSRC, the UK's preeminent funding body for science and engineering research. A specific objective was to facilitate the co-evolution of art works and technological innovations and, at the same time, to carry out research into the process. This research introduced a "studio as laboratory", which represented a new avenue of research in interactive art (Edmonds et al. 2005). Up to this point all the effort had been focused upon realizing the concepts as material artefacts and evaluating them in the studio within the project group. There was, however, a wider audience and context to consider and this was addressed when C&CRS migrated overseas and was reborn as CCS. What followed was an attempt to address the gap in awareness of interactive art and a need to study such art in 'real' contexts by establishing Beta_Space in the Powerhouse Museum Sydney as mentioned above.

The name Beta_Space derives from the software development practice of releasing new applications and products to the public before they are completed in order to gather feedback and improve their quality. Beta_Space enabled practitioners to explore artistic concepts, prototype art systems and evaluate experiences with real audiences. From the outset, the audience was involved in this process, changing the relationship of the artist and curator to the audience, and the relationship of the audience to the artwork. In these ways, the museum could play a vital role as a laboratory for the creation of new work and new knowledge. It acted as an ever-changing exhibition space showing work at various stages of production, with exhibits lasting between one week and three months.

Beta_Space is a new and powerful organisational model that enables practitioners to explore artistic concepts and prototype art systems and evaluate experiences with active audiences. Beta_Space, and its fellow living laboratories, blur the distinction between production and presentation through an iterative approach to creating and displaying art works. From the outset, the audience is involved in this process, changing the relationship of the artist and curator to the audience, and the relationship of the audience to the artwork. In these ways, the museum can play a vital role as a laboratory for the creation of new work and new knowledge. For an account of the origins and work of Beta_Space see Turnbull and Connell (2011).

End Note

1. Softboard developed by Microfield Graphics, and now only available from legacy sites was almost identical in appearance to the commonplace wall-mounted whiteboard, but went much further. When connected to a Macintosh of Microsoft Windows based computer, Softboard displays all information written on the porcelain whiteboard surface simultaneously on the monitor. Participants in collaborative discussions and brain storming sessions can share information,create new ideas, keep records, change info, fax it ,save it, download it, print it.

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New Directions for Art and Technology

George Whale

On the January 14th 2002, in a building no more than a stone's throw from Channel Four's futuristic, glass headquarters in the heart of London, a diverse group of artists, technologists and researchers associated with the Creativity and Cognition Research Studios (C&CRS) gathered to consider the future of Art and Technology. Represented in this unique grouping were several nationalities and many points of view. Some of the participants were meeting each other for the first time. The day-long, round table workshop organized by C&CRS and sponsored by the Arts Council of England, was divided into three sessions, each devoted to considering new directions on three themes: practice, technology and collaboration.

Participants

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_11

Joan Ashworth (JA)
Linda Candy (LC)
Ernest Edmonds (EAE)
Dave Everitt (DE)
Mark Fell (MF)
Bronac Ferran (BF)
Ingrid Holt (IH)
Fré Ilgen (FI)
Jacqueline Ilgen (JI)
Michael Kidner (MK)
Lucy Kimbell (LK)
Colin Machin (CM)
Anthony Padgett (AP)
Sandra Pauletto (SP)
Mike Quantrill (MQ)
Esther Rolinson (ER)
Ray Ward (RW)
Alistair Weakley (AW)
George Whale (GW)

Practice

How are digital technologies made available to artists? How are creative ideas transmitted through technology? Where exactly is artistic "end-product" located? And what is its relationship to the audience and to the market? These essential questions relating to creative practice at the intersection of art and technology were addressed during the first session of the day in a vigorous and wide-ranging discussion.

Many kinds of digital technologies, from computer-controlled devices to visualization programs, can be integrated into art practice and issues of technology usage, configuration and design became central and recurring themes. It was evident that artists had taken distinctly different approaches to the deployment of these technologies. Whereas some had worked predominantly with ready-made, proprietary hardware and software, others had opted for custom-made solutions created with the support of C&CRS technologists. Much of the discussion revolved around the implications of these choices and, in particular, the ways in which interactive and programmed approaches to art making shape and influence practice.

Joan Ashworth admitted that she enjoys the sheer awkwardness of some interactive software ("What on *earth* were the designers thinking?"), because it gives her "something to work against". It is, perhaps, a paradoxical notion that technological limitations can serve as a stimulus, but one that was echoed by Fré Ilgen ("I think they *provoke* your creativity") and by Mike Quantrill:

> My work involves sensor systems, a space of 64 squares, to which the computer responds. It was awkward at first, but the constraints are now beneficial. Now, the question is: What am I trying to *do* with this space?

Mike observed that an artist with a strong, initial idea which turns out to be incompatible with the application, is much more likely to be frustrated than one who approaches it without preconceptions, receptive to whatever possibilities might be revealed or suggested. It appeared, in essence, to be a conflict between what Dave Everitt described as "constraints at a conceptual level" and the constraints of software, a conflict which some artists had resolved by producing their own software, alone or in collaboration with software programmers.

Colin Machin spoke of his experience of creating "configurable frameworks" for artists, his aim being to provide task-oriented software with enough built-in flexibility to accommodate project evolution: "When I write software to control something, I leave decisions as late as possible then say, Now, over to you." Artist Anthony Padgett recalled that in a collaboration with Mike Quantrill, "creativity went over to the program", raising the question of where, exactly, the "art" resides in computer-mediated projects: is it in the software, in the finished work or, as one participant suggested, somewhere on a "sliding scale, or continuum", between these two extremes?

Whichever approach is favoured, any artist working with digital technology will, as Dave Everitt put it, "hit a limit at some point", although it was acknowledged that it is not always easy to determine which limitations are real and which are illusory. For, in challenging recommended practice and conventional (i.e. expert) wisdom, some artists had found them to be illusory. Fré Ilgen recounted his experience with an expert in Virtual Reality (VR) systems:

> He tried to persuade me to use four walls. I said "Get rid of all that. Let's start with a black hole!" The expert thought that without walls, I would lose my sense of direction. You don't. Who cares about gravity in virtual reality?

He suggested that artists working within a digital medium can "push the limits beyond what is seen as acceptable with that medium", a view echoed by Dave: "artists … may ask the kinds of questions specialists wouldn't raise" and open up "new lines of enquiry".

Communication was seen as a crucial element of any joint engagement with technology reflecting and shaping the human partnerships that are forged when "artists collide with other disciplines". Ernest Edmonds' observation, that dialogue can involve conceptual development, underlined the problem of describing difficult creative or technical concepts and the importance of developing mutual, or "problem-specific", languages to bridge the conceptual gap between domains. Interaction was identified as one aspect in particular need of a "natural language" of description. A good 50% of the work undertaken at C&CRS involves interaction between artist and audience or between artist and devices.

Digital technology, it was claimed, can bring other media together and encourage free movement between them, as well as have the potential to reach quite different (and larger) audiences and markets. Presentation was seen as a significant obstacle, since the use of conventional forms of presentation for digital work, for example, gallery projection of VR artworks, may “miss the point”. All of the artists had experienced difficulty in selling digital artworks, finding that people tend to be far less keen to pay for something as intangible as electronic form than, say, a painting or a print. According to Linda Candy, this may be a result of the public becoming accustomed to obtaining music and visual work via the Web. Fré Ilgen reported that even in New York, where “every second gallery shows video or computer work”, marketing is a struggle.

Most of the artists present took the view that, to survive, one must either find a supportive environment or think of other ways to make money, perhaps following the lead of artist Jack Ox, who has devised one possible solution which bypasses the usual gallery channels by marketing limited edition giclée prints online. The prints are of individual frames of VR artworks, visual interpretations of music, rendered at high resolution. Currently, she is developing a website making similar facilities available to other multimedia artists (Ox 2017).

Linda Candy recounted a story of how Harold Cohen, creator of the computer art program, “AARON”, had been approached by somebody wanting to obtain his software free from the World Wide Web. Apparently, Cohen was more than a little dismayed at the thought of parting with his life’s work so easily. Interestingly, a version of “AARON” is now being sold as a limited edition. Whether this will prove to be a money-spinner remains to be seen, but the marketing of original software may yet prove to be a viable option for some artists.

Linda’s observation that “some of the best abstract digital art is in Las Vegas” triggered a lively discussion of commercial computer art and the new forms of presentation and interaction made possible by hefty R&D investment, especially in the games industry. A fiercely competitive market means that most games are transient, and few of them actually make much money. Nonetheless, it was generally accepted that the best of them could be “both beautiful and engaging”. Mike Quantrill described his favourite game (evidently parenthood facilitates hands-on research in this rapidly changing field) called Counterstrike, a hugely popular game about terrorists which combines narrative, strategy, cooperation and interaction in an environment where players can communicate with others (and attack them?) “on a human level”. It was pointed out that these same concerns are shared by many artists. Ernest thought it significant that many of the works by internationally renowned artists in London’s Millennium Dome exhibition were located in the Play Zone.

Spin-offs from the games industry, including new, low-cost interaction and display devices and libraries of efficient software routines for real-time 3D rendering, animation and interaction were considered to be of great potential value, and ready to be exploited. Considering the speed at which these technologies are moving compared to the long-term nature of many fine art projects, Ernest believed that artists would be well advised to think ahead, because “what technology researchers are doing now may take five years to reach the market”.

Technology

The theme for the second session was "Technology". Workshop participants were asked to speculate on future technology needs and to share their vision of possible new directions in digital art. The difficulty of making such predictions was underlined by Lucy Kimbell, whose work has exploited SMS (Short Message Service) technology:

LK: Text messaging and the language of messaging evolved out of a human desire to communicate—nobody would have asked for it five years ago.

EAE: That means that interpretation of this question needs to be considered. What are the important *areas* to which technology can contribute?

The ensuing discussion was dominated by considerations of input and output, as it was generally perceived that these aspects were "less resolved" than the intermediate, processing and manipulation stages. The prominence of interactive approaches at C&CRS was reflected in a concern with motion capture: specifically a desire for cheaper, more portable sensor systems which could be set up anywhere, new "haptic" interfaces and wireless, motion tracking technologies better able to pick up nuances of human movement and facilitating "action separate from the computer".

Converting visual material for input was seen as especially problematic, since most current input technologies are unable to capture much beyond the surface structure of drawings and paintings. Ernest reported that there is currently a lot of research into the capturing of drawn structure in the computer. However, the development of VR sketching tools of the kind envisaged by Fré Ilgen looked to be some way off. Joan Ashworth reported her difficulties with 3D input: the problem, she said, is that "everyone wants slightly different things" from technology. She gave the example of car designers and jewellery designers, and their differing expectations of 3D scanning technology in terms of scale.

EAE: Apart from that, what do people find hardest at the moment?

MQ: Output.

GW: What is problematic about output, specifically? We have a range of output technologies—for example, technologies that enable us to make prints as big as a wall and rapid prototyping technologies to output 3D models directly, as sculptures.

MQ: In drawing, the trace of activity is retained. I move a lot when drawing, which is as important as the trace and I would like to capture that information—to find some way of using the movement information, to feed it back into the process.

AP: I did performances which tracked the movement and converted it into a 3D model, which could have been rapid prototyped.

DE: We're looking at making *process* visible, getting away from working towards objects.

JA: If the technology was available to audiences, they could become familiar with the process.

The idea that we need new technologies for making transient process concrete was not accepted by everyone. Ernest Edmonds remarked that "People do not think in these terms in traditional performance", and Colin Machin cited an example of a *pre*-digital record of process: the BBC's famous Potter's Wheel film which recorded (relentlessly) the process of a pot being made. It was also suggested that computers might be used "to explore ways of making artifacts that show process, like a Pollock painting".

Other specific requirements included mobile networks, enhanced home-working capabilities and faster rendering for high-resolution film output. It was conceded that commercial development of such technologies would be demand led but, as Linda Candy indicated, there is nothing to stop artists becoming more demanding, putting forward marketable ideas themselves:

> The people who might make interesting demands do not make them to the right people. More demanding people might give better demand-led development.

Reference was made to artists' engagement in technology development, notably in the specification of some graphics applications, and in (indirectly) influencing usage in fields such as advertising. Lucy Kimbell noted that artists had also been "very involved in solving conceptual issues in Web projects", though under the rubric of "design". Linda recounted that the BBC's Imagineering department, were currently seeking ideas for designing sketching tools and tutorials to online users. However, opportunities for experts to take charge of hardware and software development within their own domains were considered especially significant, not only in art and design, but also in domains such as architecture and medicine ("some of the best medical software is written by medics").

Towards the end of this second session, attention turned to the social/political role of the artist in relation to digital technology. Anthony Padgett opened by arguing that "part of the role of art is questioning, political and self-reflecting, not just aesthetic", and wondered whether artists weren't "riding on the back of" and therefore "implicated in the whole structure" of technologies developed largely for "war or pornography". Linda Candy took the view that an 'agitprop' versus aesthetic emphasis is the "artist's own choice", but that if artists want to take a political stance, then the technology can facilitate it. She cited the example of one artist who had used the World Wide Web to confront and challenge far-right political organizations.

Mike Quantrill's musing, that "maybe we have enough technology" received a surprisingly sympathetic response, and there was a general feeling that more effort should be put into promoting awareness of what is already "out there" (starting, perhaps, with more "intelligent" Internet searching and filtering capabilities), and facilitating more effective use and reuse of *existing* technology. As Anthony had commented earlier: "Often the strength of the artist is in combining existing technology in new ways".

Collaboration

The third and final workshop session was devoted to a discussion of collaboration, focusing on the human relationships at the heart of every creative partnership. Linda Candy began by presenting a classification of the many types of collaboration in art and technology [see Chapter 4: Collaboration and for more details an associated paper (Candy and Edmonds 2001)]. Asked whether collaborators needed to have shared goals, she replied that in the COSTART project, they "began with the notion of the assistant model of support, but moved closer to the partnership idea, although not necessarily with shared goals."

Fré Ilgen maintained that the purpose of collaboration is to solve a problem posed by the artist, but it was evident that even this fairly restrictive definition allowed for a number of different kinds of collaborative arrangements. "The key priority", said Lucy Kimbell, "is for both sides to agree the nature of the partnership". An artist's perspective on collaboration was offered by Michael Kidner:

> My experience of collaboration is that you learn from your collaborator. You see your own work through somebody else's eyes. It may be a shock or surprise, but it is always exciting. Neither partner knows what will come out of the collaboration.

It was generally agreed that any technologist taking on the role of assistant (as opposed to, say, full partner) had to be paid, because "You don't want them to feel that they're getting nothing" (Esther Rolinson). According to Mike Quantrill, who had worked with Esther, Anthony Padgett and Dave Everitt, the role of the technologist tends to vary from one project to another: "With Dave, we both worked on everything together instead of working on specialisms", although "there were points where the artist *had* to make a decision".

Ernest Edmonds expressed the view that collaboration offers "a different model of learning processes". All agreed that learning is a vital aspect of collaboration, especially the learning of new technologies by artists (which promotes self-sufficiency) and it was acknowledged that, in suggesting new uses of technology, artists may, in turn, contribute to the learning process. In addition, as Joan

Ashworth pointed out, working alongside other artists in a *shared* environment promotes exchange of knowledge and cross-fertilization of ideas.

Many participants felt that judgements of success in collaborative projects ought to take account of the fact that significant outcomes may take time to accrue, that ideas may evolve over an extended, interrupted timescale. For Linda, this underlined the need to sustain successful, creative partnerships:

> Organisations should provide support for sustainable relationships … partners need to be able to come back to half-resolved problems, to build skills, understanding, relationships…

Success in collaboration was seen to depend on the practices and personal attributes of the collaborators. Whilst it was recognized that collaborators need not necessarily spend a lot of time together, perhaps working alone for much of the time and meeting up only occasionally to resolve important issues, communication was considered paramount. Mike stressed the importance of talking, the need to "spend a lot of time talking, specifying the problem". Most felt that the technologist's communication skills must include not only a facility for elucidating complexity, but also a willingness to listen; conversely (and self-evidently) the artist must have something to say. Michael Kidner considered "a sense of curiosity" to be a desirable attribute in collaboration.

Issues of ownership and accreditation provoked some lively exchanges. Again, the need for continual communication and agreement was emphasized. The idea of the artist as "ultimate owner, director and developer of the work" was challenged by Dave Everitt, who took the view that "different kinds of ownership" of collaborative artwork may be negotiated, including co-ownership, wherein each partner is free to "promote it in their own way, without diminishing either". George Whale's suggestion that a written contract might be preferable to a verbal agreement was criticized on the grounds of unenforceability, with Fré Ilgen sensibly pointing out that there is "always a difference between the law and the pragmatics of everyday reality". The issue was left unresolved, mainly because many problems of protection for visual artists and their collaborators are still legally unresolved. Nevertheless, we were made aware of the need to become better informed. Bronac Ferran commented:

> Sometimes artists will want to give ideas away, other times protect them. In each case, they need to know their options.

C&CRS's approach is very much research-oriented, and the COSTART project team (COSTART) were keen to hear the opinions of artists as to how the involvement of researchers had influenced their collaborative work. The response was wholly positive—the researcher's role in evaluating, contextualizing, developing the theoretical base and generating new knowledge from which others might benefit was regarded as invaluable. Interestingly, the researcher's role as observer was seen as equally important. Joan Ashworth remarked:

> The researcher helps … you to be more reflective about the process … and may identify problems in collaboration. I found it very valuable.

Linda Candy admitted that she had once experienced a situation in which an artist had been unhappy about having a third-party observer, and she appreciated that being exposed to scrutiny can be quite unnerving for those engaged in creative activity: "People need to be willing, and trust the situation".

She elaborated on what she considered one of the most important aspects of the contribution of research, documentation:

> Published documentation provides a primary account of what people were doing… In art, there is not much process documentation; it is mostly product documentation, which people try to unpick. There is little about the evolution of thought at the time.


Directions for the Future

Finally, workshop participants were asked to think about what it is that is most important for the short-to-medium-term future in art and technology, either personally, or more generally. Here are the responses:

EAE: The most important thing is to build collaborations as full partnerships, through residencies, postgraduate study programmes or other forms of funding.

MQ: We need to build environments with supportive technologists, open to collaboration. If you have a good environment, good things can come out of it.

MK: Collaboration must be properly acknowledged.

SP: We should consider education for people on how to become an assistant, or how to collaborate. Credits should always acknowledge assistants and make clear their roles. (But they should also share the blame when things go wrong!)

CM: Aim to provide technology on a "semi-bespoke" basis—software you can configure to control your artwork. Facilitate artists to understand, use, ask questions and advance.

FI: Identify and target different kinds of artists who might be interested in the possibilities of digital technologies.

JI: The issue of time is crucial. Most artists have so little time to integrate technology into their practice.

AP: Art/religion/technology crossover. Apply technology more in the creation of spiritual happenings, developing common experience.

JA: Technologists must have artistic sensibility—otherwise they can't communicate.

IH: The social problems of collaboration can be very difficult and need to be considered, especially the issue of developing common goals.

GW: We need to step back occasionally and ask ourselves the question: What exactly are we gaining by using this technology?

MF: Move towards art that makes the artist/technician distinction unworkable.

LK: Start a public debate about the value of art led research.

DE: A stable, non-distracting, structured working spaces facilitating peer interaction is needed as well as a focal point for worldwide activity in this field, enabling networking and exchange of ideas.

AW: Go on collaborating, but ensure that the relationship between collaborators is equal.

BF: Promote opportunities to join up some of the funding bodies in shared work and encourage dissemination of process and collaboration. We need to substitute the word "problems" for "opportunities".

ER: Develop facilities for supporting an ongoing relationship and dialogue, so that I can pop in and out when I want.

LC: We need to understand what research is from different disciplinary standpoints. Science is based on the experimental method and this is not appropriate for arts research. A methodology for practice-based research in the arts needs to be explored and defined.

Conclusions

These final comments of the day reveal an overriding concern with communication, an issue which figured prominently in all three workshop sessions. Communication, in one form or another, has always been the business of artists, but it is communication *between artists and machines* that distinguishes creative activity at the boundary of art and technology, for digital technologies are no mere extensions of hand and eye but provide new instruments through which ideas, understanding, and experience might be conveyed from one person to another.

In this context, the constraints which have alternately frustrated and stimulated artists (see Boden 1990) can be seen as *communicative* constraints, and the dilemma of the artist engaging with technology has been characterized as a choice between allowing the technology to dictate the terms of the dialogue, or of bending or reinventing it to suit his/her accustomed language. Another possibility has been hinted at by Joan Ashworth:

> Digital technology has enabled me to work in a more contained and less physical way. The square footage of studio space required is less. It makes me feel restricted in some ways and my hands and body get bored with doing small movements. They need bigger gestures with more physical effort required to feel satisfied (Ashworth 2002)

Is this a case of an artist learning to function *despite* technological constraints? Or rather, has the artist begun to discover new possibilities for communication and expression *because* of them? Her use of the word "enabled" suggests the latter.

Artists, if they have something to say, will have little interest in exploring technology for its own sake, in merely illustrating its capabilities, as so much "computer art" seems to do. On the other hand, using technology in ways that fail to take account of its particularities may turn out to be equally unrewarding. It was Ernst Gombrich who observed that, "Sitting in front of his motif, pencil in hand, the artist… will tend to see his motif in terms of lines, while, brush in hand, he sees it in terms of masses" (Gombrich 1995: 56). Meaningful engagement with new media may equally depend upon the artist's learning to conceptualize in terms of those media, which is not simply a matter of shaping the technology or being shaped by it, but something much more interesting: the gradual emergence of a 'trialogue' between artist, machine and audience.

Extrapolation of current trends is a notoriously unreliable method of prediction, since none of us knows what seismic technological shifts are imminent. But what emerged from the day's discussions is that, whatever the technology employed, creative success will depend on effective communication. The artists, technologists and researchers at C&CRS are at the forefront in developing the languages that will facilitate this communication.

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An Observer's Reflections: The Artist Considered as Expert

Thomas Hewett

This article offers a particular perspective on some of the rich set of results of the COSTART project residencies (COSTART 2000). In the first section comments are made on certain important aspects of the process of collecting observational data and how some of the classical problems of observational studies were dealt with. This is followed by a short review of the nature of expertise, some observations on human knowledge, the uses of external representations of that knowledge, and how the research into those topics relates to the artists being studied. In the third section of the chapter an extensive set of quotations that were collected from digital artists during the residency periods is presented. These quotations will enable the interested reader to participate in the process of evaluating some of the observations and conclusions drawn in this chapter and in the book as a whole. Finally, some of the findings of the project relevant to digital artists considered as experts as summarized.

On Being an Observer

In any type of case study observations, the observer, especially when conducting observations live and in real time, has to continually attempt to maintain a balance between two conflicting goals. First there is a need to establish a certain degree of familiarity or empathy with the individual(s) being observed so that they become comfortable with the observer's presence and possible questions. The other need is to maintain a certain distance and objectivity which allows the observer to record information relatively uncontaminated by personal biases.

In the case studies reported here the individuals who played the role of observer for the various residencies spent time before each residency period began discussing and refreshing their perspective upon the goals of the project, the role of the observer, and nature of the observations to be recorded. Each of these sessions had

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_12

Fig. 1 COSTART project discussions. Photograph by Linda Candy

three fundamental purposes. The first purpose was to establish and re-establish basic ground rules for the role of the observer and how it was to be fulfilled, in other words the concern was to establish consistency between observers and across different weeks of the residencies. The second goal of these sessions was to review and discuss ways to deal with any unexpected or infelicitous events that might arise during the residency period of an artist (e.g. the loss of technical support time, etc.). The third goal of these sessions was to establish consistency between the observers as to the fundamental questions being addressed by the study (Fig. 1).

Expertise and the General Characteristics of Experts

Each of the artists selected for the COSTART residencies was an expert in their area of artistic endeavour. Some were more expert than others by virtue of more years of experience, but part of the selection criteria for inviting artists to participate in the COSTART project was that the individual had to be above a certain threshold level of expertise in their endeavours. For example, every artist taking part in a residency had a degree of public and collegial recognition as being a successful artist. Each of them had made a personal commitment to the practice of digital art. Each of them had had one or more juried shows. Each of them had sold examples of their art.

To frame the context for the observations and conclusions reported below it is helpful to have a short discussion of some general characteristics of expertise. In an important review of the literature on the nature of expertise and the differences between novices and experts, Glaser and Chi (1988) point out some important characteristics of experts which distinguish them from novices and which characterize the ways in which those experts deal with their professional activities. First, experts tend to excel mainly in their own domain of expertise, i.e. expertise in one domain does not generalize to other domains. Experts tend to perceive large meaningful patterns in their knowledge domain and tend to be fast at what they do when working on routine activities within that domain. When confronted with novel domain-related problems, experts tend to spend much of their time analysing problems qualitatively. Typically, they see and represent the problems they work on at a deeper or more abstract level. Finally, experts also tend to have good self-monitoring skill, i.e. they are more aware of their errors and make corrections. In addition, Ericsson has pointed out that one key factor in the development of expertise is that experts, and experts-to-be, engage in "deliberated practice" (Ericsson 1996). Deliberated practice involves consciously working with the domain and with the elements and relationships in the domain to improve domain-related knowledge and skills.

The relevance of this brief review of expertise to the material that follows can be seen by considering the types of activities in which one might expect to find in an artist engaged during their preparation for and execution of a new piece of work. First, we would expect the digital artist to have some knowledge of digital resources and their capabilities but that their view of those resources is that they are a means to an end rather than an end in themselves. Secondly, we would expect the artists to have an overall vision, or partial vision, for what they want to accomplish but to have not necessarily worked out all the details or the implementation of that vision. Thirdly, we would expect them to be willing to spend large amounts of time trying to articulate or realize that vision in a way that is satisfactory to themselves. Finally, we would expect the artist to be willing to engage in extensive, guided experimentation, working with the raw elements out of which they intend to create an instantiation of their vision. Even a cursory review of the quotations below reveals a consistency between these expectations and what the artists say about their working processes.

External Representations, Knowledge, and Knowledge Development

In a highly readable book, Norman explores a number of issues related to well-designed and badly designed artefacts (Norman 1988). In the process, he discusses the importance of the distinction between knowledge in the head and knowledge in the world. Knowledge in the head consists of our memories, which may not always be present in our consciousness when needed. Knowledge in the world consists of information that exists in our environment that enables us to remember or activate information in memory when needed. For example, we typically do not remember all of the details represented on a standard piece of coinage, but we are able to remember the meaning of those details when the coin is visible. In other words, information in the world represents an external storage location. The world, just by being there, helps us remember and keep track of things.

In a related book, Norman discusses the importance to the human mind of being able to create external representations with which to think as well as remember. He points out that the power of certain artefacts in our environment derives the knowledge embedded in the artefact. For example, imagine trying to drive in the United States from Gainsville, Florida to Muskegon, Michigan without looking at a map (Norman 1993). Not surprisingly, when one is attempting to give someone directions on how to get from known point A to known point B it is often useful to draw a map. Furthermore, this construction of an external representation can reveal that there are many details of the route between points A and B which are not known until the map is constructed. In other words, development of an external representation can lead to the development of new insights or new knowledge. For example, the author once had an extended and almost heated discussion with a colleague who had lived in Vienna for several years. The topic of the debate was the number of exits from underground to the surface at a particular subway stop. The debate was only resolved when a sufficiently detailed map had been consulted (Fig. 2).

The relevance of this discussion of knowledge, external representations and knowledge development lies in the series of quotations presented below. From these quotations from the case studies, it becomes quite clear that a number of the artists made comments indicative of the need to create an external representation

Fig. 2 COSTART project discussions. Photograph by Linda Candy

with which to experience and think about their developing vision or to enable them to clarify what that artistic vision actually was.

Extracts from the COSTART Case Studies

The pursuit of meaning through art is an act of embodiment. It is an unspoken dialogue between the self and the state that is to emerge.

The context for the technology is that of a medium for the creative work. Fundamentally, an attempt is made to allow the nature of the technology to be embraced rather than forcing metaphors from traditional creative tools upon it.

Much of this I could do by memory but some aspects I had forgotten… If I had to do this without the Whiteboard [and playback of the sequence of drawings] I would be using memory that might interfere with the creativity…

I felt my creativity was lessened if different systems were used and this was a problem… I knew that it [the preferred system] would achieve the effect I required whereas other systems might not achieve that effect.

Certain things you work on but to make it interesting to shoot, to keep it alive, you leave certain things undecided and also a bit loose. You know the parameters but how you actually perform it can change… So it's not just a mechanical process…you are actually performing through the model.

I've been working on the idea for about two years.

But as the week has gone on and as I started formalizing more in my head, now I can see the end piece I have visualized.

Technology is a two-way compromise. It encourages one to expand their working ideas and practices and yet also prevents one from creating as so much new information has to be learnt.

I always used to deliberately exploit the grain. I blow up images and they are very grainy and I still do that but with pixels.

I mean a lot of the time I do refer to the technology itself. It can be embedded within the actual work during the process itself. But I try to get it so that it's not using technology for technology's sake.

The entire thing has been on the boil… for about a year, but it's only been sort of, there's been different aspects of it… that I've been able to do to a timetable and this is one that I've just very much done tests for…

The process is vital because it informs the work itself.

The more I think about it the more I'm thinking I need to go back to the processes and the relationship between… the fundamental part of the work and how it would be disrupted by VR [Virtual Reality] by the very nature of it.

So to me it's quite strange coming in and sitting and watching and not being hands on…. …when you're trying to make an object a particular shape… it's easier for me if I can do that myself…

…when working with the display environment I want to do some mock ups for the actual installation [of the work of art] in 3D. I like the idea of taking the spaces they create on the screen or mocking up a real space and then re-drawing the real space according to what the screen space is.

These things too…from a mathematical point of view they're very tricky…but from another point of view. Let's assume something else here…There has to be a tight nature with the material…the whole thing's integrated in this system as far as possible but there's no plan. But it implies something.

It's very exciting you know, thinking it would be good to have a sound trap. You see what he's done don't you? So one could play with those models more…

If we do a collaboration, you don't want my trademark.

Well you understand what I'm doing, where should I be starting from?

Discussion on what may be possible in programming terms influenced the shape of visual ideas, which were then in turn relayed back to the requirements of the programming. Crossing between the two forms was very useful as it has allowed the ideas to emerge out of a process rather than by designing a predefined object or environment.

A creative process of experimenting with technology seems to provoke questions that may not usually be asked of the technology. Examples of this are using simple techniques but within an unusual context and working with technology that is most appropriate to the concept of the work…

Using digital technology seems to give potential for creating a different type of relationship between the object and viewer… the potential to surround the body with a responsive and evolving environment…

Reflections on Providing Support for Digital Artists

For those experts in digital technology who would provide technical support for digital artists there are several lessons to be learned from thinking of artists as experts. One of the key features of creative work is the importance the artists give to the locus of control. For most, being able to determine exactly how and in what way the creative process takes place is a matter of paramount importance. This does not mean that they necessarily need to personally handle every single aspect of that process once it is understood and mastered. They are often willing to allocate the priorities and delegate tasks when they have a sense of what the results can be expected to be. This is crucial to how successful the generation of ideas and artefacts is perceived to be. It also means that being driven or diverted by unsolicited factors, such as a tool that keeps breaking, or a technology support person who keeps trying to do things that are not understood by the artist can be damaging to the process in hand.

Another factor to be remembered is that creative people are not afraid to choose pathways that are fraught with risk and full of pitfalls. In fact, one can argue that such exploratory activities are essential to the development of a creative work of art. Experimentation with concepts, materials and tools may, in the first instance lead to failure but those failures are often fertile ground for learning quickly how to move out of the conventional space of possibilities. This experimental approach to the creation of a new work of art means that the artist will not be easily deflected from a chosen route and, if it involves a hard struggle, i.e. learning a difficult technique, then they will do so in service of their goals. Creative people are not inclined to look for easy ways, or for rigid formulaic ways, to do things at the expense of achieving a creative result. This avoidance of rigid methodologies, however, can sometimes lead the artist to introduce rigid, inefficient formulaic approaches of their own for the well understood portions of what they do in order not to disrupt the flow of their work on the development of the novel and, perhaps creative, product.

While learning new skills or techniques is an important facilitator for creative practice, the role of collaboration for digital artists is integral to that process. In many respects, the technology is new and only incompletely understood by the artist. Some artists may want to take full control of the reins of the technology because it is pivotal to the way they work. For others, it meets a temporary means to an end that can be met by a supportive collaborator. Typically, technologists with little knowledge of art practice do not easily make good collaborators. The training and expertise of the technologist are oriented around providing the most economical and efficient solution to a problem. When an artist is in the process of experimentation with the development of external representations to be tested and evaluated, the last thing that they want to be concerned with is the constraint of machine efficiency or with a premature solution to problems perceived by the technologist but not understood by the artist. Artists need collaborators who understand or are empathetic to their goals and their need to exercise control for themselves. Being on a voyage of exploration and discovery they want to find their own way. They are typically not interested in being shown a solution unless convinced that the person they are working with understands what they want to accomplish. Working through and with the eyes and hands of the person who provides technical expertise does not work well for the core creative activities although it might be acceptable for the more well-understood ones.

A Final Note

As might be expected from the brief look at the literature on expertise here, it is often the case that the initial creative process does not concentrate upon the surface qualities of the work, such as the texture of the paint or the quality of sound from a particular instrument. A focus by artists on the underlying structure of art works shows clearly in the residency reports of the interactions between the artist and technology support person. It appears from the evidence so far that computer use in art has an impact on the concern for underlying structure of the creative product as distinct from its outward physical and virtual object realization. The most likely case is that the artist as expert is concerned with making an underlying structure explicit and the nature of the computer becomes a way of facilitating that activity in ways that cannot be achieved without the computer. Rather than start with surface considerations, the artist as expert will start with fundamental structuring considerations. This may represent a case where a significant opportunity for computer augmentation using a variety of programs or even intelligent agents. By being able to use software to generate the concrete and visible realizations of various possibilities inherent in the structure decisions, the artist would be able to see within very short intervals of time the implications of choices. In other words, a significant role for the computer in the user interaction with individuals engaged in creative work would be to enable the artist to think and act in terms of underlying structures. After setting the computer to do the work of developing alternative surface representations so that the artist can quickly see the instantiations and make choices at various deep structure points.

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Realizing Digital Artworks

Colin Machin

Artists who aspire to using digital techniques in their artworks often require assistance from electronics and software engineers. The artist's desire to produce an artwork that, in some way, portrays motion or even reacts to its environment requires controlling electronics (Rolinson 2002). The simplest solution is to provide the artwork with intelligence through the use of a computer system. It is the job of the electronics and software engineers to collaborate in order to provide two elements that will provide this intelligence. First, and rather obviously, the electronics engineer must provide the computer-based hardware that will control the artwork and, if the artwork is to respond to its environment, the sensing electronics also. It is a relatively straightforward task to design and build a controller based upon microprocessor technology. The techniques are well established and are indeed merely simple manifestations of the type of solutions applied to industrial control applications. Typically, a micro-controller would be used as the computing element. Once the hardware is available, the software engineer can provide the embedded software required in order to control the artwork.

Controlling the Artwork

The software that is embedded into the controller for the piece simply manipulates outputs on the hardware, which are connected to real-world elements. A simple item of this kind could be a Light-Emitting Diode (LED). These components produce small individual points of light, which may be combined to produce patterns. In a typical piece, the LEDs could be illuminated in some kind of sequence in response to the passage of time and/or external stimuli. In the first and simpler of the two cases, the piece follows a fixed sequence whose timing is predefined, much like a set of traffic lights at a busy junction. Even where sensors are involved, the response to the stimulus from a given sensor may be predefined. This behaviour is also seen in traffic lights. When a vehicle on a minor road arrives at an intersection

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_13

it triggers the traffic light controller to enter the sequence that allows it egress on to the main road. We could borrow terms from the world of industrial control systems to distinguish these two types of behaviour, although the terms are not used in their strict senses in this context. We could assign the term "open-loop" to those artworks that simply perform fixed sequences and "closed-loop" to those that sense their environment and make some response based upon what is detected.

It does not matter whether the artwork is open-loop or closed-loop, the decision on how the artwork operates must remain the province of the artist. It is in realizing this that the software engineer suddenly understands that the job is not as simple as at first may have been apparent. We have already observed that the hardware is at the simple end of the spectrum of control systems, but that is possibly where simplicity ends. It is a well-established fact that many clients making use of a Software Engineer will be unaware of what they really require at the stage at which the requirements are specified. This is often due to that fact that the client does not really understand what is possible within software in general. Software engineers will often say that "anything is possible", although what they really mean is that "we can make the computer do whatever you desire, but you must know what you desire before we can start". When working with artists, it is here where the biggest challenges arise. They, quite rightly, have the creative talent and should not be expected to be familiar with the electronics and computing.

Embodying the Artist's Ideas

A simple approach to providing the software for a digital artwork would be to ask the artist to specify the sequence that is to be followed by the piece and to encode this directly within the software. Let us consider, for simplicity, an open-loop artwork and one that has a series of LEDs that can be lit independently to produce some effect or other. Early collaboration with Esther Rolinson at one of the COSTART project residency sessions concentrated on this kind of work (2018). Maybe the simplest 'sequence' that could be used is to illuminate a single random LED for a random, although within limits, time and to repeat this forever. This would have a particular level of appeal to a viewer experiencing the artwork, but that appeal may be limited, beyond the curiosity value associated with the viewer attempting to predict the next change. Such behaviour would be easy to permanently embed within the software that controls the artwork and indeed this approach would be completely justified.

If we assume, though, that the artist wishes the artwork to portray some artistic merit, beyond its basic structure, we must look towards embodying the artist's ideas with the LED sequence. The artist will sketch out the proposed sequence and pass it to the software engineer. It is the software engineer's job to encode the sequence into the software that is to control the artwork. The artist will doubtless be astounded by the ease with which the artwork follows the intended sequences, but will equally likely become bored with the repetitiveness of those very same sequences. The artist will have to go back to the Software Engineer and ask that the sequences be amended or expanded. This process could repeat itself many time over before the artist is sufficiently satisfied to allow the artwork to be seen in public or until the patience and resolve of the artist and software engineer finally expire. It is likely, then, that the artist will, at the end of this, still not be totally happy with the artwork and will be hankering after bigger and better things. Reluctance to bother the software engineer or exhaustion of the budget will then prevent enhancements from seeing the light of day. Further, experimentation with new ideas will be stifled by the same limitations. This scenario has a close parallel with that faced by businesses that took the step of utilizing computer systems many years ago. They either employed their own programmers or enlisted the help of software houses to write systems to support their business processes. They, too, had to specify the operation of the software beforehand and required changes to the software's operation had to be implemented by the same teams. Computerizing even the simplest of business processes required this sequence of events.

Increasing Flexibility

Nowadays, many of the less demanding business processes are implemented using spreadsheets or simple database systems. In this situation, the spreadsheet program has been written to allow the user to configure a spreadsheet to solve a particular business problem. When the user wishes to add an extra column of data, there is no need to consult the team who programmed the spreadsheet application. Instead, the user simply points and clicks and immediately the new column is added. Its functionality is then easy to define, perhaps with the insertion of a formula linking cells in other columns. This begs the question as to whether the creators of digital artworks should be required to behave as the clients of software houses did in the 1970s or should they now expect a more modern approach? It is only by allowing flexibility that the creative processes can be enabled. At odds with this approach is the fact that the microprocessor technology that is typically at the heart of the artwork's controller is not particularly amenable to supporting large point-and-click applications of the spreadsheet genre.

One method that can be used to provide the flexibility that the artist requires is to for the software engineer to provide a mechanism in the artwork's control software that will interpret sequences that have been specified by the artist. The software engineer in fact expends no effort on encoding sequences, but instead puts time into providing the mechanism. It has to be said that the time taken to achieve this is far in excess of the time that it would take to encode sequences directly, but the benefit to the artist is out of all proportion to the extra effort. Of added benefit is that the resulting system stands much more chance of being re-usable in a future project.

Let us return to our simple example of the set of LEDs in order to illustrate the principle. Suppose that the artist wishes to illuminate a particular set of LEDs for a given time and then illuminate another set for a different time? It is a simple affair to write a sequence something like that given below.

```
TURN ON 6, 7, 8, 10, 12
WAIT FOR 10 SECONDS
TURN OFF ALL
TURN ON 3, 4, 9, 14
```

It should be obvious what this achieves, simultaneously turning on LEDs 6, 7, 8, 10 and 12, then after ten seconds, extinguishing all of them and then turning on LEDs 3, 4, 9 and 14 instead. What we see here, of course, is something very much akin to a program. In fact, given that each instruction causes exactly one thing to happen, it is in fact just like a program written for a microprocessor. It is not, though, in the microprocessor's own language, but in some kind of application-specific language and the artwork controller's software is simply executing an interpreter for that language. By including statements that allow looping and both unconditional and conditional branching, we can easily build up a powerful set of instructions for commanding our artwork controller. We could command our set of LEDs to perform the sequence given above 20 times before moving on to something else by the simple addition of two statements as shown below.

```
REPEAT 20 TIMES
TURN ON 6, 7, 8, 10, 12
WAIT FOR 10 SECONDS
TURN OFF ALL
TURN ON 3, 4, 9, 14
LOOP
```

The REPEAT instruction tells the interpreter to repeat the instructions between it and the next LOOP instruction a given number (20 in this case) of times. Loops formed by this simple construct can easily be nested so that repeated blocks may themselves be repeated. In the skeleton below, indentation has been used to illustrate this nesting.

```
REPEAT 20 TIMES
REPEAT 10 TIMES
<block A>
LOOP
REPEAT 5 TIMES
<block B>
LOOP
LOOP
```

Here we see the instructions that form <block A> repeated ten times followed by those in <block B> being repeated five times. That sequence is then repeated a further 19 times before the sequence moves on. Conditional branches (GOTOs) can be used, for example, to alter the sequences according to the time of day or in response to the presence of external stimuli, thus allowing the building of complex sequences.

The controller that is integrated into the artwork will not usually have a keyboard and screen present and so these sequences will have to be uploaded to the controller from another computer—a PC or a Macintosh. The sequences are presented in textual form to this host computer where they are checked for syntactic accuracy and then translated into a form that is more economical than the textual form. This is then uploaded to the controller for storage and execution. In terms of the evolution of computing in the business environment, to which we referred earlier, the present situation is much like that at the time when SQL (Structured Query Language) was developed for manipulating databases. SQL is essentially an application-specific language that allows records to be stored in and retrieved from a database that has already been set up. Of course, SQL is a long way from the point-and-click nature of today's applications.

Visualizing the Piece: A Simulator

We will assume for the moment that the artist can master the idea of writing these sequences and examine what else the host computer can do in order to assist the artist. Before the artwork controller is installed, it is difficult for the artist to visualize the effect of the sequences that have been programmed. For that reason, it might be of great benefit to provide a simulator for the artwork. It is possible to produce an on-screen graphical representation of the artwork in two dimensions and to show them with a further representation of the elements that are to be controlled, such as the LEDs in our example. The simulator can "run" the sequence and portray the results on the image. An extension to this idea involves the artist in producing a three-dimensional representation of the artwork, in some preferred Computer-Aided Design (CAD) or other drawing package, upon which the controlled elements can be projected. Whilst working with Esther Rolinson on her project to incorporate Priva-Lite panels into glass columns, a simulator was produced for this very purpose (Garton 2001) Fig. 1 shows a screen view of the simulator.

The Priva-Lite panels are constructed as a sandwich of glass and a material that is clear until an electrical current is applied, at which point they become opaque. In this context, they behave very much as shutters. What we see in the simulator is a two-dimensional representation of seven columns each with five panels of Priva-Lite, together with their projection on to the three-dimensional artist's impression of the artwork in situ. The views represent the Priva-Lite panels as

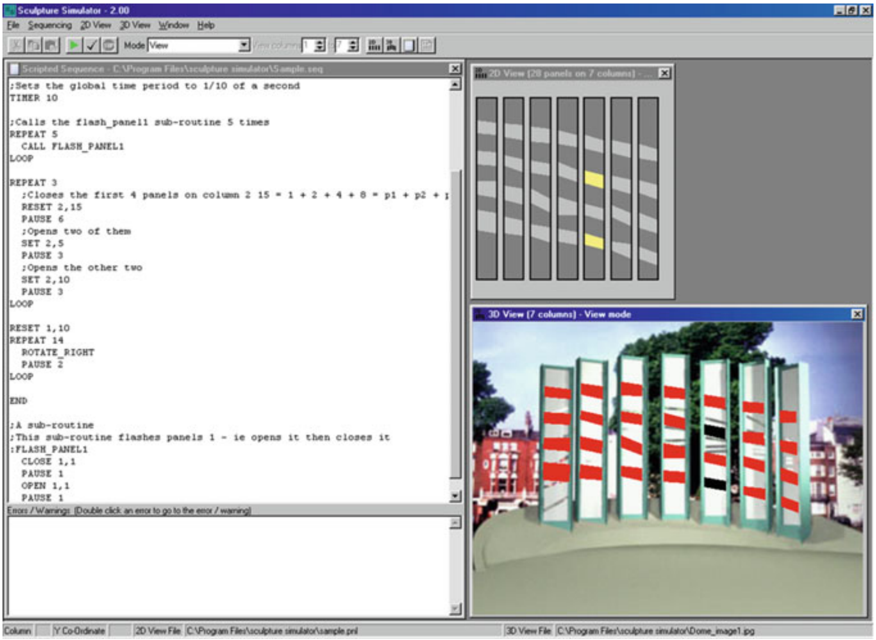

Fig. 1 Sculpture simulator

coloured areas of the screen and different colours are used to distinguish open and closed shutters. A sequence to operate the artwork is shown in the window to the left and as the sequence runs, the changes in the Priva-Lite panels are reflected in the 2-D and 3-D views simultaneously.

It has been suggested that technology has an impact on artists in three distinct areas, namely in thinking, in making and in communications within the team. Furthermore, there is a likely impact on artists and technologists alike of aiding in the development of the technology: discussed in Chap. 2 of the 2002 edition of this book. The simulator clearly makes a contribution to the making phase, as it allows the artist to visualize the sequences that are to be used in the artwork. It could also be said to be making a contribution to the communication aspect as it allows the artist to understand the possibilities of the piece. However, this useful tool could be used, in a different commission, to actually assist with the design and will clearly contribute to the thinking phase. The simulator in question is itself ‘programmable’ in terms of the numbers of columns, their spacing and the numbers and position of the panels. This simulator was designed with the particular artwork in mind, but it would not be difficult to imagine a situation where the artwork’s design (the creative bit) and operation (the technical bit) are integrated into one package.

The Next Step

We have been assuming that the artist is comfortable with sequence programming, but what if it is deemed to be too complex? What is needed here is a point-and-click interface to the programming of sequences. Some of what is necessary to achieve this step is difficult, though, especially if we are looking for integration with the design process. We would first need to integrate a user interface that can capture the artist's creative processes and enable the identification of the elements to be controlled, be they LEDs, Priva-Lite panels or whatever else. We would then need to have the software be able to visualize those elements on the screen.

All of this is conceptually achievable and is indeed only a relatively small step from the existing simulator. It remains only to enable the specification of different kinds of controlled elements. There is a parallel here in the simulation of electronic circuits. Standards exist for the specification of the behaviour of components and models of each component are processed in a manner defined by a circuit.

The technology to achieve this goal exists in other related spheres. Perhaps the most difficult aspect of this step is the manner in which the required behaviour of the artwork is to be captured. We need to be able to capture the artwork's static conditions along with temporal information defining the timing of the piece. Clearly the system could enter into a dialogue with the artist, but this would serve only to restrict the flow of the creative juices.

It will be necessary to work with artists in order to determine what they desire in such a product and to attempt to identify new ways of capturing the information that is required. Active drawing surfaces have been aiding artists for some time, although there is debate about their effectiveness and whether or not the technology actually inhibits the creative process (Quantrill 2000). More work will be required to determine the manner in which various technologies might be integrated in order to be able to capture the creative aspects of a digital artwork.

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Being Supportive

Andre Schappo

My involvement in the Creativity and Cognition Research Studios (C&CRS) artists-in-residence programme started a long time before the actual arrival of the artists for their period on site. At that time, I had a dual role in the University of Loughborough. In the academic department of Computer Science, I had been involved in various research projects over the years and had gone on to join the support services for the departmental computer systems. Later on, I also took on a campus-wide responsibility for Apple Macintosh systems support, this time in the Computing Services department. This enabled me to extend an already strong network of contacts throughout the university. This proved to be very important when I joined the COSTART project in 1998 as a technology coordinator (COSTART 2000).

There were several stages to the preparation of the technology at C&CRS before full-scale residencies could be run. Our objective was to create a fully integrated system of facilities comprising equipment, devices, software and networks into which additional technology could be added as required. Although considerable effort was spent in identifying the right kinds of technological facilities in advance, this was never going to be sufficient to enable us to predict everything that would be needed. It could also not prepare for the unexpected failures in those things we thought had been addressed.

The University departmental support staff played an important role in helping set up the new equipment and this was achieved in a very short space of time. Delays brought about by the tendering process and the delivery of equipment added to the problems of ensuring that everything was installed and tested by the beginning of July 1999 when the COSTART residencies were due to start. In the event, a number of devices were not fully integrated in a manner that satisfied our high usability goals: for example, initially, there was no easy to use method for artists to transfer files from the Apple Macs to the Silicon Graphics Origin computer. This meant that archiving files and freeing up space on the shared computers in the Studios was a time-consuming business that not all artists could manage on their own. Time to

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_14

achieve everything to our complete satisfaction was short. Having set up the basic infrastructure there was still more to be done to address the specific needs of the artists.

In order to ensure that the right facilities were in place before the artists commenced work, we held a workshop to meet the prospective residents. This was when we got down to details about their needs and expectations. Because for some, there was uncertainty about what would be appropriate, this was very much a case of anticipating their requirements. The artists did supply a broad-brush description of the kind of things they wanted to do and we had to translate that into "What would we actually need?".

Throughout all stages of the establishment of the Studios, for me personally, there was a lot of time spent exploring technologies, evaluating technologies, making purchases and setting up equipment and software and chasing new developments as they appeared. This involved liaison with other project members and my network of contacts in the university. The first liaison was mainly with artists, Mike Quantrill and Dave Everitt both of whom were accessible locally and who had had some earlier involvement via Gallery of the Future events. My role was to offer technical advice and trouble shooting and be available for general brain storming sessions. There was also a period of learning for me before the residency period. I intended to become familiar with relevant technologies and software packages. Time did not permit me to become as familiar as I had hoped. I anticipated that I would not have all the relevant skills necessary for the actual period.

The Residencies

The residencies were very challenging and interesting. It was made more challenging by the fact that during that week I still had my departmental and campus wide duties to attend to. There were, in effect two distinct roles within the research project: one of general technical coordinator and the other of technology supporter for a specific residency.

My main involvement as a technology support person was with the artist Sarah Tierney. One aspect of Sarah's work was the requirement to capture and edit video. This involved taking sequences of movements of a model. I knew that given the limited amount of time available I would not have time to learn how to do it professionally myself. This is where I made use of the network of people I have come to know at Loughborough University over the years. I contacted Paul Wormald in the Design and Technology department to see if he could help. He did more than help. He actually setup the lighting and captured all the necessary video. In the process, I did also learn something.

More generally I consider that the residency went very well. There was a good atmosphere and everyone, both artists and support staff, got on very well together. Or to put it another way it was, "Totally cool".

Experiences from the Case Study

To give an idea of the events and the experiences as they happened, some extracts from the residency I supported are included. The labels A, T and O stand for Artist, Technologist and Observer respectively. The direct quotations come from any one of those people and are included within borders. The other text was written by the researchers who collated and analyzed the data.

Figure 1 shows the artist, Sarah Tierney assisted by Paul Wormald, filming source material for a video work. The material took the form of a spoken narrative delivered by the actor Sarah Moffat. Close up shots of Sarah's mouth and eyes were taken. Later the source material was downloaded to an Apple Macintosh G3, and edited into a video work: see Fig. 2.

Case Study: The Artist Sarah Tierney

Sarah Tierney's explorations of the effects of breaking up images are an intrinsic part of the underlying concept and exploration of her own life. She described the artistic process in terms of the relationship between the artistic ideas stored mentally

Fig. 1 Making a video. Photograph by Linda Candy

Fig. 2 Video editing in progress. Photograph by Linda Candy

and the externalization of those ideas through production. The integration of "thinking" and "doing" are particularly important to her. In respect of guiding ideas, there are two interests: one is the combining of text and visual image and the other is that of time. The importance of time within her art had increased as the technology opened up all kinds of new opportunities within this element of her work.

> The thing I think about structuring is the time concept. So time is distorted, it's exaggerated and speeded up. That is connected to my interest in how long you can capture a viewer. Artist interviewed July 1999

The original proposal submitted for discussion was a project to develop a film/installation piece. The project was too large for a week's residency but in that time, the aim was to explore how to make a short film using video technology. The artist felt confident about her knowledge of Apple Mac computers and the editing application Adobe Premier and her capacity to grasp new applications provided there was someone to assist. Her expectation at the outset was that she would need to spend time exploring the software and learning as she worked. This expectation was dependent upon having adequate and appropriate expertise on call. Whilst she did not feel that she had achieved very much in terms of the production of the video itself, she did feel that substantial progress had been made in terms of developing the concept behind the piece. As she said:

> In my head I have moved on a lot but out there, physically, it has not moved on a lot. But as the week has gone on and as I started formalizing more…I can see the end piece I have visualized…Artist interviewed, July 1999

The relationship between the thinking about the guiding concept and the actual visualization of an image seems to be an important element of this artist's practice. The total concept must be realized in response to the developing physical and virtual realization.

A year later, the following feedback was received from the artist commenting on her case report:

> I am now in London and have been travelling quite a bit in America. I have made some good contacts with galleries and artists in New Orleans and I plan to exhibit there in 2001. The work will be photographic/digital images rather than video/film. I have evolved the work I did at Loughborough and I am using text. E-mail from Artist July 2000

The artist's goal of learning new skills during her exploration of new ideas was difficult to achieve. Problems were faced because of the lack of expertise in one critical software application. The time and effort spent on learning how to use the software from scratch required frequent referral to manuals. The situation was hindered by the difficulties experienced by the artist in adapting her knowledge from one video editing application to another which she found less transparent and more cumbersome to use. There was also much to be learnt about the use of the digital video camera but with the assistance of an experienced user, this part of the process was more successful and was one of the main achievements of the week.

Communication and Collaboration

The artist considered that communication with others, particularly fellow artists, was a fundamental part of the process of creating art. She reflected on her experience during the week and referred particularly to the issue of effective communication between artist and support person. She draws interesting parallels between the media and processes utilized, the preferred working environment and the ability to communicate your ideas with fellow artists and technical support.

> It's a weird experience being observed/monitored as I work. I have always worked in an isolated way. This is especially true throughout my degree at university — the nature of photography and darkrooms reinforces a very individual work ethic…When I say it's a weird experience, it is not unpleasant or anything… I enjoy the interaction of other artists and designers. You need to be a good communicator verbally as well as visually though, to achieve a mutual understanding of the work-process-thought-idea-progressing. A's diary

Whilst there are some relationships that are successful immediately, with others, time is needed to gain confidence in that person. The artist found it easier to establish an instant rapport with one assistant over the other and this is certainly evident when listening to recordings taken during the early part of the week in terms of the nature and tone of conversations. However, she did manage to establish a good working relationship with the main contact person by the end of the week and valued the calming effect of his personality in the face of technical problems. This highlights the importance that many artists have attributed during their residencies to establishing longer-term relationships with technical assistants. This need for familiarity is evident even at the most basic level such as developing a common language (particularly when discussing technical issues) that both parties can understand and work with.

In terms of fundamental knowledge of the hardware and software, the support team was proficient:

> P is definitely the star today. His knowledge of video is extensive. It would take me weeks to learn that much about video cameras. Need: more lighting and improved audio capture. Found the AGK omni-directional mike. Certainly seems to improve audio capture but Wednesday will tell. T's diary, July 1999

The artist commented on the skills of the team during an interview on the last day of her residency:

O. What do you think you got from them? Was it useful, interesting?
A. P's knowledge of video camera and his interest and T is so unflustered—a calming effect t–re horrible things with Edit DV.
O. So generally you felt they had skills you found useful and you learnt things?
A. Yes I learnt things…the video camera. Not around the computer—I am quite used to a Mac, except I am beginning to learn something about this new software package.
O. What about things that were not there in terms of support, access to people, skills?
A. It would have been brilliant if there had been someone on board who knew the software Edit DV. I think that would have speeded up the process because I have my head in the manual all the time. I learn best with someone there to give me a quick demonstration. I work better talking to someone. Artist July 1999.

The preference is for access to a person who can filter the information needed according to the task needs as they arise. Does this imply the artist does not work in an anticipatory manner but in a reactive mode? What are the implications of this for advance planning for a support environment and for training?

The problems that were encountered in using Edit DV slowed down progress considerably throughout the week. A problem of an incompatibility between QuickTime Version 4 and Edit DV was identified and caused delays until later in the week when the artist found that the next version of Edit DV was available and this solved the incompatibility problem. She had been left to get on alone while support staff were otherwise engaged and during that time browsed the website of Digital Oregon in order to find a solution. The updated QuickTime 4 compatible application was available immediately and without further cost.

The artist was conscious of her personal computing limits and the impact that it had on her working practice. However, the migration to higher end technology appeared to have marginal benefits in a number of respects. This is particularly so in respect of how she envisaged her final work being displayed. The choice of video projection versus onscreen computer-based delivery would afford significant differences in the quality of the image she was striving for.

Use of the Internet

The Internet proved to be a valuable tool, not only assisting the team to identify suitable software, but also in seeking solutions to specific technical problems.

> Looking at obtaining a DV-IN enabled DV camera. Quadrant video will hire one for £100 + Vat per day. Just found on the Web a DV-IN widget that will enable DV-IN on Canon Cameras. Widget for MVI due end July @ £99-00 + Vat. T's diary

> Thursday late afternoon-continued working with DV Edit. Explored Web site to find answers. At least the upgrade is now available so T downloaded it. A's diary

Although exposure to high-end technology during the week of the residency had enabled the artist to develop her work much further than had previously been possible, in terms of the ideas behind the work and production techniques, this would not be realistically sustainable beyond the week. This had created an interesting situation whereby she made considerable mental leaps forward but the results of which would be almost impossible to realize without the support of C&CRS or similar facility.

End of Case Study Report Extract

Lessons for the Future

From the COSTART experiences, there were a number of lessons learned. For me, the most significant ones are:

1. There is a need for a very wide range of skills and talents in order to support artists. A university is an ideal environment for artists because of the skills available. Having a network of people with relevant skills is very important.
2. Because of my other commitments I only worked part time with the artists. Supporting artists is very demanding on time no matter what their level of experience or knowledge. It would have been much better if I had been full time on the residencies.
3. Most of my everyday work is on the computer systems side. Therefore my knowledge of the various packages that the artists used was minimal. I probably needed more time before the Residencies to become more familiar with the packages.
4. Having experienced one residency I am now better equipped to handle a future residency.

The COSTART residencies required considerable preparation in order to make sure that each artist had a realistic opportunity to achieve their goals. They were also intended to be a method of learning about what is needed to make art and technology collaborations successful and, in that respect, they served the purpose well.

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Working with Artists

Manumaya Uniyal

Working with the Technology

What a creative person wants to achieve at times does stretch the limit of available technology but it is highly important to understand the constraints of that technology. The idea is to try to push the limit but ever so gently, otherwise the bubble breaks. As much as one should recognize the creativity of an artist, the artist also needs to understand the constraints of a given technical environment. Often it is not just a question of knowing how much memory and machine speed is right for the project. Having partial knowledge can be a worse problem. I have encountered many cases in three-dimensional animation where people have made computationally heavy models without realizing that with half as many image vertices, after rendering, the difference between the two models would be negligible.

Everyone wants a bright crisp image every time they look at it. What they should ask is why do they need a high resolution? I have seen cases where an image was scanned at 2000 dpi (dots per inch) filling up the entire hard drive and reducing the system speed only to display the image at 1000 dpi and be printed at 600 dpi. In some cases, this might be justified but in most it is overkill. By not understanding the basics, too much investment in technology and time is made in order to create something that could be achieved by committing far fewer computational resources.

Every time I get a new piece of kit my father always tells me, "read the manual before you do anything". At times, the excitement takes over and we bypass that all-too-crucial stage. My father, on the other hand, has this amazing patience to go through any book, but then he is a journalist and reading comes naturally to him. The trick is to read the manual thoroughly just as you would go for a driving test before driving. Most of the people I have worked with tell me where they keep their manual and want me to read it for them. Their way of reading a manual is from the back, they read the index to work out the problem and end up getting more confused. In my opinion, that's the wrong end of the fishing rod. This way you will

L. Candy et al., *Explorations in Art and Technology*, Springer Series
on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_15

get yourself hurt and lose the fish. Learning to read the manual, understanding and spending time on it will give us all a long length of working enjoyment. It is important to understand the software and its functionality otherwise you will miss out those key points.

Today's creative person cannot afford to say, "I am an artist not a computer person so I will not learn this". It is of great importance to look at the past. A number of great painters spent time learning about human anatomy and they never said, "I am not anatomist". Leonardo da Vinci looked at both the art and technology and how they can positively affect each other. Whatever is tool of the day, it is good to have more than superficial knowledge of the tool and it is not just the responsibility of the artist but also the schools who should teach young artists about computing.

Working with the Artist

If a technical support person is faced with a situation posed by an artist that entails work beyond the scope of his expertise, that person should admit the limits of his knowledge, as difficult as that might be. By saying "it cannot be done", this leads to the spread of wrong information and that, in turn, leads to the artist doing things in a misguided way. Before saying no, it is better to find out if it is not possible or could be done by someone else. Recently, I worked with an artist who had to change her whole project because of totally wrong information given to her by the technical staff.

I have had my own sleepless nights but I have learnt by working with artists that the best strategy is to hear them out. Being dismissive and measuring an idea in terms of physical effort needed to do that job is nothing short of insulting to the idea of the artist, however far-fetched the idea might seem to be. Talking (and more so, listening) also allows one to get to know the person you are working with, which, in the long term, helps more than one can imagine. It is not appropriate to have a technician who does not understand the nature of the job. The difference is how one defines oneself within that relationship. Is one an outsider, a mere technician with the job of fixing loose cables, or is one someone who is sharing and understanding the idea from the inside? It is more like acting like as an adviser than a technician, in fact you have to be a intermediary for both computer and the user. Eventually the support person becomes an integral layer between the computer and the artist. A computer is programmed to react and hence, it is a reactive device unlike humans who are interactive and proactive. Intelligence is not just being able to learn from a set of rules but being able to learn from a system where there are no rules. Most people almost bring these dead machines to life by being frustrated or angry with them.

The Residencies

The COSTART project allowed me to actively participate in the processes of creating artworks. The project entailed collaborating with two different artists by sharing my skills with them. The common feature between the artists and their artworks was the use of computers. Computers, although not central to every idea, were important in facilitating the main concept.

My own background in computer animation, as well as economics, influenced how I looked at the methods of creating artworks using computers. In any given work, I prefer to make things simple, often starting from the lowest common denominator. Simplicity is important to me for two main reasons:

- When two people start work for the first time, simple ideas are easy to communicate and help build up a rapport rather than complex ideas.
- It is easy to develop a simple idea into a complex one.

The two artists I worked with had had previous experience of using computers, one having taught Web design as well as having worked as an artist. One of the artists, seemed to be excited by the idea of learning about 3D software whereas the other artist felt that mastering the complexities of a graphics software took her away from the actual work—the animation film that she wanted to create. It must be said that both artists were keen to learn about software.

Artist One

The first artist I worked with, Beverley Hood, showed an inclination towards computers and the different software that were to be used in the project. She had earlier found three-dimensional software useful. The COSTART project gave her a chance of exploring this area further. The collaboration started with a lot of talking. We decided to explore the idea on paper before getting on the computer.

- the artist developed a rough storyboard
- the storyboard was used to examine both
- the technical issues
- the art issues

It also allowed us to be critical about the idea without affecting the actual artwork, since it had not yet been developed.

Early in the project, it had been established that certain cuts would have to be made when it came to the visual quality of the textures and model detail. This was mainly due to the short length of the project. Early discussion helped iron out a number of issues such as modelling, motion of the object etc. All through the project there was a constant flow of ideas.

Some of these idea were not as meaningful as others but as Edward De Bono puts it:

> The first idea that comes to mind may not be so interesting but the second and third that flow from it can be very interesting (De Bono 1998).

The artist picked up the basics of computer modelling and animation very quickly. She meticulously took notes, at times asking the same question over and over again until she understood a given concept. Her repeatedly asking the same question helped me modify my process of mentally developing an answer. It made me realize that I had to simplify my answers without losing the meaning. I learned that the best approach was to give out specific information within a very generic overall structure.

At first, I was giving information loaded with jargon and shortcuts. I was answering two different questions without trying to make a link between them. Soon I learnt that wherever possible, it was important to think of a correlation between any two given answers, for example, the relationship between heavily detailed models, rendering time, final model quality and economics of the whole process. A lot of the work done with Beverley Hood was hands on. At times she would ask something and I had to take over the computer and do it myself. This was mainly because it was not judged possible to explain the entire background under the given constraints of time.

Early on in the project I suggested drawing a timeline so we could see our daily progress. The timeline process was a very pragmatic approach compared to the way artists like to think about artwork creation—that is, something that flows without any limits of time and even an unfinished work of art is acceptable. Without getting into a debate about different working styles, my reasons for the timeline system were:

- to see our daily progress mainly in terms of computing skills learnt
- to be able to generate something, that could be taken away after the week.

The artist could then further explore the computer and her artwork however she pleased and she agreed to the timeline approach. The timeline approach required direct intervention by me when she had a problem. Perhaps, at times, she felt that either I was doing things quickly or not explaining them appropriately. Such issues were always in the back of my mind but the time constraints forced me to overlook such issues.

The outcomes of the project were:

- a completed piece of artwork (perhaps we can call it a draft artwork)
- the artist's feeling that computers and software can be a useful tool for creating art
- an increase in the artist's understanding of three-dimensional software.

I feel that at times that I was pushy but practical. However, as a collaborating partner, I had to play my role as I felt it right. In the end, it was satisfying to hear that the artist felt that she had gained something positive out of the week-long exercise (Fig. 1).

Fig. 1 COSTART project discussion. Photograph by Linda Candy

Artist Two

The second artist I worked with, Joan Ashworth, was an animator. She had come with an open mind to see if computers could help enhance her existing ideas. The basic concept was a short animation involving a mermaid as the lead character, set in seaside landscape with a lighthouse. Her experience with computers was similar to the first artist.

The style of collaborating with Joan Ashworth was based on the pattern developed when working with Beverley Hood (although in retrospect I feel that perhaps I should have changed the style). However, although keen on using computers, she felt that the software applications were too cumbersome and, at times, restricted her.

I also noticed, although quite late in the project, that my timeline approach burdened her. Perhaps the timeline system made her feel claustrophobic when it came to thinking and testing out her ideas. Although, I did set targets, I failed to make it clear that they were primarily there to help us manage and guide the project. Since she works on numerous commercial projects and is well aware of deadlines, perhaps she felt the timeline approach a bit too rigid in this situation. She preferred to use the opportunity of the COSTART residency as a feasibility study of using computers to accomplish a task that was otherwise done in a traditional manner.

I feel I should have modified my working style and not necessarily apply the same system that worked well in case of the first artist. From a perspective of sharing ideas, a number of things might have been left unattended, for example, some of the technical queries. This is evident from the test animations that were developed during the course of the project. I felt at the time that that a longer project would have helped us to communicate our ideas better and allowed me to share my role in the project better. In the event, we had an opportunity to follow up this work the following year and were able to build upon our knowledge of the project and one another. The final work turned out to be very successful.

Conclusion

The COSTART project gave me a chance to interact with the artists in a manner that would not have been possible otherwise. It was interesting to support an artist from the inside by getting involved with artwork and the artist. The project also showed that people with two different skill bases (technological and art) can combine their strengths and help create an interesting piece of work. It is important, though, to realize that in a project like this the main job is of the artist and the technically skilled partner should stay in the background. At times, I found that it was difficult to stick to one particular job title i.e. ‘artist’, ‘technician’, ‘support person’, while at the same time doing jobs that demanded something from all the areas. Perhaps more time spent talking before the actual process would have helped. It was also noticed that the three-dimensional software interface had an engineering look to it rather than a simple layout. We might learn from Edward De Bono when he says,

> The fact that computers can handle complexity does not mean that we do not need to design for simplicity (De Bono 1999).

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De Bono E (1999) Simplicity. Penguin Books, Harmonsworth, UK, p 210. (First published by Viking, 1998)

Demaking the High Heeled Shoe

Alex Murray-Leslie

I am co-founder of the trans-disciplinary art band Chicks on Speed (COS) a collective working to blur the boundaries between academia, pop music, new musical instrument design and theatrical fashion. My artistic practice into the field of New Interfaces for Musical Expression (NIME) began in 2007 as part of COS's growing archive of 'Objectinstruments', a term Melissa Logan, co-founder of COS and I coined to describe self-made body centric musical instruments. COS perform with 'Objectinstruments' as scenographic elements during performances. Key works I made in COS include: The High Heeled Shoe Guitar[1] and EShoe [2] with these seminal works forming the foundations of my research into audio-visual expressive foot devices.

My project 'The Liberation of the Feet: Demaking the High Heeled Shoe for theatrical audio-visual expression' (part of my practice-based Ph.D. at Creativity and Cognition Studios, The University of Technology, Sydney) consists of a series of 4 computer enhanced footwear prototypes developed and fabricated between 2013–2017. In this article, I present one case study: *Computer Enhanced Footwear Prototype 3 (CEF P3)* which was generously facilitated through an artist in residence at Pier 9, Autodesk, San Francisco, August–December 2016. I describe the background literature informing the ideation and how reflexive practice has driven the iterative design process of these physical prototypes.

All aspects of this research attempt to 'demake' the physical high-heeled shoe. In this article, I suggest 'demaking' the high heeled shoe through underlying concepts based on the literature and computer aided fabrication processes, to create new forms of expressive audio-visual foot devices. The process of 'demaking' also changes the usual purpose of shoes and associated stereotypes of high heeled shoe wear.

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Demaking High Heeled Shoes

The literature shows that shoes have important cultural, religious and social significance (Demello 2009). The traditional uses of footwear have included; protection, status, fetish object or one with religious overtones (such as the pope historically wearing red shoes). The creative practice presented, draws on aspects of this understanding of shoes in our society. I liken the process to 'demaking' the high heeled shoe in order to give shoes a new purpose and inform new processes during 3d printing which facilitate new types of footwear that can allow for complex creative expression, rather than high heels crippling our feet (Johnston and Murray-Leslie 2017).

As the overall creative practice trajectory draws on aspects of this understanding of shoes in our society, it was also important that the design of my prototype would have a direct visual connection to the high heeled shoe, an iconic object that I was intending to 'deinscribe'[3] (Pollock 1996:67) or 'demake' (therefore I chose to 3D design a recognisable foot wedge and not an abstract form to connect to the foot). I liken the process of 'demaking' the high heeled shoe in order to give it a new theatrical purpose, costuming the foot to create new experiences for the wearer. Deleuze discusses the notion of changing the purpose of the hands to the feet. The below quote summarises how this can result in the 'composition' or rearrangement of, 'the overall assemblage' (Deleuze and Guattari 1987:28), which I term 'demaking' the original artefact. Deleuze's character Slepian gets the idea of using shoes to change his identity to a dog using the artifice of shoes.

"If I wear shoes on my hands, then their elements will enter into a new relation, resulting in the affect or becoming I seek. But how will I be able to tie the shoe on my second hand, once the first is already occupied? With my mouth, which in turn receives an investment in the assemblage, becoming a dog muzzle, insofar as a dog muzzle is now used to tie shoes. At each stage of the problem, what needs to be done is not to compare two organs but to place elements or materials in a relation that uproots the organ from its specificity, making it become 'with' the other organ" (Deleuze and Guattari 1987:29).

'Demaking' can also be compared to 'defamiliarisation', a concept developed by Russian formalist literary theorist Victor Shklovsky[4] in 1917. Heinrich (2017) suggests, "paradoxically, to become interesting, it needs to become unfamiliar" something he terms 'aesthetic distance' (Heinrich 2017:11) distancing ourselves from a situation in order to give us a new point of view. Bertold Brecht's (1967) concept of *Verfremdungseffekt (*or *V-Effect*, in English *estrangement effect, alienation effect:* the idea of making the familiar strange, the effect that estranges, defamiliarizes*)* connects to Shklovskij's (1998) original coinage and Heinrich's contemporary translation of 'defamiliarisation' and each are relevant philosophical approaches, informing this practice-based research enquiry. I suggest by using the concept of 'making strange', it's possible to divert from old forms of restrained footwear like high heeled shoes (and the usual 3d printing processes of prototypes) and develop new forms of foot-wearables (with embedded circuits in connection with FM sound synthesis systems) that promote new types of creativity and afford free and novel movements for theatrical performance.

Anthropo-Technological Artefacts

Malcolm McCullough, in his seminal book "Abstracting Craft: The Practiced Digital Hand" (1998) builds a case for upholding humane traits and values during the formative stages of new practices in digital media. He reflects on a growing correspondence between digital work and traditional craft and also expresses the necessity for improvisation. This act of improvisation as described by McCullough could be compared to Lamontagne's 2016 concept of humans and machines performing in a scientific laboratory together as part of the fabrication process. Interestingly McCullough and Lamontagne support anthropological and psychological concepts that led me to improvise with a 3d printer, fabricating the new *CEF P3* in an improvised and performative way, which I unpack later in this article.

These concepts include considering anthropo-technological ideas when designing prototypes. Anthropo-technological is a term that unites the traditional techniques of anthropology, such as ethnography, participant observation and acknowledgement of reflexivity can be used by designers to adapt and improve technology. Notable researcher of interaction and experience research, Genevieve Bell is a particularly prominent example. This term expresses the need to bring together data science, design thinking and anthropology to drive new approaches in engineering and computer science; and exploring the questions of what it means to be human in a data-driven economy and world and reflect this in such anthropo-technological designs. The Computer Enhanced Footwear described here are anthropo-technological artefacts as they are informed by anthropological concepts about the feet and footwear[5] and seek to embody these ideas in the physical design of the foot appendage and the way we use can our feet differently with such computational appendages. The computer enhanced footwear seek to extend the body with technology following humanistic intelligence (Mann: 2001) principles, promoting a vision that puts human beings and the creative act at the centre of technological development (Mann et al.: 2013).

Reflection-in-Action

Reflection-in-action is a methodology introduced by Donald Schön (1983) and explains how professional's problem solve their work through improvisation with improvements taking place and opportunities arising though reflecting whilst carrying out creative practice. In the context of this research I've experimented with the fabrication process of 3d printing prototypes, identified characteristics and refined the prototypes based on these experiences in action. Formalising the process, my reflective practice has been achieved through writing it up which captures new knowledge facilitated through the creation of an artefact (Scrivener 2000).

Case Study: Hacking the Objetconnex 500 3d printer, artist in residence, Autodesk, Pier 9, San Francisco August-December 2016.

The ideation for *CEF P3* began at the cult Preylinger Library, San Francisco with its large collection of tech magazines from the 1980s and 90s. I was curious how the editorials featured new computer graphics programs, physical media and hardware developments from these periods. It appeared redundant and yet humorous, knowing at the time this information must have been compelling, influencing graphic design styles and computer art of the time.

I was particularly interested in an article by David Palermo (1991:15) highlighting the term ‘blendo’, which he described as computer art tools that encouraged the synergistic use of several programs. I discovered ‘blendo’ was part of a movement that considered ‘genre-bending’, ‘digital postmodernism’, or ‘synergistic art’, an aesthetic idea to come out of computer graphics programs. Scanning further through the magazines, I noticed how new material technologies also influenced the presentation of digital media on which music is stored, such as the cd (compact disc), with aluminium/mylar[6] printed surface, which the advert seductively claims is the latest sexy and fashionable looking ‘laser technology’(see Fig. 1).

Mylar has since been commercialised and used to coat fashion accessories with strips of mylar film embedded in nail art and readily available via amazon. I was drawn to this connection between an outdated music distribution vessel and it’s superficial looking coating (the added coating on a cd was decorative and served the purpose to reflect the beam to convey the data information embedded on the under

Fig. 1 Panavision laser technology advert featuring mylar coated discs, Compute! Magazine (1991:15)

laying transparent compact disc). After gaining new understandings through the literature my goal was to see what would happen when this knowledge informs my 3d design, which would be physicalized through an unusual combination of materials and the latest state of the art technology like 'blendo' did. The difference of course was that I was making a physical prototype using this 'blendo' synergistic strategy. I began by asking myself a series of questions prior to 3d printing *CEF P3*:

How can the background literature inform my prototyping ideation and artefact development cycle?

How can the material change through me intervening or hacking 3d printing process and facilitate new forms that are unrepeatable?

How can I use technology to drive aesthetic styles and trends in art making, including my own?

How can my 3d printing method enable and nurture free creativity and drive a more humanistic way of working with digital fabrication processes and facilitate a warm outcome?

How can this new understanding of using the 3d printer extend the technologies involved? (Candy and Edmonds 2002).

I began the prototyping project at Pier 9, Autodesk after 3d rendering a foot wedge in *fusion360* CAD (computer aided design) program in connection with CAM (computer aided manufacturing) processes, sending the STL file (3d rendered data) to the Objetconnex 500 3d printer. I cut short strips from the various mylar film colours making a simple test 3d printed disc embedding the mylar half way through the process. This was done to see that the printer wouldn't crash during the print job (due to the new layer thickness added by the mylar film, which could potentially interfere with the filament extrusion print heads, rollers and UV lamps). The initial tests were successful and I was given the go ahead by print shop lead Gabrielle Patin (though without polishing the surface, it was still unsure that this mylar embedding process would be effective at all). It is important to note the experiments conducted opening the 3d printer midway in a print job would not be permitted in the everyday contexts of Objetconnex 500 3d printers, like universities and industry. I was very lucky to be working with an expert, trusting team, who're notorious for taking risks to make new forms of art happen.

I continued my exploration by sending 3d rendered wedge STL files (right and left) to the Objetconnex 500. Firstly, the support material was laid, followed by 100 slices of PLA print filament (transparent 'digital material') at this point I paused the print job and lay down the mylar in random sizes (cut in an uneven choppy fashion). After repeating this for 1000 slices, I noticed that the sizes, configurations, surface textures and colours of the mylar I'd embedded in the filament were creating a diversity of effects; luminosity and reflectivity, and the more random layers of mylar colours and surface designs I laid down (see Fig. 2) the more illusionary and multi-dimensional the material was becoming, the colours and visual effects of the material changing, depending on the angle of viewpoint.

The process of printing the 2 foot wedges was long, normally an 8-hour task, through pausing the process to embed the mylar took 16 h. Reacting to this long repetitive process, I decided to interact with it, seeing the print bed as a stage for

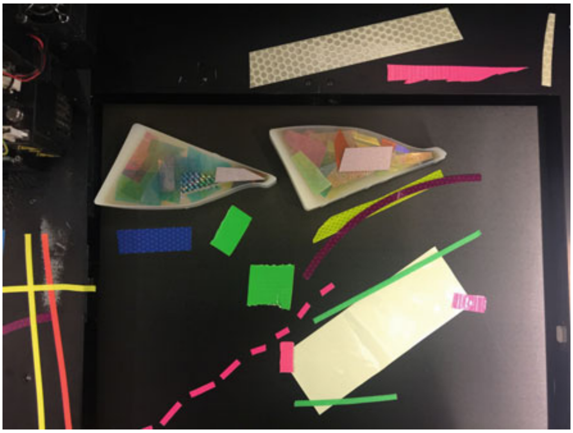

Fig. 2 Performing the Objetconnex 500; fabricating *Computer Enhanced Footwear Prototype 3*. Image depicts a lens-based representation of the performative printing process, where mylar was inserted into every 100 print filament slices and taped elements were added to the print bed 'stage'. Pier 9, Autodesk, San Francisco, 2016. Photo by Alexandra Murray-Leslie

Fig. 3 *Alexandra Murray-Leslie performing the Objetconnex 500, a cyborg craft* collaboration with Steve Mann, Pier 9, Autodesk, San Francisco 2016. *Photo* Steve Mann and Alexandra Murray-Leslie

relational performance, or comparable to Fluxus instructional performances, as the 3d printer and I were performing a set of instructions. I began by photographing and filming the printing process inside the 3d printer, followed by taping areas around the 3d prints (see Fig. 2) and performing physical choreographies intermittently when the print job was on pause, applying the tape and mylar whilst wearing a costume (see Fig. 3). Following the finished wedge prints extraction, I began the long process of sanding out surface imperfections and polishing them, guided by Noah Weinstein's (2012) instructable.[7]

Concepts Learnt:

Exploring the literature, informed my own thinking and drove new footwear designs.

Following Schön's (1983) reflection-in-action methodology furthered bizarre interactions with a 3d printer and new material outcomes.

There were unexpected 'side-effects' as a result of physically interacting with the 3d printer, including lens-based works:

- scene for a music video.[8]
- collaboration with Steve Mann (see Fig. 3) during the printing process.

By making the 3d printer strange (my art making process promoted creative thinking and a new extension of 3d printer technology.

Conclusion

The digital processes, tools and systems associated with 3d printing became part of my creative practice and affected the outputted physical design (see Fig. 4.). It was through experimenting during the 16-hour process (in a bizarre way) and reflection-in-action, that informed unexpected outcomes, unusual extensions of and alternative models for using technology. I built a new relationship between the artist and technology through an improvised performance with a 3d printer that reassessed the superiority of formalist orthodoxies embedded in 3d printing machine technology and thereby creating "experimental amateur scientific practice as an artistic practice" (Cantrell 2016). Ultimately the practice-based research described in this chapter has drawn out new forms of artistic expression.

Fig. 4 Left: *Computer Enhanced Footwear Prototype 3* worn by Dancer Elizabeth Bressler. Right: *CEF P3;* showing outcomes of embedded mylar in every 100 slices of the 3d print. Pier 9, Autodesk, San Francisco, 2016. Photos by Alexandra Murray-Leslie

End Notes

1. *The High Heeled Shoe Guitar*: https://www.youtube.com/watch?v=AJiSfdINuag.
2. *Chicks on Speed: Don't Art, Fashion, Music* exhibition and opening performance with the *E-shoe,* staged at *Dundee Contemporary Arts, Dundee,* 5th June 2010 https://vimeo.com/43260701.
3. Pollock (1996:67) introduces 'radical underfeminization'; the dilemma for women artists in the early 19th century to produce work inside the cannon of modern male artistic production and the need for an 'inscription in the feminine' in the future work made by women. I draw parallels to Pollock's statement to technology having ultimately shaped the form, function and aesthetics of footwear for better or worse, which has ultimately led to shoes shaping our feet, (Bernard Rudovsky describing modern shoes as 'foot deformers' in 1947). This practice based research attempts to metaphorically deinscribe the high heeled shoe to liberate the feet to create a new "inscription of the feminine".
4. "The purpose of art is to impart the sensation of things as they are perceived and not as they are known. The technique of art is to make objects 'unfamiliar', to make forms difficult, to increase the difficulty and length of perception because the process of perception is an aesthetic end in itself and must be prolonged. Art is a way of experiencing the artfulness of an object" (Brooker et al. 2011:841).
5. Humans have worn shoes for 40,000 years, anthropologists suggest that, initially, shoes were developed as foot coverings, for protection for the feet (Trinkaus and Shang: 2008) and later, shoes became fashionable or status symbols (McNeil and Riello: 2011).
6. *Mylar* is a brand name for polyester resin, which is a type of clear, thin plastic. The foil-covered *Mylar* used to make balloons and other shiny products is an extremely thin layer of aluminium metal (less that 1/100th of the width of a human hair in some cases).
7. http://www.instructables.com/id/How-to-Polish-Resin/.
8. *We are Data remix* music video: https://vimeo.com/207064196/04df14ac93 directed by Alexandra Murray-Leslie, music by Chicks on Speed and Cora Nova, 2017.

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Art as Digital Exploration (Vectors and Nodes)

Dave Everitt

This article builds upon the earlier account of my practice in art and technology within the COSTART artist residencies (1998–2003) and shows the new directions taken since that time. My practice involves a combination of research across disciplines, programming and (in previous work) live performance with public participation. Collaboration, on joint work and with artists on their own projects, is also a factor in spawning independent projects or smaller spin-off works. There are enduring themes but no central concept—patterns from multiple connections form an evolving creative direction. When 'vectors' of inquiry meet, conceptual and practical 'nodes' of more focused work appear. These might be a programming sketch or web-based piece, music, written reflection, a short story or spoken flash fiction, an academic paper, a proposal, or more research where an expansion in knowledge enlivens existing or dormant threads. I manage a complex, non-linear process where research is almost continuous, and collaboration, meetings (planned/unplanned), invitations or events can initiate work. Some of the main projects and collaborations are covered here.

Among other long-term work outside this field I co-develop software for energy-saving initiatives in student residencies; significantly, my partner in this project, Graeme Stuart, has also been a co-collaborator for another artist's public work, and produces his own creative pieces. A network of contacts/friends/practitioners is probably the most essential factor feeding into my own practice.

In 1998 as a visiting artist within the framework of a research project investigating computer support for creativity at Loughborough University (COSTART), the process of expanding my fledgling digital practice into exhibitable interactive art-technology works began in two distinct directions; 'The Emergency Artlab' in 1999 (Everitt and Quantrill 1999) creating participatory public work derived from research with Mike Quantrill (plus other collaborators), and the heartbeat-driven work 'cubeLife', work on which began in 1998 with (then) Masters and later Ph.D. student Greg Turner (Edmonds et al. 2004). The early stages of my approach as a 'digital explorer' were covered in the previous edition of 'Explorations' (Candy and Edmonds 2002). The research—which vastly underpins visible outputs—is a

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_17

continuum from before that time to the present. To give a complete picture, one ongoing work, early public projects, and more recent collaborations are covered.

CubeLife

Number patterns are a perennial interest of mine. Certain integer patterns can be made to display rich arrays of interwoven permutations, fluid to classification while hinting at underlying structure. These suggestions of order within disorder, symmetry within asymmetry, hint at the complexity of both the natural world and human experience. The meaning we construct around pattern is one of my major research topics. For example, magic squares and cubes (integer grids where rows, columns and diagonals sum identically) with their complex combinations have a symbol-laden cultural history, from origins in China and the Vedic mathematics of India, through Dürer's famous engraving, to musical composition (Davies 1975) and process-driven work by other artists (e.g. Paul Heimbach).

Before my residency at COSTART I had coded an application to draw and catalogue the 'magic lines' formed by tracing the integers of magic squares in sequence, using Bill Atkinson's prescient tool HyperCard and the programming language HyperTalk (Everitt 1999). My research had expanded far beyond the popularly-known examples originally associated with the seven planets by humanist theologian Agrippa (1531–1533). There emerged two threads:

- *Mathematical and philosophical enquiries* concerning the nature of symmetry and permutation/combination,
- the *cultural history and use* of magic squares and their association with human meaning.

This drove the artwork towards visualizing their 3-dimensional counterparts: magic cubes. An initial sketch in Java by friend and programmer Ben Daglish (Everitt 1998a) initiated a process that continues under the broader 'cubeLife' theme, in which the periodically-exhibited artwork became an ongoing enquiry into these and other areas.

In 1998 my coding skills were not sufficient for realizing the vision of connecting mathematical objects and behaviours with the human heartbeat, so I supplied Greg Turner with enough pseudocode (Everitt 1998b) to begin producing 'proof-of-concept' sketches in Java. The first version of the heartbeat-driven screen/audio work cubeLife was exhibited in 1999 with two other artists under the thematic group title: 'bioMatrix'. Further development with Greg's Ph.D., and a later period funded by an Arts Council England grant, added the significant element of flocking-based behaviours, plus an online component and the ability to create high-resolution images (for screen shots see Everitt 2011a). The updated version was exhibited in 2011 and also used in an audio-visual performance where participants 'donated' heartbeats to build a multi-layered sound and display.

When the original input device (an infra-red pulse detector clip) failed, I updated cubeLife to use hand-held heartbeat grips. Greg's robust original code meant only a few days' work, and at the last exhibition (Everitt 2011b), cubeLife ran continuously for two weeks.

Exhibited, cubeLife only exists when people add heartbeat data, each initiating a magic cube and associated sound sample, in virtual space on a screen that remains blank until the first heartbeat. Each cube leaves traces of movement while the audio plays (treated audio from a water-filled clay bowl recorded by collaborating musician Kate Rounding). The initiated objects and sounds interact and finally decay, each session producing a unique combination of forms, sound and colour. Non-repeating cycles capture attention in a way similar to natural forms; the comfortable environment invites people to linger and share something created by their collective heartbeats.

The Emergency Artlab

The Emergency Artlab (e-artlab 1999) was an outlet for experimental work with Mike Quantrill under COSTART. Our first collaboration—an infra-red sensor grid that visualized human movement over time—provided the cover image for the previous edition of 'Explorations' (Candy and Edmonds 2002). The e-artlab involved other artists and collaborators as opportunities arose. The idea was to take collaborative practice-based research in art and computing into the public arena with minimal lead time and direct public participation. This approach meant that—apart from an initial guiding theme—the outcome could not be determined in advance; it developed with the public event, was tested in that environment, and transformed by public involvement with the emerging work. We wanted to explore the process of integrating human and computing activity in such a way that the underlying processes of both were free from invasive pre-set goals, enabling the public situation to influence right up to the last few hours of preparation.

Live participative digital performance was an ideal medium for serious, yet playful, comments on the electronic gathering of data in society, and two public works emerged from research with Mike: '64 Samples' (Everitt et al. 2000) and 'Club Confessional' (Everitt and Quantrill 2001). Both exposed 'process' and public participation as integral to the eventual form of the works.

'64 samples' used participants' portrait images and disguised audio of their personal data to shape the final 'performed' work: a virtual 'cube of flesh' concealing 64 smaller cubes with facets showing barcodes, flesh scans and portrait images gradually protruding from their container, controlled by live code. Pip Greasley's score, created from the vocal information offered by each participant, accompanied the performance. Matt Rogalsky clipped the audio into minute snippets to accompany a further web-based work of rapidly-shifting portraits covering all 64 participants.

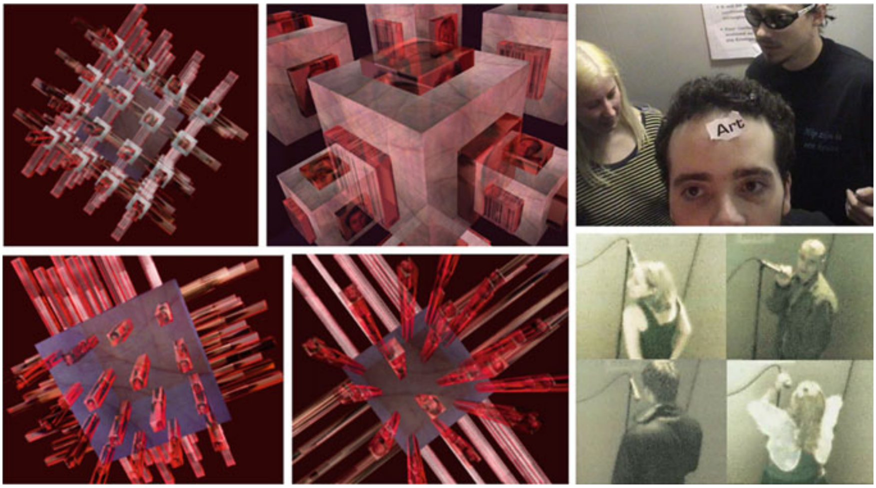

Fig. 1 Left: '64 Samples' still shots, performed at the 'Wired and Dangerous' conference, Leicester, UK, 2000. Right: 'Club Confessional' participants; top: Pop centrum 013, Tilburg, Holland, 2001; bottom: 'The Junction', Cambridge. Images: Dave Everitt and Mike Quantrill

'Club Confessional' was performed in Cambridge and Holland during 2001. A soundproof white cube on the dance floor invited audio 'confessions' from participants (some quite real), piped anonymously into discrete locations around the club, while their soundless video played over the dancers (Fig. 1).

Collaboration

The unexpected and unpredictable outcomes of collaboration galvanise my own creativity. The division between solo and collaborative work is vast: the former makes recognition and public exposure more accessible; the latter is a private and often hidden process, continuing without pause behind the scenes.

Unpublished personal reflections about a COSTART report describe the collaborative process well; this covers work with Mike Quantrill, but every collaboration has unique qualities:

> Reflecting this complexity within a single work involves juggling with the interaction of many variables, without losing sight of the whole. A procedure based approach (we do this, then we do that, therefore this occurs…) proves completely inadequate in this case, and the evolution of discrete modules of procedure that, while remaining distinct from each other, are also interdependent, is an issue that MQ and DE have recognised from the start […] It is crucial to the development of the work that the mapping [is] in a constant state of evolution and change. The artists are unwilling to 'pin down' what they 'want to do', but they periodically map out key features in the landscape that may - or may not - provide reference

> points along the way. However, there is always the possibility as the work progresses that what emerges will eclipse these original references, or modify them.

Revisiting this text revealed how I have gradually internalised this collaboratively-learnt facility as an individual: enabling emergent properties to determine direction, recognising when more focus is required.

Collaboration with those more productive or located in their own field of practice means managing the 'benign imposter syndrome' of my own generalist qualities. Although I may not follow specific disciplines or always be as productive, I understand the artist's world as well as the field of computing, mediating between them with ease both in my own practice and while working with others. Truly co-creative collaborations as a 'translator' between art and code offer a peculiarly semi-vicarious yet real sense of achievement. This quotation about collaboration with Esther (in Candy et al. 2015) offers a succinct description:

> Working with someone who has a knowledge of the process of making an art work and programming seemed to allow many different ideas to emerge when at times the direction or desired outcome was not clear.

As well as opportunities to build networks and relationships for producing larger works, collaboration with ideas also produces incidental yet almost exhibition-ready small works; more well-formed than sketches and still worthy of attention, but perhaps not self-contained 'pieces'. These can also spring from an approach that frames 'research as a primary process' (Everitt 2013), either as an independent practitioner or in collaboration, as mentioned below.

Collaborating Towards the Codeable, Plus Spin-off Sketches

In late 2013 I was re-introduced to Esther Rolinson (a fellow artist from COSTART around 2001) to help formulate ideas for her forthcoming light sculptures 'Splinter' and 'Thread'. I used Processing sketches to realise 'light behaviours' that animated her drawings or became starting-points for the finished works.

Phone and email conversations helped to formalise her descriptive concepts:

> …the work you have shown me [is] thought provoking and I'm considering the relationship/difference between setting parameters to evolve a structure and a virtual drawing-based practice …the processing files… have set me off on a train of thought [later:] It would be good if you can give me guidance on […] how I can best describe the lighting activity in a way that can be translated into programming. (Esther, in Everitt and Rolinson 2013)

This led to a key document outlining programmable requirements—the entire process is covered in Candy et al. (2015). After this initial phase, Graeme Stuart (my co-developer on other projects) continued the work with Esther and Sean Clark (hardware development) to realise the finished piece. During development, initial sketches were discussed and adjusted during focussed sessions, then put aside. However, I then encountered a familiar pattern that often occurs during collaboration. Some of the digital sketches, specifically accidental results or even (from Esther's viewpoint) rejects, suggested alternative potential:

> Pictures 13 - 15 look more like they are drawing the pathway of the rotating triangle… so not a sense that they could exist in a real space (not that this is bad!) (op. cit.)

I then followed my own minor trajectories independent from the original purpose. Adjusting the parameters of one animation (representing 'dust in sunlight') echoed, in a less structured but controllable manner, the patterns created by the magic cube structures from 'cubeLife'. I re-coded variations on another sketch to produce dynamic and rapidly-layered coloured textures; quite removed from the original visualisation of slowly-moving translucent triangular forms. Just as in real life, small changes produce radically differing outcomes. Once there is a stable core, hours pouring over and balancing parameters for the desired result can follow.

Other Collaborations, Past and Present

I maintain multiple collaborative partnerships. Around 2010 I worked with Gareth Howell at the Institute of Creative Technologies (IoCT), visualising GPS data as part of a larger project (an ESRC application where the original collaborator become too busy—a hazard of institutional work). The initial data from walks through a city showed nothing more interesting than the route, but while learning about vectors, a coding diversion—not an error as it was valid code—produced parameters yielding entirely unexpected results (Everitt 2013). I also experimented with low-power lasers and mirrors with artist and friend Aidan Shingler and, in 2010, created the stone-cut astronomical graphics for his 'Star Disc' astronomical sculpture/venue (Shingler 2011).

In 2017, I completed an electro-acoustic ambient album with musicians Jim Tetlow and Chris Conway as 'Memory Wire' (Conway 2017) with elements and one specific track using digital granular sampling of my acoustic guitar (unrecognizable as guitar, which is the aim). For live performance videos of work with Memory Wire see Tetlow (2013); the collaborative musical context is explained in a video of related monthly event 'Quadelectronic' (2014):

> It's about improvising, being in the moment, listening to the other musicians… and responding with them instantly, so you have to be really… mindful of your fellow musicians

Currently, I am contributing a piece to a future work by artist Alice Tuppen-Corps, which is already suggesting as-yet indeterminate spin-off works, connecting personal accounts with astronomical data.

Reflection

> 'art is what we do when we expend great time, care, and patience on an activity without knowing why' —Jack Burnham, Beyond Modern Sculpture (1968)

Research into computing and creativity itself was explored with Fania Raczinski (Raczinski and Everitt 2016) in a collaborative presentation and paper at the IEEE conference on Computing and Creativity. This surveyed and critiqued (with her research) the notion of machine consciousness; quoting the late Harold Cohen's (1999) well-informed dislike of the word 'creativity', and exploring the concept that, paraphrasing Barthes (1967), 'the birth of the truly creative computer must be ransomed by the death of the programmer' because,

> a truly creative computer must be able to act without human input, yet any computer process presumes a significant amount of human input in order to produce such so-called autonomous behaviour, so the question is whether that behaviour can ever be regarded as truly autonomous—no matter how independent it appears to be. (Raczinski and Everitt 2016)

Although I never expect anything from computers other than to follow my instructions, the challenge is to hone those instructions while refining the ideas behind them. It's relatively easy to produce pleasing visual results, but communicating a concept or a feeling effectively is the real substance.

The emergent participatory excitement of the e-artlab work presents an archival challenge; the anticipation as ideas formed and participants engaged in unpredictable ways can only be described in retrospect. Although 'Club Confessional' was repeated three times at two locations, within a clearly-defined conceptual framework, the specifics of each event were unpredictably unique.

The lines of my own inquiry determine direction. The vectors are prolific with smaller works and sketches; the rarer nodes almost invariably spring from collaborations. Making stable and empathic working relationships is as conscious a pursuit as the creative process itself, whether intellectual, practical or both.

Conclusion

The landscape for art-technology practice has changed since the first publication of 'Explorations'. Then, in conversation with an Arts Council England staff member, I was informed that 'digital art' follows 'a separate aesthetic'; a statement confirming our role outside the boundaries of accepted art practice. Since that time—possibly beginning around 2000 with the Arts Council England 'Wired and Dangerous' Digital Arts Conference, in Leicester, UK (with'64 Samples as the commissioned work)—the landscape has become populated with a fresh influx of practitioners. With all massive popular shifts there is caution, partly because trends can lack self-reflection and ignore historic context; the phrase 'sticking an Arduino on it' was voiced by another commentator. The boundary between ‘wow’ and thoughtful creative content can become blurred.

I am old enough not to mind—in a positive sense—what else is going on. I only need space to practice, with enough collaboration and peer contact to help keep the vectors of that practice defined well enough to converge into the rarer phenomena that manifest as nodes, as outputs.

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Part III
Research

There is a need to establish empathy with the individual being observed so that they become comfortable with the observer's presence. Tom Hewett

Research

The legacy of the recent past is that artists are individuals who work exclusively on their own. While this has probably never been true, the art world remains fixated on the individual. Compare this to scientific research where claims for individual ownership are less valid and there is acknowledgement of group effort. Ray Ward

Well you understand what I am doing, where should I be starting from? Michael Quantrill

The characteristics of any resources, materials, tools or techniques that form a part of the creative work are in themselves critical factors that influence the process. Linda Candy

Theme: Research

Linda Candy, Ernest Edmonds and Fabrizio Poltronieri

This chapter discusses a practice based action research approach to the study of art and technology. Such research seeks to find an understanding of the creative process drawing on knowledge from other fields. We consider ways in which creative practice can be studied based upon methodologies from the social sciences and the Human Computer Interaction. Included is an account of how this was achieved in the COSTART (COmputer SupporT for ARTists) project, which was concerned with the nature of creative collaboration in digital art practice. The chapter describes the research approach, one that enabled the artists involved to take a significant role in the research rather than have them confined to being purely subjects of study. The core chapter is followed by nine contributions on the subject from artists and researchers.

Introduction

The reflections by practitioners throughout this book raise issues about the role of digital technology in relation to creative practice as it is seen today. A number of artists have noted how involvement with computers has stimulated them to move forward in their conceptual thinking. They have been encouraged to break with previously established conventions and explore new methods. One artist discusses the importance that digital technology has had in encouraging him to shift the very idea of what he considered to be 'art'. Another found that using Virtual Reality was the trigger that caused him to re-think the nature of his paintings. Others have found that involvement with the technology caused them to re-formulate the boundaries of their artistic scope, for example, by adding time as a dimension of the work. In general, the challenges inherent in working with digital technology can have a positive influence in encouraging artists to break with their existing conventions, a development that is a core element of truly innovative practice.

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_18

In this chapter, we consider the ways in which creative practice can be studied based upon methodologies that have been developed within the social sciences and the field of Human Computer Interaction (HCI). A practice-based action research approach combined with case studies of artist residencies enabled the practitioners to take a significant role in the research rather than be confined to being purely subjects of study.

Practice-Based Research and Human-Computer Interaction

Artists and technologists are exploring virtual and physical interactivity by pushing technology and art forward on several fronts, from programming tools to interactive installations combining sound, position and image. By putting such initiatives in place and, at the same time, providing a means of informing our general understanding, it is possible to learn from the experiences and apply the lessons immediately. In order to make that effective, it is necessary to bring to bear systematic approaches to acquiring knowledge using sensitive methods for gathering and analysing necessary data. Additionally, if the knowledge acquired is to be immediately useful, it must be deeply rooted in the actual context and experiences of the participants.

Action research is a case study method that aims to identify existing assumptions in practice and then develop new strategies for change in the light of that knowledge (Lewin 1951). This process includes participant self-evaluation but does not rely on it alone. The practice-based action research approach that we have applied to the study of digital art and technology, embodies the integration of practice and research. Practitioner accounts of creative practice are combined with the observations of external researchers in order to arrive at a multi-view perspective on situated studies.

The research analysis draws upon two main sources of information: the collaborating parties' records of ongoing events and the records of non-participants, the observers. It is the task of the research to collate and analyse these multiple views and then to stand back from the events and try to evaluate them in ways that might be interesting to different audiences. Those audiences might be organizers of arts and media centres, research and development companies looking for improvements to the technology or, indeed, other artists and technologists wishing to learn from the experience of others. From an analysis of this rich set of information, answers can be proposed to research questions such as:

- What are the requirements for art-technology environments?
- What are the opportunities for technological innovations?
- What are the implications for creative practice?

Practice-based action research draws on the field of Human Computer Interaction (HCI) from which a strong focus on *interaction* between people and technology comes. Because interaction between individuals, groups and many forms of digital technology is so important in digital art, there is much to draw upon from HCI. Moreover, HCI can gain from the creativity and innovation that drives the intersection between art and technology. Human Computer Interaction (HCI) provided the basis for the Practice-based Action Research approach to art studies referred to here. It is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and the study of their use in practice. It is an interdisciplinary subject which exists within several mainstream disciplines: computer science, psychology, sociology and anthropology and industrial design. From a computer science perspective, the focus is on *interaction* and specifically interaction between one or more humans and one or more computer systems. A range of interpretations of what is meant by interaction leads to a rich space of possible topics.

The HCI research agenda has been influenced by the drive to meet the needs of a changing population of users, and also by the very character of the disciplines that have come together in this field. HCI is multi-disciplinary and eclectic in its concerns and, for that reason, contending forces jostle for the central agenda. The philosophical and subject disciplines are diverse. For example, Lucy Suchman (Suchman 1987) and Terry Winograd (Winograd and Flores 1986) whose work has extended the range of HCI approaches, draw upon ethnography and conversation analysis for their theoretical frameworks.

HCI research methods are drawn from significantly different scientific principles: from predictive modelling to prescriptive guidelines, tools and methods and the notion that 'theories' are embedded in the products or artefacts themselves (Carroll et al. 1991). These approaches can be viewed as supporting both practice in design and engineering and the theoretical foundation vital to a strong scientific discipline (Marchionini and Sibert 1991).

A distinguishing feature of HCI research is the stress upon immediacy of results. The demand for new products and effective design principles places an intense pressure upon researchers to deliver immediately applicable knowledge that can be applied using the existing technology. As a result, the need for well-designed and engineered products often takes precedence over the quest for long term scientific knowledge. The drive to improve computer systems design by rapidly turning research results into products or artefacts has influenced the traditionalist approaches. This is exemplified by the work of Card, Moran and Newell and Norman where the methods are valued for their practical application (Card et al. 1983; Norman 1988).

There is an impetus in HCI to transfer research results quickly into sound applied principles which may be in conflict with developing longer scientific knowledge. There is a tension between achieving generalized principles and the context dependency of applied knowledge. Some have argued that a participatory action research approach is the best way to acquire knowledge that can be applied in context (Warmington 1980). A 'reflexive' approach, that is, one that recognizes a number of co-existing facets of scientific concern, can offer a positive way forward (Avison and Wood-Harper 1991). The need for making the stakeholders' viewpoints an integral part of the research activities is a key issue that has led to the notion of participatory research.

Participatory research has a long tradition and has gained a firm foundation in HCI. The term 'participatory' refers to the involvement of users in the design process and usually in the early stages when the initial requirements are defined (Candy 1995). There are well recognized problems arising from the fact that user views are not always articulated in a way that can be readily translated into system design characteristics. In addition, the initial requirements are unlikely to remain static. In participatory research, there is explicit recognition of the inter-related roles of the personnel involved. The matter of participation extends to system designers, prospective users, research investigators and any other person active in the project. All interested parties have participatory roles to play alongside the user. The research and design activities operate as an iterative cycle of investigation, analysis and feedback into design and development.

To improve the process of innovation, the methods include constant monitoring by participants on the basis of which modifications and adjustments are made. This involves the use of a number of data collection mechanisms: field diary notes, questionnaires, interviews, case studies. These provide multiple perspectives and feedback can be translated into modifications and directional changes. It enables improvements to be made in the current context rather than at a later time (Mumford 1981). In this respect, it differs from traditional experimental research which seeks results that are relevant to the general case.

Studies of Creative Practice

Understanding the ways in which creative process has been influenced by the growth of computer use is a key concern of this book. Research studies of the creative process, as distinct from studies of the outcomes or artefacts of this process, have been much more extensive in the field of design than in art. Although there are many differences between the fields of design and art, they have similar characteristics in terms of the creative process itself. It is, therefore, useful to broaden the discussion to examine the issues surrounding creativity in general and design in particular.

There has been considerable research into how designer's carry out design activities. In both product design and software design, common characteristics have been identified. The view of design as an hierarchically organized planned activity as opposed to design as an opportunistically driven mix of top–down and bottom up strategies has been explored in a number of empirical studies, e.g. Guindon et al. (1987) and Ullman et al. (1988). Maccoby studied prominent designers and engineers whose contribution to their fields was unquestioned by their peers and the world at large (Maccoby 1991). Although they represent a spectrum of different fields and cultures, they exhibit similar ways of thinking and working. Most are "systems thinkers", in the sense that they look for an overall broad scope before moving into specific detail. Other studies indicate that design is often solution-led, in that the designer proposes candidate solutions early on in order to scope the problem better. Designers impose constraints that narrow down the number of solutions and help generate new concepts. Designers also change their goals and add constraints during the design process. Boden suggests that changing a constraint might be at the core of creative thinking (Boden 1990).

Taking account of these studies and our own investigations into innovative designers, various characteristics of the creative process have been identified with a view to identifying the kind of computer system that could be supportive to the designers' creative practice (Candy and Edmonds 1994, 1996). These studies in creative process have provided the foundations for the research methods we applied to art and technology practice.

New ideas do not just come out of thin air. The conditions for creativity are very important and outstandingly creative people seem to be able to arrange for the right conditions to be available. The use of complex tools, such as computers, forms a significant part of the context in which these conditions for creativity exist. Our studies identified aspects of the creative process that are relevant to art and technology practice. Examples of the aspects identified are:

- Breaking with convention

Breaking away from conventional expectations, whether visual, structural or conceptual, is a key characteristic of creative thought. Events that hinder such breaking with convention are avoided, whereas positive influences are embraced.

- Immersion

The complexity of the creative process is served well by total immersion in the activity. Distractions from this immersion are to be avoided.

- Holistic view

The full scope of a design problem is only fully embraced by taking an holistic, or systems, view. The designer needs to always be able to take an overview position and, in particular, finds multiple viewpoints of the data or emerging design important.

- Parallel channels

Keeping a number of different approaches, as well as viewpoints, active at the same time is a necessary part of generating new ideas. The creative person needs to work in *parallel channels*.

The creative process includes the following activities, each of which has its own characteristics.

- Ideas generation
- Problem finding and formulation

- Applying strategies for innovation
- Acquiring new methods or skills
- Using expert knowledge

Digital artists are very involved in finding support for the last two of these. Much of the collaboration that we observe in the artist's discussions and from the studies of their residencies is addressing these activities. Digital artists are concerned with finding and creating the environments in which they can work productively. The early digital artists had little choice but to acquire the necessary computer expertise themselves if they were to be able to achieve anything at all. Their experiences were rarely collaborative in the sense we mean today where people of different skills and backgrounds combine their efforts to make the technology accessible for art practice.

As an example of the role of digital technology in the development of an artist's expert knowledge, it is interesting to consider two artists whose contribution to computers in art has been very significant over many years.

Harold Cohen's computer system, AARON, is the best known and most successful example of a computer program that creates drawings and paintings autonomously (Cohen 1995). Cohen's artistic knowledge about creating drawings and painting was captured in the form of a computer program which could then create new works itself. In the process of developing the program, the artist's process involved evaluating AARON's drawings and re-examining the knowledge in the programs in the light of his judgement. He then modified the program many times to include the new insights in the program. The creative process was one of externalizing his existing drawing and painting knowledge and then, once it was 'made visible' by the computer, acquiring 'new' knowledge. When he began this work, the drawings were concerned with strictly organizational issues in the sense that they were basically abstract. Cohen has since moved into expressing knowledge about colour in the computer program which, for some time has been generating figurative art works. The figurative knowledge in the computer system required more knowledge about the world, e.g. plant pot relationships to the ground area and the physical composition of human faces, as distinct from the earlier drawing object relationships e.g. perceptual groupings.

For Cohen, creativity is something that is a process of continuous change, as distinct from single events. That change, as his work exemplifies, is in the mind and actions of the human and the process is essentially a directed one. There have been many cycles of his exploratory, pioneering work but during all that time, his goals have been consistent. His work is unique and the basic concept of developing an autonomous creative computer has rarely been taken as far as this. Cohen explores the implications of his work for art practice and the changes that it has brought about in concepts of art and ownership in his contribution to this book.

Another artist who has made pioneering contributions to art and technology in quite different ways is Manfred Mohr, whose work has been transformed by the visualization possibilities of technology. Mohr's work involves the construction of two-dimensional views of six-dimensional cubes (hyper-cubes). His goal is to express geometric knowledge about the cube which is encoded in the computer system using a programming language. The computer program then generates graphical entities from which he makes artworks using conventional media such as canvas and laser cutting and often special computer output devices to implement his intentions. The goals of two parties to the process, i.e. the artist and the computer, are clearly differentiated: the computer program generates purely geometric objects whilst the artist makes aesthetic choices on the basis of which he goes on to make artworks. The artist cannot do the bi-dimensional geometry in his head and the computer requires the artist to specify the geometric knowledge in a computationally tractable form. For Mohr, the interactive process with the computer is one with which he extends his capability as an artist:

> what fascinates me about a machine is the experience of a physical and intellectual extension of myself.

A productive relationship with the computer is dependent upon both the power of the programming language used by the artist and his own ability to develop its capability to achieve his goals. Mohr's approach is to retain ultimate aesthetic control over the final outcomes rather than leaving the final choice to the computer (Gomringer 1998).

This symbiotic interaction differs from that of Harold Cohen's. The role he chooses for himself is to specify to the computer the critical underpinning knowledge about art from which the computer generates the drawings and paintings. In using a computer language to make a computer create works, rather than a software application to create the drawings and paintings himself, he is expressing a fundamental premise on which his whole approach is based, exemplified in the statement:

> I inevitably get nervous about the notion that somebody could make art without a profound grasp of the underlying disciplines involved. (Gomringer:14)

Cohen's artistic vision places high value on expert knowledge about art and its role in computer-generated art. Mohr's vision involves exploring generative processes that are not accessible to human perception but are, nevertheless, able to be specified using the method he has chosen. The final artworks remain the province of his artistic decisions. For each artist, the particular points in the creative process when he chooses to interact with the computer language and the outcomes it generates, are different.

Research on Art and Technology Practice

We know that digital technology today is far from simple and its use in art even less so. It is also clear that much of the work being undertaken today involves collaboration and this in itself an interesting issue to investigate. But, how can we study art and technology collaboration? How can we learn what is appropriate in terms of the environment of expertise and technology? How can we identify the requirements for new computer systems or environments? These questions require a research process that can address the complexities of an actual creative practitioner situation. A theoretical framework provides a route map for directing the overall aims and objectives of any research activity. However, it is equally important to determine how to acquire empirical data that can give rise to “evidence-based” action. For gathering information about events and experiences of real practice, appropriate methods are needed.

The question that follows from this is what are the most effective methods for studying artists working with technologists in digital art? Artists are highly individual and are also inclined to be very strong-willed in the pursuit of their art. Therefore, they are unlikely to welcome being treated as subjects in standard laboratory experimental situations. In truth, scientists and technologists are no different from artists: it is just that they are more often involved on the other side of the fence as the investigators. The methods to be used need to take account of the particular circumstances of the people involved. In research into human activities, controlled laboratory conditions are not achievable without sacrificing the context that gives them meaning. There are rich layers of meaning that are relevant to the description and interpretation of what is happening. When studies of creativity are carried out, the ‘real-world’ context is an important consideration.

The starting point is to ascertain the artists’ needs and expectations, not only in terms of technology required, but also access to the skills and knowledge of other experts. The requirements gathering exercise is an on-going process that informs the acquisition of new technology and access to the technical expertise. The scientific paradigm, based upon the rationalist tradition, has dominated computer system research and development, resulting in a preoccupation with the technology itself, its performance and formal characteristics. When the human user of the system is introduced, the tendency has been to use the same approach and contrive situations where the user and system can be observed and a limited set of variables manipulated. Unfortunately, human behaviour, especially creative behaviour, is too complex to be understood in much detail with this approach. One way forward is to conduct case studies of creative projects in actual development situations.

A case study is an investigation of a specific set of events within a real-life context in which a number of factors are considered as evidence (Bruce 1993). The units that are studied and analysed may range from individual studies of outstanding people to histories of innovative corporate culture. The method is most applicable when events are not amenable to control by the investigator and when the questions posed are open-ended and multi-factored. Questions are asked about why and how something took place in order to understand the meaning of specific instances. Explanations are based upon observations of existing events or recoveries of past events. The findings from such studies do not necessarily apply generally although it is common to compare results with other similar ones. A common use of the case study is to generate hypotheses about a wide range of events which may then be studied in single variable controlled conditions using traditional experimental methods. It is used widely in many research areas from medicine and public health to social science.

The practice-based case study method can be used to study exploratory projects developing new art forms in a collaborative environment where artists and scientists can work together as equal partners in the exploration of the use of digital technology in art practice. The following sections give an account of how this was achieved at C&CRS via the COSTART (**CO**mputer **S**uppor**T** for **ART**ists) project (COSTART).

The COSTART project was concerned with the nature of creative collaboration in digital art practice. Candidates for the residencies were identified using the criteria as follows:

- Evidence of the artist's involvement in collaborative work
- Evidence of prior public exhibition of work
- Close match between needs and resources
- Ability and willingness of the artist to discuss their work

The selected candidates were invited to a workshop when the opportunities and requirements were discussed with prospective technology support staff and researchers. It was particularly important that artists were prepared to participate actively in the research as it involved recording events as they happened and being willing to discuss openly their emerging ideas and problems encountered throughout the time in residence. The resources available to the artists were to consist of more than a physical environment in which to work. They included daily support coordinated by a designated contact person and specialist consultations with technical experts throughout the residency period of five days and for follow up work after that time for one year. The technical environment provided facilities for all residency projects, and a range of software and hardware in use or of value to many digital artists. The initial technical requirements had been identified from the earlier residencies and from our prior knowledge of the digital art world and digital technology.

Case Studies of Artist-in-Residencies

Artist-in-residencies are commonly opportunities for developing new approaches and works within specific art projects that are defined to meet the specification of the commissioning body. Normally, the 'research' is carried out by the artist to progress the work rather than for the benefit of general knowledge and a wider audience. Nevertheless, keeping a record of ideas and actions that documents the personal creative process is common practice amongst many artists. An extension of this practice is where the artist accumulates material towards an academic qualification. This kind of primary information is one view of events that practice-based action research uses.

The research process begins with the collection of many types of information about the activities, exchanges and outcomes of the art-technology residency projects. This is recorded, compiled and structured in transcription records and case study reports. This provides primary evidence for the extraction of features and the allocation of feature values. The results of this exercise may be applied to individual case studies which are then compared. An example of how this was done in relation to evidence about the nature of collaboration can be found in Chap. 4 to follow.

In 1996, a series of case studies of artist-in-residencies took place at Loughborough University in the East Midlands of England. The events were monitored overall and before and after interviews conducted with the artist participants. In one case, the artist did not wish to use a Virtual Reality system to simulate what he called "real" reality (Edmonds and Candy 1999). He wanted a black space without the constraints of gravity in which to create sculptural objects, move them about in relation to one another and determine combinations of outcomes. To help him achieve this, a personal tool kit for creating virtual sculptural environments was created.

> In my work I have to emulate the struggle with gravity […] I never will be able to create real motion which I simulate in my normal art work which I can create and explore in VR […] 'By hand' I defined a relative complex rotation-movement of every shape around the sphere[…] The movement of these few forms make an extremely strong impression of depth and enough sense of orientation. The result was intoxicating. I finally could see the movement I imagined for years!
>
> Ilgen On the Use of Virtual Reality

The experience of using this digital medium had a significant effect on the artist leading to a change in his experience of creating art forms. The experience with VR inspired him to develop a kind of painting that visualizes the simulation of the colour space: *Virtual* Painting*s* as he called them.

That experience, and those of other artists, demonstrated that more understanding of artistic practice and the role of technology in the creative process was needed. So, whilst the outcomes of the first residencies were interesting, it was apparent that there was a need to carry out more extensive studies. We also became more aware of the importance of collaboration in art and technology and therefore, the role of technologists themselves figured more highly in the planning for the studies.

Of the twenty artists who attended the orientation workshop, seven projects were found to be viable and the project planning began in earnest. Timing was a crucial factor. Each artist was allocated five days of full time access and support during which time, a technologist and an observer had to be available. As it turned out, the residencies were able to be scheduled on site for three weeks overall making a maximum of three artists working in any given week. This was fortunate as the load on facilities and, more important, people, proved to be a critical issue. Whilst the artists changed by week, the technologists and observers did not, making it essential that the degree of commitment and effort was high.

The response by everyone to the demands of the situation was extremely positive and the level of commitment was demonstrated by the universal demand for twenty-four hour access to the buildings. Living on site was an opportunity for the artists to give full concentration and effort to the work and to take advantage of the separation from the demands of normal life. For most of the technologists, life outside the project carried on as usual which meant they were rarely free to give the totality of their time to the residency. However, in one case at least, it was not unknown for overnight stays to take place, often matching the artist's long hours. This is not to say that time resource had not been allocated for the technologists to support the work, but that the time available was not enough. The idea that for some, a part-time involvement, whilst continuing to do normal duties, would be possible within normal hours was a fond hope. But in truth, few of the people involved worked conventional office hours.

As for the observers, because their role was to observe, interview and discuss with the collaborating parties by arrangement, there was more control over the time commitment. Nevertheless, it was a full-time activity and the follow-up work compiling the information that had been collected when everyone else had gone home, was considerable (See Hewett in this volume).

Information Gathering

Each residency began with an initial planning meeting between artist, technologist and observer. The discussions were recorded on audio-cassette and field diary notes were kept by all. In addition, video snapshots of activities were taken by the observers. Problems arose with sound quality in the recorded conversations due to some noisy equipment in the main studio. Also, for the video recording of the interactive sensor system, which required large projected images, the lowered light reduced the visual quality of the recordings. Where there were gaps in the chronology of events, we relied on the diaries to piece events together.

For each residency, in addition to the individual diaries kept by artists, technologists and observers, other records of events consisted of photographs and archives of work in progress, much of it in digital form. These data were documented as daily summaries and highlighted events into which transcription of discussions were inserted. The outcomes of the data collection were, for each residency, a set of transcription records and a case report based upon the transcription and the interview data. The transcription records form the basis of an ongoing record of artists' activities after the residencies and can be updated as new information is received.

Case reports on each residency project drew on the primary source data, i.e. the complete transcription records of the residency as well as follow up interviews and email communications about ongoing work. Artists provided feedback on the accuracy of their own case reports to complete the record. The case reports were then compiled according to the principal research topics. The information consists of primary sources from the first-hand records of the participants in the studies including artists, technologists and observers. In addition, a secondary level is included which consists of comments by researchers on the chronological records structured according to a set of pre-defined research topics.

Case Study Records

To give a closer sense of the kind of records that were accumulated, extracts from one of the case studies now follow. Of course, to really gain a full sense of the history, the reader would need access to the whole narrative and all the associated images, videos and sound and, indeed, the opportunity to partake in the interactive experiences too. For such primary evidence to make sense, it also helps to have the motivation and fortitude of the historian, who might be happy to bury deep within the material of the past or, indeed, the recent present. Assuming the reader would prefer a snapshot instead, we begin with examples of the two main types of record, i.e. transcription and case study report, followed by an extract from each. They all refer to the same artist residency project.

1. *Transcription Record*

The *Transcription* is a set of chronological records of the artist-in-residency for each project comprising all participants' field diary notes. Three distinct viewpoints on the events were compiled as a transcription by a researcher. This acts as a guide to the residency events as well as any associated material such as computer files, images, drawings, audio-video tape recordings which provide additional views of the events that a text record cannot supply.

In the first extract below, the initial planning meeting is recorded in terms of items such as the outdoor location, the subject of discussion, the terminology used, the drawing actions and the main topic: how the technologist is working to elicit constraints from the artist in order that the programming can begin. A verbatim extract from the observer's diary is also included. We know they went to Herbies (a university eating house) for the meeting, the start and end time of the session, whether diaries were used, and the fact that audio tape recording number one was taken but that no video recording was captured on this occasion.

Extract

A: Artist	**T: Technologist**	**O: Observer**

Date July 26TH Location - 1 park table outside Herbies; 2 in C's Office; 4 in Studio

Session	Start	Finish	Activities	Diary	Video	Audio
1.	14.33	15.35	Initial planning	Yes	No	Yes, Tape1

First meeting takes place outdoors on picnic bench. T & A begin discussion of what A wants to accomplish during the residency time. A describes building an environment using ephemeral animation, with things growing inside forms… (Picture in A Notebook drawn to illustrate for T.) T begins to explore the constraints which A wishes to impose, e.g., "it must be light behind glass." A develops sketch to see if he has captured the concept. A. expresses further constraints involving such things as "organic growth over time," with different objects having different growth periods and with various environmental inputs (e.g., temperature). Over most of the session T is working with A to elicit the constraints which must be identified before any programming can begin. They also spend time in discussion of a tentative plan for the day and rest of the week.

From Observer's field diary:

A and T discuss building an 'environment using ephemeral animation'. Using a sketchbook, A describes what she wants to achieve in the hope of learning about an alternative and how to bring in programming. T tries to get a grasp of what the constraints are within the piece. A. wants to maintain some control to build shapes inside the sculptural form. A. stresses the importance of growth occurring over time ('organic growth') as a central element of her piece. A was keen to understand how the piece could be achieved digitally and they both agree that the piece must work aesthetically. T explains how other artists have used digital media to set growth patterns of entities and describes the work that he and E have completed in order to illustrate his point. T suggests that A experiences the grid he and E worked on in order to get a true sense of what can be achieved. T considers what is possible with software available and explains that it is relatively easy to program colour, transparency and objects. T and A discuss what their priorities are for the rest of the week. A. wants to understand how the programming and technology works to produce the patterns that she wants to see within the piece itself. A is keen to make the programming unpredictable and for the environment itself to change the patterns in subtle ways. The environment will be directly affecting the piece…

End of Transcription Record Extract.

2. *Case Study Report*

The Case Study *Report* consists of comments on the information from the transcription record. Additional information such as the prior survey response, the artists' CVs and subsequent activities are also included. This record is significantly different from the previous record because it includes commentary and interpretation by researchers associated with the source information from the transcription. The reports were structured according to the topics as follows:

- Goals, outcomes and achievements
- Support implications of artists using digital technology
- Opportunities for digital technology
- Impact of technology on art practice

In the extract given, the researcher has not been able to find any indication of the artist's fundamental ideas from the transcription record and has turned to the survey results for evidence. This is followed by the artist's comments on the residency experience. She refers in detail to the nature of her creative process and the problem she has in communicating her ideas digitally when she does not know how to write programs. The technologist is satisfied with the outcome of the week too but expresses it in terms of progress in converting ideas into "a way of thinking that was modular". He is considering this from a systems analysis perspective because this is an essential precursor for the program design to begin.

In the section headed "Support Implications", the researcher speculates (possibly based on the artist's remark that is shown) that the success of this collaboration was because the technologist understood the artistic process well enough to help the artist define the technology requirements without compromising her preferred method.

In the extract headed 'Opportunities for Computer Technology', the commentary weaves together the information about how the artist used traditional drawing media alongside new technology to distinguish between direct engagement with the media and indirect engagement through the support person. For the artist, there is also a distinction between tools for developing new ideas using hand drawings, and tools for delivery of the results of these ideas using computer technology. However, with exposure to new forms of technology, the potential for enhancing the creative process itself through better visualization techniques, becomes apparent. However, as the final extract on control of the creative process indicates, a critical problem was how to have access to the power of the technology for her thinking and making without sacrificing artistic control.

Case Study Report Extract

The artist does not refer to the ideas underlying her work in recorded interviews or conversations throughout the residency. Nor are these referred to within the diaries of the artist, support person or observer. In her original project proposal, A described the main concerns underlying her work as 'The relationship between architectural/light structures and programming.'

In the initial survey, A described the concepts in her work as:

Aiming to make sensitive environments or architectural additions to environments. Continuing interest in how we experience spaces, travelling through them, resting and traces left in places… I always make work with the idea that it will be pleasurable or thought provoking to look at. A's response to Questions 109 and 113 of Survey.

Although, as anticipated, no major 'products' resulted from the week, A's ideas evolved during the residency, particularly the aesthetic qualities of her work in relation to the possibilities of the technology. This development work is perhaps indicative of the stage that the project had reached prior to the residency, as well as the method by which the artist usually works.

A on her achievements from the residency, in her diary:

The five days helped me to evolve a new approach to using digital technologies —something that I had previously considered but was uncertain how this would develop. I've been thinking about things like: how can I communicate the precise ideas I would like to achieve and be hands off (the computer). This has definitely included going through an instinctive creative process in drawing images in grids-which was effectively like an animation story board—then breaking this down and reforming it as programming idea.

T reflected on the overall achievements of the week in his diary:

We tried to look at A's ideas for image-movement. What I tried to do was help A to be able to convert her ideas into a way of thinking that was modular—as this was a stated goal at the beginning of the work. In balance, I think we went some good way to achieving this.' T's diary.

Support Implications

Art-Led Process: a key to the success of T and A's working relationship would appear to have been the level of knowledge that T had in relation to artistic process.

Working with someone who has a knowledge of the process of making an art work and programming seemed to allow many different ideas to emerge when at times the direction or desired outcome was not clear. A's comment.

The technology support person's understanding of the artistic process enabled him to tease out the information that he needed in order to pursue her goals, working closely with her to help define how to achieve what she wanted using the technology. He took on board the artist's approach and worked with, rather than against, her method.

Opportunities for Computer Technology

Drawing using traditional media (such as pencil and paper) and the production of storyboards were devices used throughout by the artist, even though the end result will incorporate high-end technology. It appeared to be a very natural way for her to externalize her thought process. Pre-prepared illustrations were brought to meetings and drawings were created spontaneously when discussing work with support people. The development of the artist's work relied heavily on interplay between traditional drawing and mark-making techniques (which she was directly engaged in) and experimentation with new technology (which she engaged indirectly with through the support person). Paperwork was produced by the artist, from which the programming would be developed separately by the support person. The sensor position system was useful: being able to walk around and experience the effects on the body in the space immediately sparked off ideas. The artist made a distinction between tools used for the *development* of ideas (primarily drawing by hand) and tools utilized in the *delivery* of ideas (computer technology).

Conclusions

This chapter discussed a practice based action research approach to research in art and technology practice. Such research seeks to find an understanding of the creative process drawing on knowledge from other fields. Whilst artists and technologists collaborate in creating digital art, at the same time, researchers observe events for themselves and then collate and assess all the contributing sources of information. The goal of researchers is to arrive at a coherent view of events across a number of separate situations. A distinctive characteristic of this kind of approach is that actual digital art projects are developed in tandem with a research remit. The dual aim of the research is to acquire information that guides change in the existing situation and also to inform our broader understanding of art practice and future digital technologies. The chapter has shown how this may be done and, in particular, presented the details of a practice-based action research approach to the problem that enabled the artists involved to take a significant role in the research rather than have them confined to being purely subjects of study.

In the early history of digital art from the late 1950s, bringing art and technology together was for the most part, the achievement of individuals working alone. That situation has changed dramatically in the ensuing years. In the following chapter, we consider how increasing collaboration can be seen between people of different disciplines and skills. The paradigm for digital art is shifting towards collaborative practice as a norm. Whether this pattern of collaborative practice continues to grow or not will, perhaps, change as education develops and responds to the art and technology developments presented here. We may see a growth in the number of artists who are expert in computer technology to a similar level as those in print-making, carving or welding. On the other hand, the advantages of collaboration extend beyond merely the acquisition of technical skills. Collaboration provides opportunities for more ambitious creative projects. Furthermore, the many funding initiatives that explicitly encourage joint activities also contribute to this growing trend. For most digital artists, the importance of using and having access to expert technological knowledge cannot be over emphasized. On the other hand, by their own account, some artists have been struck by the way in which digital art collaborations lead to the blurring of the distinction between artist and technologist. In both situations, access to expert knowledge and opportunities for the collaboration needed in order acquire that expertise, prove to be essential in enabling the realization of successful digital projects. An interesting aspect of collaboration is the way in which it provides participants with more than one viewpoint about the nature of the creative process. One artist notes how the process of collaboration with a technologist, and the kind if discussion that it requires, encouraged her to reflect on different views about how to proceed with the work and what method to use to produce it. Collaboration helps the participants to address tasks via a number of parallel channels of thinking, which draw upon different types of knowledge. From this process, entirely new understandings can emerge that transform the outcomes of the creative work.

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Creating Graspable Water in Three-Dimensional Space

Joan Ashworth

By building characters and being inside them in a variety of invented situations I am attempting to visualize a sense of being and physicality for other people's eyes. In the Stone Mermaid project, I aim to express some of the feelings I have for the texture of stone in and out of water. The main aim of the work I have done at the Creativity and Cognition Research Studios (C&CRS) is to develop the water element of this project which must appear to have the 'graspability' of cloth as well as the movement, translucence and flow of water. I have written a narrative called *How Mermaids Breathe* which explores the fertility of stone women who live in the sea and control the waters movement from its edges. The design of the project was inspired by the chalk stones of Birling Gap beach, the sculpture of Henry Moore and Cycladic Art.

In my practice, I am attempting to communicate ideas through narrative in a three-dimensional environment. I mean to express character, feelings and emotions through moving figures and trying to inhabit their bodies to enable them to perform: expressing feelings through movement just as the human body does. I create this movement using the stop-frame technique of animation. I approach animation as a "method" animator, as I need to rehearse a movement myself before moving a puppet or model. Not that the movement needs to be hyper-realistic, but something of the movement needs to be recognizable by an audience. The movement needs to create resonances that communicate a particular feeling that can be read by the audience. Additionally, I prefer a cinematic approach to film making rather than a theatrical approach. By this I mean that I want the audience to believe that the characters on the screen are actually involved in, and reacting, to the shown actions. They are not actors in a play who are re-enacting something that has already happened in the past. I also use focus and depth of field in my work to enhance and reinforce the emotional focus of a sequence. Textures, lighting and sound are all critical in the construction of my images.

I discovered digital methods of production through making commercials, title sequences, and short graphic clips for broadcast television. After seven years of making thirty-second pieces I became frustrated with the short production and

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_19

screen times involved. Just as an idea would become interesting, the project would need to be shot, delivered and on air. I then took over the running of the animation course at the Royal College of Art, London to help me focus on developing longer projects and to spark off ideas with other artists. However, because the running of the Course is very demanding, progress of my own work has been slow and not much sparking has occurred. In that context, the opportunity to have time and support through my contact with C&CRS has been invaluable and given my film project the space it deserves.

Influences

The work of the choreographer Pina Bausch is very appealing to me because it takes an everyday movement and by repetition makes the mundane a celebration. According to Sanchez Colberg,

> Bausch has always been fascinated by a variety of behaviour and has developed a unique vocabulary of movement from it. Her pieces have always been geared to making her audience see what is either taken for granted or ignored (Sanchez-Colberg 1993).

The visceral and extreme movements of the dancers in Bausch's choreography is meaty and vigorous showing the characters' determination and belief in their own world. This claiming of space through movement is an element I will explore further. For additional inspiration, I have looked closely at natural history footage of underwater worlds. I have a hunger for creating three-dimensional spaces and atmospheres through movement and sound. For my film, The Web (Ashworth 1987) much inspiration came from the interiors of buildings and the narrative in Peake's Titus Groan (Gilmore 1981; Winnington 1993) gave me a thread to connect these interiors.

My current project has had a long gestation period beginning with cloth and binding. This was a development from a sequence in The Web in which a character binds his knees with cloth to stop them clicking. These sources I combined with story of The Little Mermaid, wanting to show that when the mermaid swapped her tail for legs every step she took would be like walking on sharp needles, as if her new legs were foot-bound. I explored these ideas for some time, but the narrative became too complicated. Eventually I stripped the story down to a mermaid in search of semen to fertilize her eggs. I liked the idea of her not being prepared to change into human form to procreate. Because of this reluctance to transform, she risks her race dying out. She has to consider the compromises and sacrifices of breeders.

The look and style of my mermaid characters evolved into ancient, long-lived creatures and eventually stones. Their texture and shape were inspired by the chalk stones on Birling Gap Beach, Sussex, which have some of the qualities of the work of Henry Moore. This, in turn, led to Cycladic Art (Fitton 1989) and the Bronze Age fertility idols discovered in excavated graves. Some of these figures are thought to have been carved by women and look as if they have been frequently carried around in pockets as they are worn smooth in parts. This smoothness and their association with fertility fits very well with my narrative. Also, the digital process I am using involves modelling a figure in plasticine and then scanning it three dimensionally. The process of scanning and smoothing the information softens the detail of the original sculpting and so mimics the work of seawater wearing away a pebble or the many touches of a Cycladic figure by ancient Greek hands.

Residencies

During the time I have been visiting C&CRS, I have chosen to focus on developing the look of the water for my Stone Mermaid project. I was not convinced that computers could give me the look I wanted which in my head was a mixture of cloth, ink and moiré patterns. This mixture needed to move and behave like water, but also, for narrative purposes, be graspable like the edges of a tablecloth. At this point I was still at the chalk stones stage of my character design and I wanted to put together a sequence of an animated figure moving through an inky cloth-like volume of water. I wanted to see the surface of the water and under the water to assess the combination of textures and their effect on the moving stone figure. It was also important for me to find out if I could work with the texture of the material being removed from my hands by being composited within the computer. My previous work had involved building and animating with real materials which, through touch, suggested how they should move. I relied on this contact for knowing how to perform. However, I knew that I had little choice as the water I had in my head could not be created organically.

Digital technology has enabled me to work in a more contained and less physical way. The square footage of studio space required is less. It makes me feel restricted in some ways and my hands and body get bored with doing small movements. They need bigger gestures with more physical effort required to feel satisfied. By retaining the need to sculpt the stone mermaids in clay and then scan them in three-dimensions, I am able to combine the physical and the contained ways of working. As I progress, I want to refine my methods of working and find more ways of combining the digital with the pleasures of the tactile and physical.

I visited the Studios at Loughborough several times for short periods—the longest being five days. The supportive atmosphere and practical arrangements are very productive for me. It is stimulating to be able to talk through some of the work both technically and creatively and be more reflective about the processes involved. Ironically, it is what I provide for my students but it is very hard to get that support and feedback once you cease to be a student. On my first visit, I worked closely with my technical support person and relied heavily on his skills as I was unfamiliar with the software identified as being the most appropriate. This was quite frustrating at times as it was difficult to build an understanding quickly enough and hard to work through someone else's eyes and hands in a collaborative way. In spite of the frustrations, the first residency was immensely fulfilling and enjoyable. During subsequent visits I worked with a different support person and attempted to work more independently by choosing to use software which was much easier to learn or that I was already familiar with.

The residency helped me to develop my current project and formalize my time allocation to it. Each visit offered an opportunity to discuss ideas behind the project that I found very useful. I accepted that I was too keen to keep deeper ideas hidden. It is easier for me to discuss the technical aspects of a project than to discuss the deeper meanings. Too much discussion feels too probing especially in the early stages of a project when the idea is raw and embryonic. By excavating some of these layers through reflection I was able to progress the project.

Having achieved some promising clips of graspable water I am continuing to develop the stone mermaid project. It has reassured me that working digitally is appropriate for this project. I have been learning 3D software to give me insights into some of the restrictions within the software as well as the freedom to experiment. I have been preparing myself for animating the characters I have invented by imagining their motivations. I swim to imagine their movements in water and view wildlife films to examine how difficult it is for water mammals to move on land.

The next stage is to raise finance for the production costs. When finance is found, I will put a small team together to make the film as it will require more skills than I have. I will continue to visit C&CRS to work with the support of the staff there as I refine and develop the water animation. The next challenge is to create a storm as my experiments so far have been with a relatively calm volume of water.

Art Practice with Digital Technologies

Digital technology has encouraged more and more people to work with moving images and particularly animation. The accessibility and ease of use has brought a breadth and freshness to moving image with many painters, sculptors and photographers creating time-based pieces for exhibition in galleries and public spaces. This is a challenge to more passive viewing spaces such as cinemas and family living rooms. The film industry is in a turmoil of excitement and despair as the changes in technology ravage through traditional film and video production and role definition. For a while, expert skills seemed redundant as new tools enabled one person to do everything. Gradually, the roles are separating out again, as new experts are required to push the limits of the technology. New technology has influenced the content of films with narratives being selected for their ability to show off some of the latest tricks and skills of the film-makers, for example, The Matrix and Toy Story. Is this stage coming to an end?

The role of an animator has changed and broadened over the last ten years as live-action work, feature films and commercials, rely more on frame-by-frame digital manipulation of images. As the tools have become more sophisticated, more time and budget is spent on them. Most artists find that many of these post-production tools are out of their price range but by viewing films they are influenced and given a hunger for sophisticated image manipulation. Many artists become hooked into advertising and promotional films in a symbiotic relationship which gives the advertisers a fresh look to their product and the artist access to the latest high-end equipment. I found it unfortunate that many of the experiments and artistic achievements produced for advertising are quickly archived and forgotten as the next job comes barrelling through. It is important for these production and post-production companies to take time to reflect on their strengths and areas of genuine innovation. It is also important for artists to develop continuing relationships with talented operators of these tools, to keep getting the best from the equipment and the people.

Burning Issues

There is a kind of slipperiness and insecurity about digital technology which film and film-cameras do not have. The tools for filmmaking are mechanical and reassuringly cool to the touch. Changes in design of film tools are slow which creates a feeling of stability, confidence and expertise in their users. Digital tools tend to be plastic boxes with their function more removed from their shape. The tools are found under buttons and moved around with fingertips rather than the whole body. This inevitably has an impact on how an artist's work progresses as different thoughts are triggered by different physical situations.

As an artist, it is important to question whether you are putting your energy into the idea and expressing it as simply and directly as possible. It is a big investment of time to learn how to use any new tools, and digital tools can change or develop quite rapidly. Digital advisors with artistic sensibilities are needed by artists to guide them through the exciting but confusing software and hardware jungle.

Within art and design there is still snobbery about computer created art, partly because often there is more than one version of a piece which can take away its uniqueness and collectable value. Collectors of art need to be reassured of the value of digital art as art and not just technical wizardry. It is easy to be branded a technician once you admit to being able to use a machine. It is easy to get distracted and become a technician once you can use a machine.

Another reason for people's distrust of digital art is the perception of the computer, not the artist, making the art. The artist's hand and skill is not always so obvious. Unless artists learn to customize the digital tools then the work of many artists can look very similar. Getting beyond factory settings takes time and commitment. The environment at C&CRS is extremely valuable in advising artists on which tools to choose for their particular project or way of working and goes some way towards encouraging artists to being involved in creating the tools they want (Figs. 1 and 2).

Fig. 1 Prototype Still from the Stone Mermaid, 1999 © Joan Ashworth

Fig. 2 Still from Stone Maiden film, 2000 © Joan Ashworth

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Contemporary Totemism

Jean-Pierre Husquinet

My artwork has developed over many years and has been guided mainly by the use of symmetry and asymmetry. It is also influenced by the use of a 'system' of an association of the twelve notes of the chromatic scale with the twelve colours of the chromatic circle. This research aims to create 'parallel' harmonic musical and plastic structures. To that end, the phases undergo successive restructuring and different types of material are used. The main idea behind my work is the relationship between colour and the structure of those colours together with music and also the structure of the music you create. I am trying to create a code or language that has a relationship: this means that I am not working with musical theory but with visual images in the form of colour structures.

Correspondences Between Colour Structures and Music

There are many aspects of those two worlds that are very different. You cannot structure music and visual art in the same way. But there are some rules that you cannot avoid. The main goals are to respect the known rules and to try to match the relationship between the colour structures and create music out of them. For the time being, it is mainly the visual work that is driving the music and not the opposite. I am not actually trying to put into images a particular kind of music but instead trying to build a logical system and construct a visual world of interest to me.

In respect of the structures underlying the artworks, the visual images drive the music: therefore, the structuring takes place in the visual domain rather than in the musical. I work with professional musicians and the main idea is not to write either music that changes into images or to make images that change into music, but to try to build an entire world. This means that, ideally, all the elements should be interrelated from the beginning.

The way we have worked is that I use musical chords and notes which are given to me by one of the musicians. All the notes are related to one another which I have

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to use in that section, so I do not use another colour which is not included in that chord and the way I am using them gives like a rhythm and the melody and it is the interaction of those voices working with the colours which re-creates all the melody. The best word for this is 'structure' because it is built either visually or musically in structures—that's the goal.

Figure 1 shows notes for a work called Crinan 1, made with my collaborator, Ernest Edmonds. On the left are the schematics that represent images to be projected in sequence. The note was produced during a debate about the correspondence between the music and the sequence of images. It illustrates how we explored a way of mapping inter-connections between the image structures and the musical notations.

The evolution of my work has progressed by successive steps: from the two-dimensional picture to the third-dimensional material (e.g. wood, metal). One of the first phases was the assembling of coloured cubes, then by assembling tubular structures, this paved the way to discovering the material which has really allowed me to evolve and access other plastic aspects… the rope!

Rope Works

In the early stages of its use, the rope material was painted according to sections of different lengths, each section having a numeric value in relation to the value of a musical note, that note being shown by its colour, one of the twelve colours of the chromatic range.

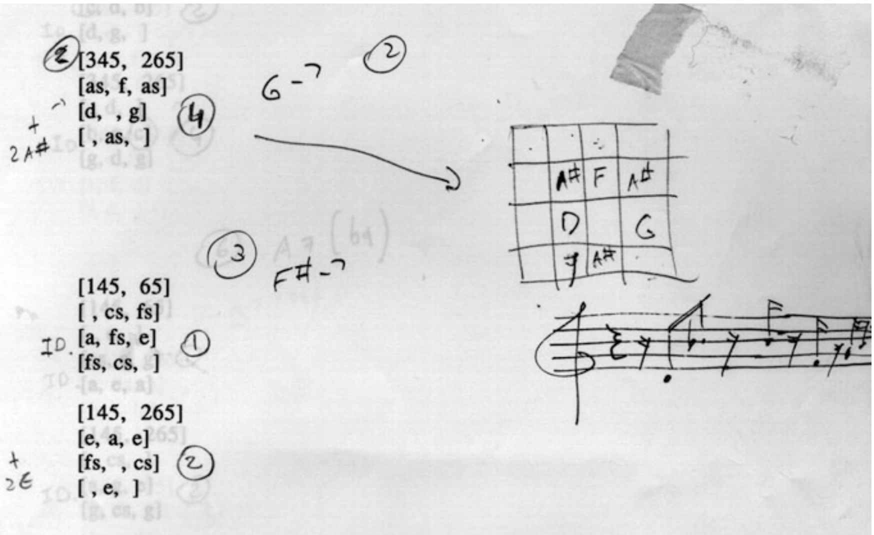

Fig. 1 Notes for Crinan 1 © Ernest Edmonds

I use three different methods: the first, for me the more interactive one, is three-dimensional work using rope. This allows me a lot of flexibility and the material is cheap and easy to paint. The rope works can be developed in a space and attached to some existing elements, such as trees. This allows me to visualize the world in three dimensions. This is, however, constructed first in two dimensions because the colours which are painted on the rope determine the musical beat. The rope in the space is not properly the music but it is the rope in itself which provides a reference for the music.

The second medium of the music is two-dimensional—painting, wood, canvas more in a classical way—and the third one is a line-based system. I have been developing line-based images, which are very interesting in the sense that music cannot be reduced to one surface, either two-dimensional or three-dimensional. Line-based parts are much more interesting because they can develop a system which allows you to visualize the notes at the same time as you are hearing them. The people who are seeing and hearing it can appreciate and understand the work much better that way.

The ropes were hung in space by the use of anchor points or existing intersections. At that stage of the research, I started to be interested in the intersections of the ropes and to realize a series of paintings in the form of a cross. This has naturally led me to explore the problem of the knot (Husquinet 1999–2000) Because I knew nothing about them, it took me two years to learn how to manipulate them, patiently.

That inquiry has led my thoughts on to unexpected, experimental ways and also to some fascinating reading matter. The further I go on, the more I become interested in the relationship between what we call 'shamanism', in terms of communication, empirical, and the rationality of sciences.

In the past, knots were of great interest only to biologists, chemists and physicians at first. Then, a first attempt in mathematics on the use of knot was done by Vandermonde during the seventeenth century. His efforts led to failure and we had to wait until the twentieth century to see mathematicians work at it again. Among these searches, we can mention the mathematicians John Conway and Vaughan Jones who discovered the polynome of the same name, which restarted the studies of knots invariants. The research on knots theory is described in the excellent book by Sossinsky (1999).

A common point seems to exist between scientific objectivity, using rationalistic methods, and artistic empiricism, using intuitive methods: it is that each one is looking for a form of purity, a truth which would be their own, to discover the unexpected and to discover the harmony which is hidden behind "disorganized" appearances. Poincaré wrote: "It is the search for that special beauty, the sense of harmony of the world, that makes us seek the facts to contribute to that harmony" (Thuillier 1997; Asher 1991).

Residencies

When, in January 1996, I received the invitation to participate in an artist's residency with the theme "the artist and the computer" at C&CRS, Loughborough University, I was persuaded that the computer could have an answer to the questions I had in mind since I thought those questions were perfectly rational and purely logical. I was rather disappointed when I saw that these things were not as simple as I had imagined. In the residency, I had access to the skills of a software engineer. For a week, we tried to solve a concrete problem about the focusing of a knot network, tightened in space which had to be of a scheduled length and on which different sections of colours were applied.

Working Collaboratively

To build a computer model of a net of ropes of different colours and precise lengths, we had to call on the expertise of Rob Doyle, without whom nothing would have been possible. A close collaboration between us was quickly established and finished with concrete results. The graphics program used was so complex that I was unable even to draw a single line However, with this collaboration, it was possible to make computer models of my ropes in specific proposed spaces as shown in Fig. 2.

At the beginning, it was strange to work with somebody you had never seen before and to explain to him precisely what you were trying to do. In his efforts to help me, he tried to find some solutions to my problems while I was not there, which did not work for me. The problem is that working with the particular program was quite a slow process so it took some time before we could actually see something on the screen that looked like what I was hoping to see. It was strange to see somebody actually doing the work for me because, as an artist I am used to doing it myself. This was interesting in itself because having it done by somebody else you have some answers to your questions, by way of a person and not through the computer. You have somebody who mediates between you and the computer who tries to explain to you what is possible and what is not possible.

Unfortunately, after much effort, the week was soon behind us. It was a week full of numerous discoveries and friendships, benevolent collaborations and mutual comprehension, which, to me, have allowed all of us to understand more about our respective disciplines and have created the need and wish to see each other again in order to go even further. I came with lot of expectations and five days was too short a time. I was surprised to have discovered there was no software that exactly served my purposes, and, for the other three resident artists as well.

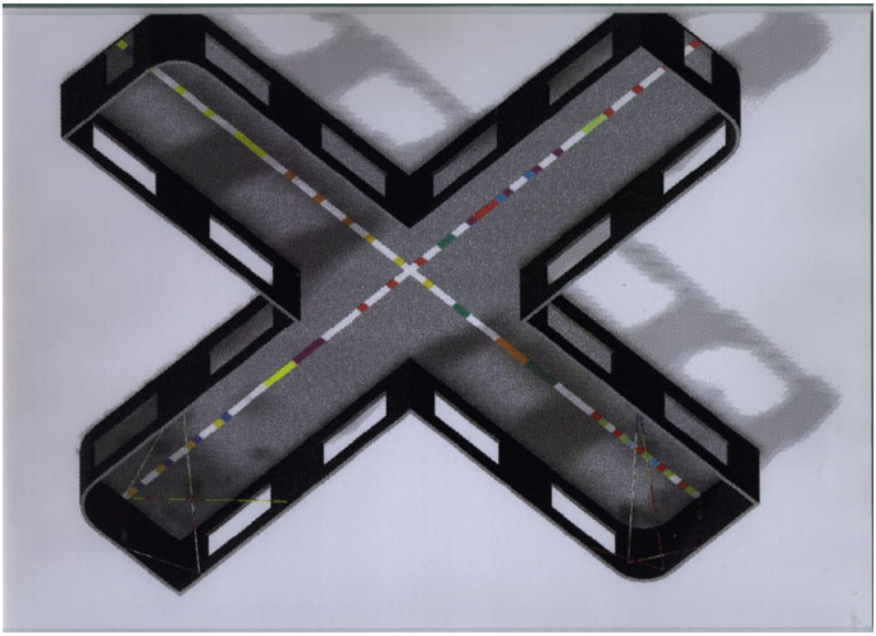

Fig. 2 Rope works 1996, computer print © Jean-Pierre Husquinet

There were many unresolved questions and needs that could not be achieved for the time being because the software did not exist. I had been under the illusion at that time that all software was so sophisticated that it could do almost anything.

I was very pleased to work with the computer and I gained a very good idea of what computers could provide in the future. I did not think the computer could influence my work in terms of art but the time available was too short to really accomplish much. I needed to think about it more. There are other aspects of art practice which the computer will never give to anybody in the sense that if you are working with the material you have it in your hands. It could be anything. It could be metal or wood or earth or whatever you use, it doesn't matter. The contact with that material and what you do with it, opens some fields that the computer will not open, although it will open other fields, of course.

There are a number of improvements in computers that I would like to see in the future. For example, the textures you are provided with are not the kind that artists work with but rather are more dedicated to graphic art. You can actually probe one single joint on a surface, but it is very difficult when you want to take that drawing and put it into another space. With the software I have been using, it is possible to draw a house or a roof or whatever but once you want to put some particular structures into that house which are not architectural it is more difficult: it takes more time to put ropes inside the virtual space than to actually build the house.

Reflections

There are two things which are interesting in being an artist: one is the process of the development of the ideas and the other is the artefact that is generated—the work. As far as I am concerned the process is much more important than the work itself: for example, with the Rope Works, these are never permanen*t* objects because they can be re-used in a different context. Once the installation is in place it stays there two or three weeks and then can be brought down. If it is still in one piece, I can reinstall that piece somewhere else perhaps with significant changes in the environment and the configuration. The artefact has no value as a material object. Its value lies in the concepts underlying the work and its importance in helping me move my ideas forward. That is why I don't really mind if old pieces are destroyed. You can probably relate that to having a musical score that you have written: in this case it is a visual score which I have painted and every time you develop that space, you are rebuilding another structure. If you think of it in musical terms, it is as if you were thinking of a musical score again, and playing it again but differently, rather like playing jazz.

Working with Ernest Edmonds on the correspondences between colour structures and musical theory provided me with the opportunity to develop ideas in common. The links between the relation of a musical structure and a visual structure is very difficult to handle and requires collaboration between people of different skills and knowledge. The more I advance, the more I need the help of technology such as the software AVID for the images and Pro Tools for treating music. However, these programs are not dedicated to my purpose and I really would need a particular program, suited to my needs and thoughts.

For the time being, technology is already helpful to my work and would probably be even more helpful if I was involved more closely in workshops or residencies such as those at C&CRS in a regular manner. This brings me to think that residencies ought probably to be done over different periods of time in order to understand the partnership better.

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Integrating Computers as Explorers in Art Practice

Michael Quantrill

Recently I have had a number of opportunities to explain my work to others and I have been surprised by how difficult it has become to articulate it. This is an especially thorny question for me, not least because it is my struggle to communicate the meaning and motives for what I do that forms the basis of the work itself.

Communication occurs in many forms. Mostly this is translated by the mechanisms used to carry it. I refer not just to the external and observable. These mechanisms begin at the moment the desire or impulse to express something in a tangible form occurs. It has also become increasingly clear that methods exist that approach a means of communication that we cannot easily explain, but are undeniable by our experience of them. These methods include the processes of drawing and movement.

One view of the drawing process is that it is the search for meaning. A conscious investigation of a space "in between" that results in transformation and the emergence of insight. When absorbed in the drawing process, something occurs that is compulsive and intense. One response to this is to make marks on paper. However, the making of marks is simply one way to try to express the process of transformation that is occurring.

But, what is really going on here? What is this transformation? I have tried to grapple with answers to these questions for some time now. It seems quite certain that the truth will never be really known but maybe we can get close enough to make the journey worthwhile. Drawing has always proved to be such a revealing process. I have thought about what makes this so. To my mind it is the immediacy of the process that gives it the power to investigate and reveal. From the impulse to the mark there is no intermediary that actively transforms the intention. I cannot offer any explanation of why this is so, but I accept that it is so.

I have been involved in the process of drawing from as early as I can remember. It is a behaviour I have engaged in instinctively rather than analytically. It has always been a testing, groping process. This has left me with something of a dilemma as I have a strong feeling that digital technology offers possibilities for the artist that can be enlightening, but by nature it demands an algorithmic

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_21

predetermined input where all variables have been considered beforehand. My desire is to reconcile these two very diverse mind sets and explore the possibilities that emerge. Reflecting on this, it seemed very appropriate to use drawing as the process with which to explore human–computer integration and to search for ways to enable the technology to be used as a medium during my residencies at the Creativity and Cognition Research Studios (C&CRS) which have led to several publications (e.g. Edmonds and Quantrill 1998; Quantrill and Edmonds 2000).

I believe digital technology offers new ways to translate and transform. In human terms, this involves the translation of our intentions, our goals and our state.[1] With regard to machine media, it takes the form of translation and transformation of new media and machines from a purely functional context into a context where their architecture itself is an additional contribution to creative works.[2]

My approach is to use drawing as a gateway to exploring these possibilities. Specifically, I am using it to explore the notion of human–computer integration. The idea is to use the properties of computing machines to enable forms of expression that are unique to a human–machine environment where the human is the focus, but the expression is a composite of both human and machine, in this case a computing machine environment.

Residencies

My connection with C&CRS has been a very fruitful period and has involved a number of residencies over the last three years. Before I go further, I will say something about my work and the motives behind it.

Drawing with the Soft-Board

One of the devices I have used is called a ‘Soft-board’, a whiteboard (4 ft by 3 ft) connected to a computer. The whiteboard is similar in design to any conventional whiteboard except it has a laser matrix across its area. There are four colour pens as well as small and large erasers. The laser matrix enables pen and position data to be transmitted to the computer. The application program on the computer looks similar to a drawing package. There is a re-sizeable window, which maps to the physical whiteboard. The resolution is high (4000×3000 points approximately). Any actions made at the physical whiteboard are immediately represented in this window. Drawings are entered onto a “page” using the four pens. A page is one virtual workspace displayed on the monitor. A set of pages forms a sequence. When any mark is made it is recorded as a set of points for the current page. Both positive pen marks and eraser events are recorded. At any time, a new page can be generated as a new blank canvas or inclusive of the previous page’s marks. The controls for starting and stopping recording and entering new pages are situated both at the whiteboard and within the window on the computer. This enables completion of a whole sequence with pen in hand, never having to touch the computer.

The drawings are made at the whiteboard. However, due to the integration of a computing machine, the creative process is fused with a machine interpretation and so the final piece is an inseparable intertwining of human and machine processes and the works cannot meaningfully be deconstructed into the human and machine parts. Really, what is going on here is that one process is occurring in a natural, instinctive way, the conscious progression of work from sketchbooks, and another parallel process is occurring under the surface. This 'under the surface' process resulted in a time-based dimension, amongst other things, being added to the work that was not expected at the start of the process.

It is important to emphasize that the work with the Soft-board does not use an input device obviously designed for a computer, such as a graphics tablet or mouse and that complete freedom of movement is enabled in the space that the work takes place. Such freedom of movement enables a creative space to develop that allows the work to progress without an awareness of the constraints usually associated with electronic media and the need to make allowances for them. This space is a dynamic, integral part of the creative process (Figs. 1 and 2).

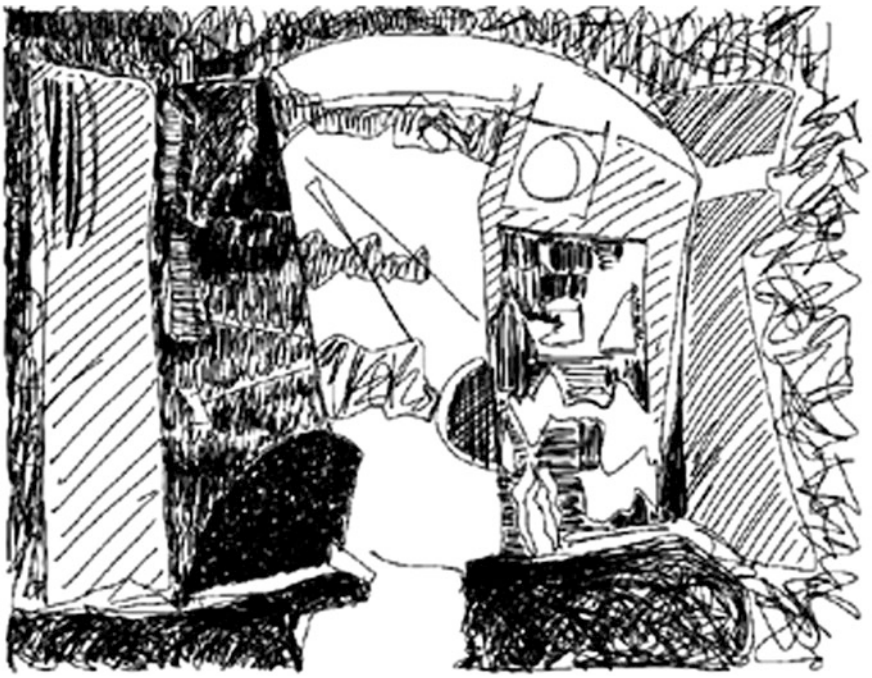

Fig. 1 Soft-board drawing © Michael Quantrill

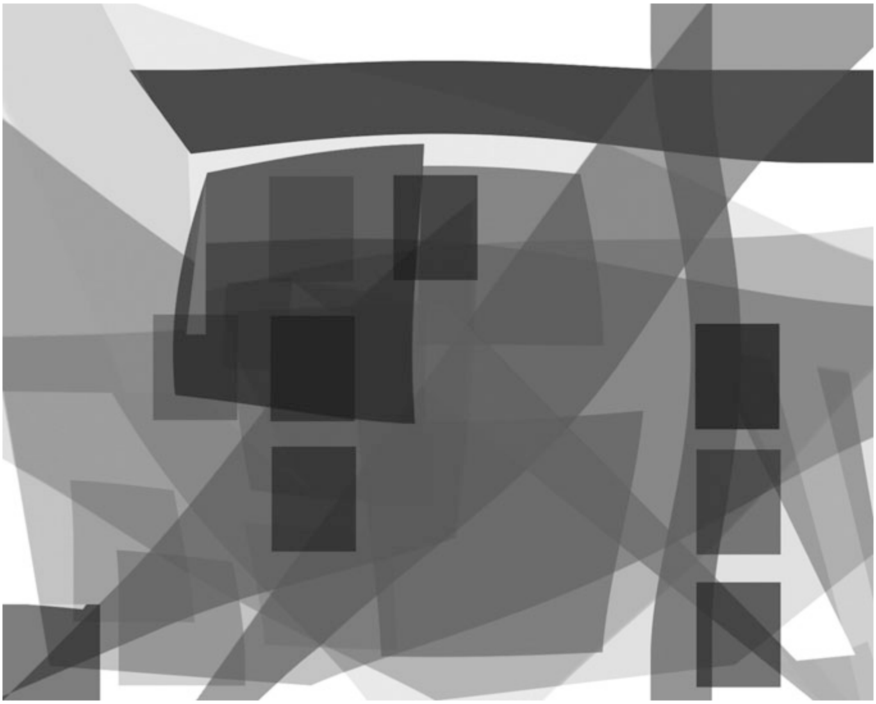

Fig. 2 Artwork from sensor grid © Michael Quantrill

The Sensor Grid Interaction

In 1998 I worked with artists, Leon Palmer and Anna Heinrich to develop software for an array of infrared position sensors. Their work has involved high-resolution data projection onto various surfaces. In this case they wanted to back project the view of a corner of a room which is deconstructed as people move around a space. This was exhibited at the *Under Construction* exhibition held at Loughborough University.

The experience of using this space coincided very well with the ideas that were forming from the work with the Soft-Board. For this and other reasons it was decided to build a permanent array of sensors, referred to as the sensor grid. The area is approximately 12 ft by 12 ft and the array of sensors is an 8 × 8 grid connected to a computer. A display is projected onto a screen on one side of the sensor grid and a sound system is also connected.

The search now began for a process akin to drawing that could provide the same lines of enquiry without the cognitive load imposed by a connection to a computer. The process turned out to be that of movement. At the outset, the outcome of any use of this space was not defined, as the nature of any development and use is a product only of this environment and to impose expectations upon it would be to defeat the purpose. The prime concern is to create an environment where creative works can take place as a function of a person's movement through the space. Movement was chosen because of its parallel to drawing. As children, we quickly integrate movement into our world and it becomes deeply embedded in our being. We do not utter conscious commands to transfer the energy needed to reposition our bodies. Our minds act by stealth. We see, we feel, we desire and before we are aware, we move. The underlying process of movement is often ignored and yet is an intensely informative expression. The nature of any 'drawings' reflects the interactions with the media that underpin this process.

Focusing on movement as input means that the participant can be unaware of the physical connection to a computer. They move as they wish. They go where they please within the system. However, the computer is able to record and analyse in parallel with the movement and in reaction to it. This means that creative functions can be implemented within the computer that are part of the overall system including the participant but without their explicit control. The computer in effect acts by stealth.

From the start, it seemed clear that to progress these ideas it would be paramount to discover a language that encompasses both the individual's role and aims as well as the system attributes, form and context. This language will be a composite of the individual, the machine and the space.

Some first steps are a series of 'sketches', or preliminary programs, constructed to experiment with the sensor grid. To begin with, simple geometric shapes form the basis of the visual data. The workstation can produce very attractive and complex representations of real world objects but these are loaded already with metaphor. Of course, geometric shapes embody metaphor, but less so perhaps. The idea is to reduce visual complexity by using shapes, colour and lighting in ways that are not in themselves inherently complex. This allows the process of moving and sensory co-ordination to evolve simply and naturally. Some of these sketches were developed in collaboration with Dave Everitt (see Everitt (2002) in first edition of this book).

It became clear that there are a number of ways to use the system:

- Use direct and event-driven immediate feedback: e.g. a sound is triggered as a beam is crossed.
- Use periodic/continual event and/or process-driven feedback: e.g. the more a person moves about, the more a certain image changes.

Time-based feedback as a function of stored and processed data: e.g. a 'landscape' or map, is built up over time from the density of movement about the space. Movement through time is thus translated and realized as a map across the space. Any or all of the feedback will be integrated within the system. This feedback will form part of a trace that cannot be reversed or erased. It will become part of the work. This trace itself may well form part of further feedback, which itself becomes part of the work. This may continue in a recursive fashion so that the work grows constantly and continually changes form. At each level, the experience of the individual using the system will change as this 'landscape' changes.

From the initial responses to the experience of using the Soft board, through the first experiments and sketches with the sensor grid, a path is emerging that I believe is going to be rich to explore. The prospect of human–computer integration raises many questions and we have, as yet, few answers. It is hoped that ways can be found to use the unique properties of this technology as a medium. An attempt is being made here to create an environment that is intense, dynamic and allows the technology to inform the work. The intention is to use the underlying medium (the machine) without imposing metaphors from traditional art media. This is no trivial matter and much is still to be defined and gleaned from the process. What is clear, however, is that this space has real potential to provide opportunities for artists, or any individual with intent, to find ways of expression that may be surprising and informative on whatever level they wish to permit it.

End Notes

1. 'State' here refers to complete our mental, physical, emotional state along with any other classification of what makes us who we are.
2. The additional contribution comes from the fact that the architecture forms part of the medium for the work. Therefore, the effect is as with any other medium, in that it acts as a carrier and the carrying process has an observable effect on the message: e.g. a drawingDrawing made with a pen will emphasize different facets of the creative process to a drawing made with a soft medium such as charcoal or paint.

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Hybrid to Simulated Invention

Beverley Hood

Through my creative practice, I interrogate the impact of technology on the body, relationships and human experience. My artwork is experiential, and presents performative situations that attempt to challenge audience perceptions of how physical, emotional or human qualities, and states, are affected by our ever growing and multifaceted relationships to technology. Throughout my practice, I attempt to express and reflect upon the complex and slippery overlaps we now tread between real world and technologically mediated experience. I use creative strategies, such as the mixing of live and mediated performance, to create subtle layers of contradiction. My aim is to question and disrupt the validity, use and meaning of established and defined technological spaces and conventions, in order to critique and deconstruct their impact upon our lives, and notions of what it is to be human and alive. Uncertainty is an important feature of my work, and I purposefully create situations that challenge the audience's ability to tolerate uncertainty, in an age where we appear to be able to find all information at our finger tips. It can also be uncomfortably intimate and emotional. Reflecting upon the floods of personal data (over)shared using technology, that risk becoming "better than something" in Sherry Turkle's terms, i.e. the machine world expression of emotion and intimacy could be preferable to the messy realworld version of actual people (Turkle 2011). My creative practice attempts to create performative situation that have the potential to create authentic and meaningful emotional encounters mediated between ourselves and technology. The results can be confusing, moving and disconcerting. Although my work utilises technology, it is not techno-centric and is in fact a highly critical interrogation of its fallibility, reliability and potential otherness. My aim is to question our consumption of technology, through multi-faceted creative experiences, that provoke questions about the real, simulated and 'other-ness' of the digital realm. I am interested in the distinct, diffuse and evanescent creative spaces and contexts, that technology creates, and the implications and effect of this on our everyday existence.

I have used a wide range of media in the creation of my artwork. This has included Internet, sculpture, interactive installation, and digital photography. In

L. Candy et al., *Explorations in Art and Technology*, Springer Series
on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_22

recent years this has become largely ephemeral, immersive and performance based, from large scale participatory works to Virtual Reality experiences.

My early work paired traditional and non-traditional processes, as a way to explore interests in the hybrid possibilities of new combinations of materials and media, such as sculpture and printmaking with new technologies, where they overlap and differ. These hybrid approaches offered the opportunity to combine the physical and virtual realm, both in the process of development and the presentation of final works. In my more recent work these overlaps are more complex, sophisticated, and slippery. Rather than a binary opposition of traditional versus non-traditional, real versus virtual, my work has progressed into embedding these overlaps in a more multi-layered, rich and liminal manner. Recent works have re-interpreted these overlaps using the actual body i.e. performers, as an enacted re-enactment of the real/digital relationship, as something in flux, uncertain and contingent. Moving back and forth between the real and digital realm, these overlaps become so fluid, dense and liminal, they are difficult to trace or pin down. My work reflects upon our current relationship with technology, which is now a complex, porous living experience, where technology permeates every aspect of our lives, if we so choose.

Artist Residencies

I was artist-in-residence at the Creativity and Cognition Research Studios (C&CRS) for one week in July 1999 as part of the COSTART research project. My aim for the residency was to experiment with the potential of 3D computer animation and virtual reality, towards the development of a sculptural installation called asex[1]. This work stemmed from my interest in representations of the body using new technology, particularly the exaggerated and erotic nature of many of these pre-fabricated physiques, for example, within computer games. The work, asex, was a reflection upon these representations and an attempt to create a bisexual form.

The project is an example of my then hybrid approach to creating work, specifically combining traditional processes with new technologies, exploring where they connect and differ. The installation involved three distinct sculptural processes of development (both traditional and non-traditional), individually applied to the same conceptual form. My intention was to allow each process to influence the form as it developed, creating three objects which rather than being replicas of one another were shaped by the process of their development.

The three processes were bronze casting, 3D computer animation and rapid prototyping. The 3D animation created at C&CRS was the first stage in the work to be developed, as none of the objects at that time had been realised. The residency gave me the opportunity to make substantial progress with the animation element of the installation, and the work as a whole. A vital part of this opportunity was the access to equipment and software that the residency provided which at that time, had been previously unavailable to me.

Initially I had intended to work at C&CRS experimenting with Virtual Reality (VR) environments, to explore the possibilities of creating virtual, malleable objects. Soon after I began working on the residency I realized that a VR environment was not appropriate for the installation, as it did not allow me to create and maintain, a physical relationship between the objects within the installation, i.e. it was not possible to move fluidly between the real object and VR environment. This was around the time that Ronald T. Azuma published his "A Survey of Augmented Reality" (Azuma 1997), but I was as yet unaware of the potential of AR. I therefore decided to re-direct my attention to the potential of projected 3D animation, which had the potential to be a more cohesive installation element.

As part of the COSTART project residency I worked with Manumaya Uniyal, a specialist in 3D animation and VR. This was a great opportunity for me to work with someone more experienced in this area, enabling the work to develop more quickly and for myself to gain some fundamental skills. An interesting experience, it was challenging to develop a working relationship in such an intensive period and was a demanding situation, requiring much flexibility and communication. I find such situations can be very dynamic and hugely beneficial in the creation of work, as the situation was at C&CRS. To develop and experiment with ideas required many discussions to establish aims and technicalities. Such communication is integral to the process of development for my work, and highly influential in establishing a level of technical and conceptual understanding. This experience, in many ways, provided a template for how I have gone on to collaborate with a range of technical specialists, in the years that have followed.

A great deal was achieved in the week and I developed a sequence of wire-frame animations. The use of wire-frames rather than texture mapping the objects was a decision that evolved through the process of development and such decision making was totally facilitated by the residency. Without the means to try out the various options I was considering, I was in no position to come to such integral but fairly straightforward conclusions.

After leaving C&CRS, I compiled these animated sequences into a single animated movie and from this I later developed an animated screensaver. I am interested in the potential of creating work, which lends itself to distribution, and have also developed artist books and multiples. The 3D animation transferred naturally to being a screensaver, distributed as a digital multiple.

The asex screensaver was exhibited independently from the larger installation work in the following exhibitions: Sum of Parts, Fruit Market Gallery, Edinburgh (2000/01), Infinitude, Gallery of Modern Art, Glasgow, (2000) Jesus, Mary and Joseph, Stills Gallery, Edinburgh and 114 Byres Road, Glasgow (1999/2000).

Eidolon and the SCSC^{HF}

Eidolon is an example of a project developed through a more ambiguous artist-in-residence situation. The work is an immersive performance developed from

2013 to 2017, at the Scottish Centre for Simulation & Clinical Human Factor (SCSC^{HF}), at the Forth Valley Royal Hospital, Larbert.

SCSC^{HF} is a state-of the-art professional training facility, undertaking simulation based medical education for medical students, nurses and professionals. A range of patient manikins, embodied with physical responses, such as pulse, breath, tears, and voice, are accommodated in a multi-purpose simulation environment that mimic clinical hospital locations, such as operating theatres and hospital wards. This extraordinary setting provokes a profound level of conviction and commitment by trainees, to the simulated scenarios they experience. The Eidolon project further explored and challenged the notion of the patient manikins as people, which is a concept the SCSC^{HF} trainees must buy into, in order to achieve a meaningful learning experience. The simulation centre training participants do not truly believe that there is a person in the scenario but they must believe enough, so that they perform as they would in real life. The Eidolon performance added a new dimensions to this conversation. My interest in the simulation centre was not in the technology itself, but in its affective potential and implications. It was my intention to question head on, to embrace and bring to life the challenges the simulation centre presents.

The project started through a serendipitous introduction to the SCSC^{HF} in 2013, through Babs McCool, Charitable Arts and Wellbeing Coordinator at Forth Valley Royal Hospital, while I was working on Mapping & Tracking, a locative media project organised by Artlink Central. The Mapping & Tracking project used the Forth Valley Royal Hospital site and surrounding forest, as its canvas and backdrop. From my first visit, I was intrigued by SCSC^{HF} and the possibility of developing a performance work that would open up a window into this unique space within the NHS, a world of high level technology, that is normally only accessible to medical professionals. The general public visit people in hospital or are patients themselves, but don't often get the opportunity to see the people, and equipment, which is being used, to help train healthcare professionals to be safer.

I set about obtaining funding to make such a performance project possible, beginning with a Creative Scotland grant, to undertake research and development, in 2013. This enabled me to undertake a period of observation, which included shadowing the SCSC^{HF} staff undertaking medical training scenarios for doctors, nurses and paramedics, from students to consultants, and using equipment from patient manikins to laparoscopy simulators. I operated as an observer, a viewer, a commentator and re-interpreter, attempting to challenge the activities of the simulation centre, through new insight and perspectives.

For SCSC^{HF} Eidolon was the first real foray into "the arts". Access to facilities, staff support and time was gifted by SCSC^{HF} to the Eidolon project, as support in kind, i.e. without cost. Such generous support by partners working in non-arts fields, with the vision, openness and curiosity to be able to speculatively enter into such arrangements is invaluable, and without this, projects like Eidolon would not happen. Such situations are fragile and challenging, but extremely potent. The success of Eidolon means that the SCSC^{HF} is now much more open to getting involved in other arts projects.

Towards the end of the research and development period I started to collaborate with actors Stanley Pattison and Pauline Goldsmith. This initially involved workshopping ideas, e.g. the ManiChat vignette, which features the manikin in conversation with an attending medical staff member (Stanley Pattison), prepping an upcoming medical simulation. The manikin (voiced by Pauline Goldsmith) melancholically meditates on its life as a generic, technological body, attempting to expose the real manikin, as opposed to the 'patient' it typically becomes within medical scenarios.

Following on from this initial research and development, the work went into further exploration and an early stage of production in 2014, funded by a Knowledge Exchange Impact (KE-Impact Award), from the University of Edinburgh. This funding enabled me to continue working with the $SCSC^{HF}$ staff, bring in more performers (specifically dancer Freya Jeffs), to expand the number of vignettes in development, and start to bring the work in progress to an audience through a series of 'showings'.

The structure of training at $SCSC^{HF}$ was re-enacted literally within the developing performance structure, borrowing their three stage method of training: briefing; simulation; de-brief, which Eidolon employed as a loose performance infrastructure. However, the typical simulated medical scenario structure was disrupted and punctured by a series of atypical events, an experiential series of immersive promenade encounters or vignettes, woven into a fractured narrative. The performance structure, still in development, was presented 'in-progress' as a single sequence narrative for audiences to experience, as a group in tandem, and as intertwining narrative sequences experienced by an audience split into multiple smaller groups. The Eidolon performance 'showings' brought together medical professionals, simulation technicians, actors, dancers and audience, all scrubbed up and robed so that performers and audience intertwined in an immersive, participatory experience (Fig. 1).

Fig. 1 Eidolon360, 2017, VR experience still. © Beverley Hood

In 2015, I was awarded a Small Arts Award, from the Wellcome Trust, and an additional Knowledge Exchange Impact Award (KE-Impact Award), from the University of Edinburgh, which enabled me to take the work into full production and bring it to public presentation. The SCSC^{HF} staff themselves were still very much embedded within this production process, both as technical and performance collaborators, sounding boards, and an audience group with a very specific knowledge and experience, to present showings of work-in-progress to.

The final production funding enabled me to further expand my collaborative group, in particular, to bring theatre and film director Jeremy Weller, on board as project Dramaturg. At this time, the performance existed as a series of separate vignettes, which had been performed in various combinations, at public showings in December 2014, March and July 2015 and April 2016. Documentation of the previous performances, and the audience feedback sessions that were part of them, were recorded, and subsequently analysed by myself and Jeremy, and our reflections fed back into the evolving production. Jeremy's role was to assist in creating a cohesive whole, from these multiple parts, the vignettes. To build a narrative structure, and emotional texture.

The Eidolon project that developed is a live performance created for the unique setting of medical simulation suites, and is experienced as a series of interconnected performance vignettes, presented within various spaces of the simulation centre, that the audience move between. It intertwines patient manikins, medical professionals, simulation technicians, professional performers and audience. The performance echoes, yet at the same time disrupts and transgresses, the everyday activities of the simulation centre. This disruption triggers the appearance of empathetic, emotional, ambiguous, and, at times, uncomfortably human, fissures, within the typical clinical simulation scenarios. It investigates the emotive and psychological potential of training manikins, centring around a technological body that is literally, physically manifest in real space (as opposed to a virtual, screen based representation of a body). Eidolon unsettles the ethical boundaries and taboos around the relationship between medical practitioner and patient, or patient manikin, and hints at the possibility of latent physical, psychological and emotional realms within human-like bodies. The manikin's disconcerting potentiality, bring an enormous sense of the 'uncanny valley', identified by Japanese roboticist Masahiro Mori in 1970s (Mori 1970). Switched off the manikin is inert, plastic, lifeless. Turned on, it has a pulse, a heartbeat and can be spoken through. The obvious plasticity, combined with a disconcerting blink that catches the corner of your eye, the breath you can feel upon your hand, resonates deep within our perceptions of what it means to be human and alive. It challenges us to question how many or few physical indicators are required to suggest an authentic presence? How does technology shift, interfere, enhance or change this? And it is here, in this almost indescribable space that denotes what becomes manifest, human, conscious and alive that this most recent work has taken me.

The simulation environment overwhelms us in its clinically accuracy, not just as an aesthetic experience but through the actual medical equipment in use. Alarms and monitors sound, live gases and drugs are introduced to the 'patient'. This is an intense space, that is simultaneously unreal and a heightened version of the real. In the world of simulation, the aim is to achieve 'psychological fidelity' (Curtis et al. 2012), where the participants being trained, gain such a resonant, multi-faceted, and physically embedded learning experience that it can be drawn upon as embodied knowledge in-the-field.

Eidolon is experienced by the audience as a state of sustained uncertainty, occupying the real, the experienced and the mediated, the live and transmitted, existing somewhere between rehearsal and performance. Importantly, it is not only the performers and medics that are active participants, the general public also enters the work as participants, required to directly participate and bring their own content, in both discussion and tasks during the performance, rather being cultural tourist/observer. The performance alternates between multiple variations upon the underlying deceit, within the $SCSC^{HF}$, that in some way the manikin is real. My approach was to subvert the typical and highlight the 'otherness'. This led to my embedding both the simulation itself i.e. a medical procedure where audience were totally immersed in the performance, wearing scrubs, and given roles in a simulated operation, for example a femoral hernia repair, and given a role (e.g. anaesthetic assistant), working alongside actual medics. But it also led to alternative routes, disrupting the existing procedures of the simulation environment with a series of atypical events or performative vignettes. One moment the audience might be participating in a simulated operation, the next they are tucked away in a classroom, watching a live multiscreen CCTV video feed of a seemingly private encounter happening elsewhere, or are placed behind two way mirrors, observing the tender re-building of a dis-assembled manikin. They are privy to hidden conversations and relationships between medics and apparently conscious manikins, unsure of whether they are performer, participant, or whether to act in a 'role'. Unease and discomfort are ever present. Throughout the performance, there is also an undercurrent, and a tension between the performers, who appear to get on better with the manikins than each other. Their encounters with the technological bodies, are where the tenderness and care are kept, not person-to-person.

In 2017, an additional element to the work, Eidolon360, was developed as a Virtual Reality (VR) artwork, experienced through a VR headset. Revisiting VR, some eighteen years later, I am now fascinated by its creative potential, particularly in creating empathy through immersive narrative. The work was developed in collaboration with Dr. Tom Flint, from the Centre for Interaction Design at Edinburgh Napier University, and transports the viewer from the role of passive filmic observer, to being the subject of the performance. The viewer, reclines on a hospital bed, and upon placing the headset on, finds themselves in a medical simulation centre, inhabiting the point of view of resuscitation manikin Resusci Anne, herself lying on a hospital bed. A medic (actress Pauline Goldsmith) approaches the viewer and sensitively recounts the origin story of simulated CPR (cardiopulmonary resuscitation), an intriguing tale of a mysterious drowned young woman, L'inconnue de la Seine, found in Paris in the late 1880s, who became Resusci Anne, the face of CPR, and has since been revived by over 300 million people worldwide. Eidolon360 attempts to pre-sent an emotionally resonant anecdote, as an immersive experience, scrutinising the overlaps between real life and simulation.

For the SCSC^{HF}, the benefits and contributions of Eidolon are multifaceted. On a practical level, the performance demonstrates to members of the public what happens in a real operation, the care involved, the equipment used and the communication between healthcare professionals. Much of what people thinks happens in a medical operating theatre comes from TV, which is often dramatised. Eidolon presents the audience with an opportunity to be a part of the medical team (in a safe manner). From the SCSC^{HF}'s point of view, the more the public is aware of their work, the better it is for the simulation centre. For doctors and nurses, Eidolon provided them with an opportunity to see an artistic performance in a familiar space but in a new context, making them think about their relationship with the equipment they train on, and to each other, especially as that equipment (particularly the patient manikins) becomes more and more life-like. Eidolon has also expanded the SCSC^{HF}'s view of the simulation centre as a place of learning. This used to mean a place specifically for healthcare professionals to learn but now includes a much wider audience.

The Eidolon performance's focus on uncertainty and empathy, exposes the empathy required to be a healthcare professional. The SCSC^{HF} focuses on non-technical skills (leadership, communication, situation awareness, etc.) rather than purely technical training, but had not previously explored empathy. As a result of the Eidolon project, this is now a real concern. So much so, that SCSC^{HF} is developing new training courses addressing empathy, for example, when dealing with end of life situations. Eidolon has been performed at The World Congress on Biomedical Ethics, Edinburgh Art Festival, the Scottish Centre for Simulation & Clinical Human Factors, Larbert, and at the Clinical Skills & Assessment Centre, Edinburgh Royal Infirmary as part of Professional Development courses for Advance Practitioner Nurses, studying at Edinburgh Napier University. The Eidolon monograph was published in 2016, with essays by Nicola White and Marina Warner. Eidolon360 was exhibited at the Interactions Gallery, British HCI 2017, at the University of Sunderland, and talks about the work have been widely presented including the Society in Europe for Simulation Applied to Medicine—SESAM Paris 2017 and Consciousness Reframed, DeTao University, Shanghai [with an accompanying paper published in Technoetic Arts (Hood 2016)].

The Eidolon project enabled me to take my creative practice into a unique and complex, environment, working with a highly accomplished interdisciplinary group of creative practitioners and medical professionals. This was a situation that constantly challenged me to re-examine my creative practice and approaches, in an attempt to remain creatively engaged, adaptive and agile. The project attempts to engage the audience with challenging questions about where humanity and consciousness lies within the body, and the effect of technical mediation, upon psychological and physical presence. What constitutes a real, authentic and meaningful experience within a simulated environment?

End Note

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Playing with Rhythm and Technology

Brigid Mary Costello

A common thread running through all my work is vitality—the sense of bringing things to life or animating relationships. This has led to a focus on rhythm, play, and the way that dynamic rhythms can create a vitality that encourages play. I create installations where the audience interacts with something and a response is then generated by a computer (or computers), so the artistic work emerges through the audiences' interactions. Lately I have also been creating generative data visualisations where the work emerges through a computer's interactions with a data set. I have a background in cinematography for film, and so moving images always play a large part in my work. I either use video images or animated images but some projects have combined both. That means that I am usually working with software for editing audio-visual media and also with software for creating 2D or 3D animation. Some projects use sensors in combination with interactive authoring software and others are created using a gaming engine. All of my projects involve programming in some way. I often work by myself but when I do collaborate it is mostly with sound designers or musicians. I have also collaborated with animators, programmers and even furniture designers. Collaboration for me is usually sparked by a combination of needing to create something outside my skillset and a looming deadline. It would be a very rare project that did not involve learning some new technology and its related skillset. My projects can also involve combining multiple technologies in new ways. But that's the fun part, provided you have time.

As an example, Fig. 1 shows one of my interactive installations called Just a Bit of Spin (2007–9).[1] This work is about the language of political spin. The visuals in the work are stop-motion video animations that were edited into short clips. They were then combined with audio clips that could be played and sequenced in response to interactive input using the visual programming software Max/MSP (Cycling74). This was done in collaboration with programmer Alastair Weakley. The interface is a physical spinning disk that mimics the old animation devices of early cinema. The disk is connected to a sensor that detects the direction and speed of movement. The computer reads the sensor data and feeds this into a computer, which then generates the video and audio responses. Alastair came on board to help

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_23

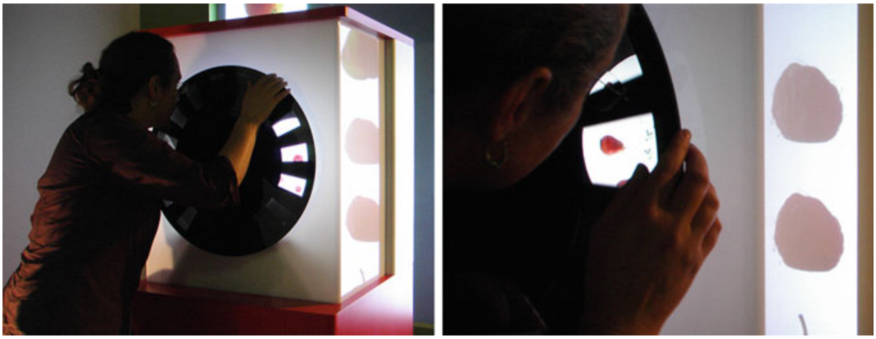

Fig. 1 Images of the artwork *Just a Bit of Spin* exhibited Powerhouse Museum, Sydney 2007. Photograph by Brigid Costello

solve an issue I was having with the smoothness and responsiveness of the video playback. Initially the video was divided into separate files and there were lags as each file would load and unload. Alastair's solution was to merge all the files into one and just shift in time across this file when calling up the different visual responses. The tactility of the disk and the look and feel of the cabinet that housed it were also an important part of the project and they were created in collaboration with furniture designer Joe Westbury. His late 1960s aesthetic with its rounded corners influenced the look and feel of the cabinet and later fed into the design style of the exhibition poster. The work was exhibited in places where there was very little supervision and lots of people passing through: so, both collaborations helped ensure that the work was accessible for all ages, robust enough to withstand a lot of use, and also safe for the public.

I would say that an important aspect of working creatively with technology is having an awareness of (and often resisting) the creative assumptions built into authoring tools. You need to consciously think about how a technology might be shaping your process and its outcome. This is particularly obvious when working with gaming engines, where, for example, the facility to destroy things is such an easy and inbuilt feature. That focus on destruction comes from the traditional structures of the types of shoot-em-up games that these engines were originally designed for. So, when I work with a game engine, I try to resist the lure of the ease with which you can create explosions, fragmentation or objects impacting with other objects. I also think that the ever-increasing tendency towards more and more "drag and drop" user-friendliness in creative software is similarly a double-edged sword. It can make producing creative works easier because people need less skill and effort to produce something. But it can also mean that people are using templates, filters, transitions, code snippets and the like that can make what they produce less creative in terms of novelty purely because it limits the palette that they are choosing from. With technology that someone is very familiar with, this palette is not constraining because they know how to move beyond the set structures when they want. If someone is a beginner, these set structures can end up driving design decisions when perhaps they shouldn't.

Although novelty is an important part of artistic works, it is the novelty of interactive art interfaces in combination with the tradition of "look but don't touch" in art galleries that can make it difficult to engage an audience. This can be a big issue for works that like mine that only exist in the moment of interaction. My approach to that has been to work with the creation of experiences that encourage playful engagement. Play experiences combine exploration (what does this do) with investigative creativity (what can I do with it). My theory is that if you can create a playful relationship between an audience and your technological interface, then this combination of exploration and creativity will overcome any shyness or timidity that might be caused by the interface or gallery environment. In order to maintain this type of playful engagement I have found that it helps to foster repeating cycles of exploration and creativity and that these cycles need to have a rhythm that produces a lively dynamic between the person interacting and the computer (Costello 2014). The vitality of this playful dynamic comes from the combination of a variety of different rhythms: rhythms that emerge from the relationship between action and response. This relationship is the driving force of all play experiences: you do an action and when something then happens in response you feel causally responsible for it. Groos describes this as the "pleasure of being a cause" (1898). In computer interaction, this causal relationship is a key compositional tool and can have many different rhythmic characters.

There is the fast feedback of direct control that relies on a tight micro-timed coupling between physical human input and computer output. This is the instantaneous connection between action and response that is like flicking a light switch and having a light turn on. Its playful power relies on the timing between action and response being so short that the human interactor has no doubt that they caused the response. The micro-second speed of the response also impacts whether something feels like direct real-time control or whether it feels "sluggish", with response times of 50–100 ms needed to create the pleasurable sense of real-time control (Swink 2009). In *Just a Bit of Spin* this rhythm occurred when the person interacting changed the spin direction of the disc, triggering a different sequence of images and audio. The person interacting had a sense of direct control over this change.

Then there is the slower more emergent sense of causality that comes from feeling like you have set something in motion or had an influence over a future sequence of events. Spinning things have a sense of vitality because of the way they continue to move after you have provided the original energy boost to start them off. It feels like you have breathed life into something. A lot of work in *Just a Bit of Spin* went into getting the weight, balance and mechanical motion of the disk just right so that it had a pleasurable tactile and vital motion that encouraged interaction. The speed of playback of the video and audio also mimicked the speed of the disc, amplifying this sense of bringing something to life and making the loss of energy as the disk slowed down more evident. This sparked lots of investigative play with the disk interface. I have found that you need both these slow emergent rhythms and the more usual fast rhythms of direct control for a play experience to engage attention for any period of time (Costello and Edmonds 2009). It's a matter of interweaving direct and emergent rhythmic characters and having them operating across a spectrum of speed.

Another crucial rhythmic aspect of a play experience relates to the levels of energy exchanged in these causal relationships and the quality of unpredictability in the responses. In play, energy and unpredictability work together to create a sense of a lively presence that can be played with. Technological interfaces don't automatically have either of these characteristics and so, if you are aiming to create playful rhythms, they must be factored into the design in a way that creates dynamic vitality. This vitality occurs in the moment of interaction and, in computer-based interaction designs, occurs as a result of the shared relationship between human and computer. As an example, think about bouncing a tennis ball. Its playfulness is a combination of the energy you put into the ball when you throw it and the energy it gives back when the ball hits a surface. The quality of the surface the ball hits creates an element of unpredictability as does the relationship between the skin of the ball and the way your moving hand connects with it. If the ball returned exactly to the same spot each time you bounced it (i.e. lacked unpredictability), you would quickly tire of it as a plaything. Equally if the ball was flat and failed to bounce high enough to meet your hand (i.e. lacked energy), you would soon get bored. Now imagine the same scenario with a large heavy basketball and then again with one of those super bouncy small rubber balls. Each has a different playful rhythmic character that depends on the combined energetic system of you, the ball, the surface, and the unpredictability you all produce together. I find it useful to think about interactions between humans and computers in a similar way. For instance, in *Just a Bit of Spin* there were three different levels of audio-visual content. These provided the type of unpredictability that the wall's surface gave in the example above. The switch between them only occurred when the person interacting put a lot of energy into the work by shifting the disk back and forth quickly (like scratching a record). The computer system and the human interactor create a rhythm of action and response with a dynamic vitality that emerges through an exchange of energy and unpredictability. Thinking like this about human computer interactions gives you a whole palette of different characters you can give to an interactive experience, depending on whether you match the scale of human energy, amplify it, reduce it or modulate it in some way.

A favourite definition of mine describes play as free movement within a more rigid structure (Salen and Zimmerman 2004: 304). The exchange of energy described above contributes a lot to this movement within play but it is the variability of unpredictability that is key for creating the freedom in that movement. Not having freedom of movement or being predictably precise is often the reason given for descriptions of computer-based art forms as mechanical, scripted, dead or lifeless. To counter this, electronic music synthesisers add imprecision to the rhythms of sounds in order to mimic the freedom of movement within human performance. The listener perceives and values not just the sounds but also the "sonic trace of the body" that is embedded in the rhythms of their presentation (Iyer 2002: 403). It is this trace of human motion that contributes to the sense of vitality. A similar appreciation of the traces of gestural bodily movement has been found to occur in viewers of visual art, with studies showing that the motor regions of the brain are activated as viewers imagine the gestures that produced the strokes (Gallese 2017). In *Just a Bit of Spin* those images and sounds that similarly contained traces of the moving body generated the most playful behaviours. In particular, a raspberry that squished and squelched as if pressed by a finger and a pear that disappeared with loud crunching bites (Fig. 2). This appreciation of imprecise rhythms is not just tied to traces of human movement. Our rhythmic perception is attuned to the imprecise periodicity of the natural world for ecological reasons. As prey, we need to move unpredictably to survive and as predator we need to attend to and read unpredictable rhythms in order to capture our prey (Hasty 1997: 94). The vitality we perceive in imprecise rhythms, our skill for hearing their imprecision and the pleasures we feel when we do all come from this ecological source. Inspiration for creating the freedom of unpredictable rhythms within playful interactive design can therefore come from the rhythms of all kinds of natural world movement from human, animal, insect or plant to oceans, weather or geology.

When I talk about unpredictability in terms of rhythm and play, I am not talking about the type of randomness that is relatively easy to simulate on a computer. Randomness has none of the rigid structure that play requires. If our bouncing tennis ball responded randomly each time we bounced it, we would hardly ever be able to catch it. There would be little pleasure or satisfaction in predicting where to position our hands, as there would be no pattern to learn. Rhythmic perception involves both anticipation and prediction. It is satisfying to correctly predict where a rhythmic event will land, but it is also satisfying to have a structure of prediction that is surprised. This is what musicians do when they expressively slide around beats, playing ahead or behind of the expected rhythm to create a groove. In order for us to perceive the groove we first need a structure of expectation so that a beat can be predicted, anticipated and our prediction surprised by a timing variation. A random collection of rhythmic events would not provide enough structure to

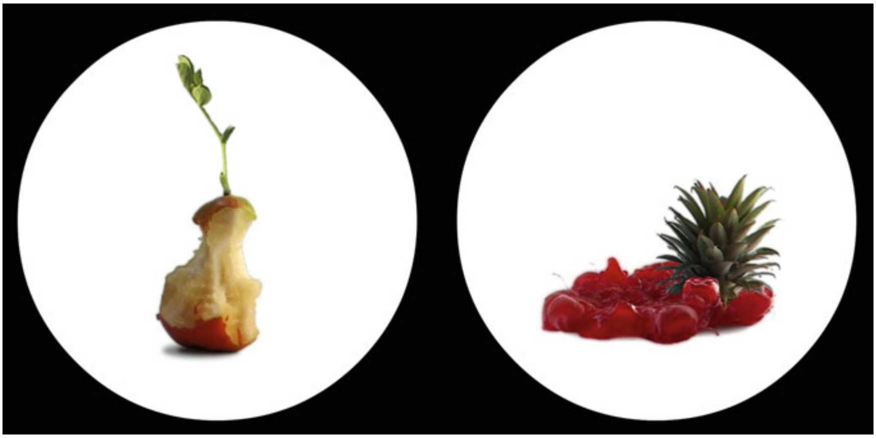

Fig. 2 Example image of two screens from the artwork *Just a Bit of Spin* 2007. Photography by Brigid Costello

create a stable sense of prediction. Thus, in *Just a Bit of Spin* there were layers of rhythmic material with different tempos and speeds and the complexity of their composition, when played by the person interacting, created a feeling of unpredictability. All these layers, however, were contained within an overarching structure that had a predictable learnable pattern. In music perception, the variations in timing of performed grooves create tension in the listener and are an important creative tool for composers (Roholt 2014: 108). This same kind of rhythmic tension can be used creatively in computer-based interaction design. We can strive to create rhythmic structures of action and response that both the computer and the human interactor can expressively play or groove with.

Thinking about human computer interaction in terms of rhythm has led to my current focus on improvisation as a form of rhythmic play that I would like to evoke through my work. I don't just mean that I want the computer to feel like a musical instrument that can be played expressively. I would like the relationship to feel like both human and computer are improvising together. Improvisation in a musical context is described as a moment-by-moment relationship between possibility and constraint. There is the palette of possible musical actions that can be performed and the constraint of the "dynamically evolving subset of this palette that is physically possible at any given moment." (Iyer 2002: 408–9). Hours of repetitive practice go into training the performing body so that the musician is able to make choices from that palette in the moment of performance. And here is where the art installation again butts up against the issue of the novelty of its interface and the common timid, single-use patterns of the art audience. While the computer can be programmed to mimic a trained musician, the audience member will necessarily be a novice, unless the work taps into an existing knowledge set. This was why the Just a Bit of Spin interface used the record-scratching gesture as a way to shift between levels. This was a movement that those interacting with an earlier prototype had quickly done and were clearly familiar with. The challenge for artists is to communicate the palette and accommodate the variable skill levels of each audience member. Also, if the computer is truly to feel like a co-performer, then it will need to listen to, learn from and respond to the rhythms of the human interactor.

The power of artists working with technology lies not just in the merit of their artistic product but also in the knowledges that their practice can produce about our relationships with those technologies. I see my work as contributing to creating an awareness of the intersection between technological and human rhythms. To raise questions about the ways these rhythms might disrupt, resonate or combine and to shed light on the energetic flows that create their patterns.

End Note

1. Video documentation of Just a Bit of Spin can be viewed here: https://youtu.be/hEaQw_VsdpM.

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Differentiating Interaction

Jennifer Seevinck

I am an artist and researcher working with the concept of emergence to create digital, interactive art systems. My interest in the electronic arts began in the 1990s when I was working with procedural computer graphics and architectural metaphors for creating virtual space. From 2000 I was building virtual reality (VR) environments for immersive and augmented reality systems for a range of applications, but in 2007 I began practice-based Ph.D. studies in order to focus on interactive art. This led to my interest in emergence and participant experiences during interactive art. It has continued to inform my work including the artworks discussed here, a recent monograph on *Emergence and Interactive Art* (Seevinck 2017), and my approach to teaching. In summary, my creative practice is largely driven by (1) emergence theory, (2) the conceptual framework or initial problem of a creative work, and (3) the research I do into people's experience of interactive art. This approach has meant that I'm also exploring interaction in concrete, formal ways. In the first section of this chapter I discuss these three aspects alongside creative work. In the latter half of this chapter I discuss some of the expressive potential of interaction.

Emergence

Emergence occurs when something new that is not immediately obvious or expected comes about. This is a new 'whole' that is more than a simple sum of parts. It is a Gestalt that is heterogeneously different to its constituting parts. And, by virtue of this heterogeneous novelty, it is also creative. It may also, at first or to our best understanding, be unexplainable. A comprehensive discussion of emergence and how it relates to interactive art has recently been published (Seevinck 2017). As is elaborated there, emergence can be understood as either *physical* or *perceptual*.

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_24

Physical emergence occurs in the natural, physical world. For example, a flock of geese is more than simply a collection of birds. Rather, this flock constitutes the specific interaction of the individuals to travel in each other's slip stream, resulting in reduced wind resistance for individuals and an ability for the flock to travel further together, than individuals would alone. The 'interaction between the parts' or individual birds, means that the flock is more than a simple sum of the birds and rather an emergent whole.

Perceptual emergence is the emergence of new shapes, behaviours and experiences in people. It draws on design research efforts in emergent shapes; new forms that 'emerge' perceptually when viewing drawings of multiple shapes that interact with each other (such as through overlapping or adjacency) to suggest new understandings. By drawing overlapping squares, one can, for example, perceive an emergent triangle shape. Similarly, one's ability to perceive the characteristic 'V' shape in a flock of snow geese is an example of perceptual emergence. Observation or more specifically, perception, characterises this type of emergence. It occurs within an observer, audience or participant and is, unlike physical emergence, reliant on an observer to exist. It is the experience of something qualitatively new, surprising and different to what was there before. It also involves some sort of creative interpretation or understanding in that observer, audience member or interaction participant.

Concept

In my work a concept drives the creative outcome, and the concept comes from an initial situation. The situation can be social such as a conversation or it can be a physical site such as a landscape. The situation functions as an early 'problem space' that, through the iterative processes of sketching, making and reflecting, informs a framework for the creative decision making. These processes work hand-in-hand with emergence theory.

For example, in 2012 a project with artists with Cerebral Palsy involved conversations that led me to questions around creative agency and creative experience. This drove my interactive art work, *Of me With me* (2015), where participant interaction is through a drawing gesture that generates echoing and divergent line drawings. These dynamic compositions facilitate a creative experience that is new, unpredictable and familiar to the participant because it stems from their initial drawing line. The system utilises a generative algorithm, coinciding with my work in *physical emergence* theory. The visuals that are created also enable the participant to experience creative, *perceptually emergent* compositions.

In later works *Light Currents* (2015) and *Dichroic Wade* (2016, Fig. 1) the concept stems from a place. Specifically, the physical landscape of the Brisbane river and light on the water informed early aesthetic investigations. The work

Fig. 1 Dichroic Wade Seevinck 2016 *Photo* A. Hearsey. Image courtesy the artist

involves bright colours and highlights from illuminated, dichroic glass pieces that move in response to people inside, as well as changes in the wind conditions outside, via real-time data feeds from online weather reporting agencies. The data feeds and concept around wind on the river relate the work to the site beyond the white gallery cube. It also gives form to the *hybrid*, real-networked place that we inhabit; one which crosses both spaces and where we increasingly exist across both, as a matter of course and, arguably, new ways of being in the world. Explicitly facilitating interaction in this hybrid type of space is discussed more later in the chapter. More discussion of the art systems can be found in Seevinck (2017).

Research and Making

My approach to creating artwork draws on both research and practice to inform one another. The practice sets the research agenda and the understandings gleaned through research inform the practice. It is a type of Practice-Based Research approach (e.g. see Edmonds and Candy 2010) and for me, the creation of the interactive artworks involves methods from Reflective Practice (Schön 1983), iterative design and interaction technologies. Evaluation of participant experience of the interaction also informs the ongoing thinking and making. Evaluations are conducted at various stages and include observing participant interactions with the art systems and conducting interviews. As well as influencing my practice and research, evaluation findings can contribute to more general understanding of people's experience of interactive art (e.g. see Seevinck 2017).

Towards a Differentiated Understanding of Interaction

Digital technologies have undergone rapid and significant changes. We have seen a shift from digital revolution in the 1990s through to the social media era (Paul 2015). Computation itself has shifted from the procedural execution of steps as in the processing of an algorithm to an emphasis on interaction (Dourish 2001). The domain of Human-Computer Interaction (HCI) has similarly changed, moving from an understanding of the user that focused on human factors through to understanding them as actors, and to considering broader contexts for computing beyond the workplace and participation (e.g. see Bannon 1992; Bødker 2006).

Digital art has also grown, changed and diversified. We see themes from artificial life to telepresence in the work and a variety of ways in which artists relate to technology or experience (e.g. Shanken 2008; Lieser 2010; Candy and Edmonds 2011; Paul 2015). With the increased capacity and influence of technology, we are expanding our understanding of the aesthetics around computing and digital technology. I also think that we have an increased capacity and opportunity to pursue a more nuanced understanding of interaction. This interest in the subtleties and variations of interaction has, for me, come about through practice and research. In making and writing about interactive experience I have started to think about the different aspects, or dimensions of interaction. What, for example, might be its essential or 'concrete' elements?

The idea of essential elements in art was core to the Concrete Art movement of last century. They are the material elements of work, such as the brush strokes or pigment. Importantly, they are also of greater concern than what the painting might depict. As artist Max Bill said, the work is about "*the fundamental elements of* painting*, the colour and form of the surface*" rather than naturalistic representation (Max Bill in Chilvers 2009).

In my practice I have been thinking in terms of concrete elements of interaction. *Light*, *response* and *gesture* have become focal points and I've investigated them as a part of the process of making interactive artworks. They are discussed next, alongside artworks that helped me understand and explore them.

Light

Light is a primary concern for *Light Currents* (2015) and *Dichroic Wade* (2016). I have worked to manipulate it directly, using pieces of suspended dichroic glass to reflect, filter and transmit, and effect shapes of colour on surrounding surfaces of wall, floor, ceiling or people. The colours are the product of layered materials and direction of materials. In this way, this direct manipulation of light as a material is articulating colour, movement and shape. Light is treated as a material that can be varied to create various effects along these dimensions. This is a different approach to that of modulating imagery for a projector. Rather, in these works, light is used in a painterly way and as expressive in its own right: it is the focus of the work. The manipulation of this element (light) is a primary concern for the work.

Light Currents is the first in this series of interactive artworks. Its technical implementation draws on the technologies and techniques of Physical Computing including sensors, actuators and a microcontroller (O'Sullivan and Igoe 2004). It consists of light, dichroic glass, wire and internet. The glass tiles are suspended horizontally on tautly spun steel wire. They are agitated by servo motors via vibrations sent along the wire, causing 'shimmers' of reflection to occur as they move. When a participant moves in the space, one of the servo motors moves and vibrates the glass tiles. The other motor also drives movement but this is informed by changes in the wind outside, as communicated by weather stations online, in real-time.

Dichroic Wade is a different system that is part of the same body of work. Here the glass pieces are suspended vertically as pendulums which move using three servo motors. Weather is accessed through internet servers and in real-time. Participant presence is also monitored though with the addition of facilitating proximity through an ultrasound sensor, to give a sense of people's approach. Where no participants were sensed in the gallery space, wind data from outside agitates the pendulums of glass pieces. An approaching participant can, however, interrupt the display to further agitate the same servos and suspended glass pieces. *Dichroic Wade* facilitates a variety of different reflections and has more opportunity for turbulence as well as cascading rhythms than I found with *Light Currents*. In making these works I became interested in exploring the different system behaviours and the types of response that could be generated.

Response, Gesture

Dichroic Wade utilised different types of responsive system behaviour. As mentioned, the proximity of a participant to the work was sensed in this work. It was coded so that when one approaches the work the agitation of the pendulums and the reflections would increase. This is a fairly common and easily understood type of responsive feedback because we already have mental models associated with, for example, going closer to a fire which will feel hotter.

Another more *solitary* mode of response was also implemented in this work. This was a 'crescendo' of movement followed by a period of stillness that would be triggered when a visitor was very close to the work, at the height of the sensors sensitivity. It is solitary in the sense that it is a self-contained composition, playing out without waiting for any more input from the audience to the art system.

Dichroic Wade and *Light Currents* also facilitate a *layered responsiveness* to the participant. I think of this as a combined response that blends participant presence/proximity *and* the changes in the weather outside. Both influence the behaviour of the servos which, in turn, agitate the suspended glass tiles. The combined layered response model visualises different places at the same time: the physical place inside where the participant and the work are as well as the physical place outside where the wind is blowing. And then there is also the virtual, internet data space that is augmenting the interior place.

Different types of responses provide different opportunities for meaning making. The immediate action of moving in front of this work causes it to change, agitate, and give a predictable feedback response. Or it can cause a crescendo of movement and a more solitary response. There is also the potential for types of distended meaning-making to occur, when the interaction is stretched out across space and place, as in the response that results from behaviour or input from the weather outside or other distant or seemingly separate elements.

The interactive artwork that uses drawing gesture as an input, *Of me With me* (2015) also explores aspects of response, though in a different way. Interaction involves a drawing gesture which is soon followed by 'echoes' of that gesture on the screen. Here the speed, direction and tempo of the participant's gesture affects the imagery and it echoes dynamically with slow, fast, staccato, fluid etc. gestures. This occurs across multiple scales and levels of detail, all in real-time, and an overall composition and movement arises that is new and unexpected yet also retains a pattern of self-similarity. It can be described as an *unfolding*, *echoing response*, where a participant's incoming, real-time gesture is both source and echo for the amplified, generated drawing. During evaluation of the work, highly variable and differentiated participant gestures were observed, ranging from making points, fluid contour drawing through to zig-zag gestures. Gesture and response are the focus of this work; they drive the echoing system behaviour and emergent imagery. The manipulation of these concrete elements of gesture and response were a primary concern.

Common to *light, response* and *gesture* are *space* and *time*. These can provide further insight into interaction and its expressive potential, and are discussed next.

Time, Space

Light, response and *gesture* all occur in *time* and *space*. And *time and space* are variable qualities, as has been explored by artists, architects, scientists and so on. Thinking about their nature in the context of interaction is useful because it can provide us further insight into the nature of interaction.

Firstly, thinking about *response* in terms of *time* reveals a range of possibilities. Response can be immediate like a key press or it can be delayed. The *influencing* behaviour of Ernest Edmonds *Shaping Forms* works (2007, 2011), for example, facilitates a system response to a participant action that is delayed: it occurs a day or two after the person acted. Tempo and rhythm, as explored in music and film, can also help thinking and exploring responsiveness in interaction. Response can also be thought of as an 'event', a type of temporal moment as in the 'crescendo' described above. Or it can be considered alongside gesture, in terms of relating to the participant's speed of interaction, as in *Of me With me* where the incoming speed of a participant's gesture directly affects the system speed.

Space is arguably also a variable quality despite our is a tendency to think of it as even: as a homogenous void between objects. Instead, space is informed by a myriad of factors from the quality of the light entering a room, the temperature or materials we encounter, through to personal context and meaning. The axial progression to the altar of a Gothic church will take us through different spaces informed by not only the increased ceiling height but also the quality of coloured light coming from the windows either side and our sense of getting closer to the altar and God. An encounter with Richard Serra's *Between the Torus and the Sphere* (2003–8), similarly illustrates the changing experience from tight to expansive, from being with others, to being surrounded by others, to being aware of them, or alone. Here there is an experience of tension in the space that makes one place feel different to another. These spaces are not all the same.

Hybrid Space for Art

Modern networking technology has meant that time and space are different in other ways as well. Not only do we have the metaphorical real-world space of VR, but we also have the pervasive presence of that digital data space in our everyday. Developments in Ubiquitous Computing mean that wireless networks and connected devices follow us and our audiences everywhere (Weiser 1991). Satellites and wireless internet servers have increased in both quantity and reach, and our smart phones are not only facilitating one-to-one communication but are also streaming announcements of this ongoing, other virtual world—from social media status updates to proximity alerts based on our current location. The ubiquity of networks and smart devices that prompt and interrupt us mean we are continually immersed in data and inhabiting this other virtual world in parallel to the real physical world. The virtual, networked layer overlays our understanding and the meaning of being in traditional, real world places and contexts. Everyday spaces have changed as we inhabit hybrid digital-physical space (e.g. see de Waal and de Lange 2008). This change also affects the art gallery. The white cube is now similarly hybrid, including virtual space in addition to the physical. Our understanding and experience of artwork in the gallery changes along with this change in context. Conventional or interactive, whatever the art form, its audience and space are mediated by the pervasive data networks and the space for the artwork more complex, multiplicitous and ambiguous. Artists can explicitly engage with this hybrid space to effect response this way. My artworks *Light Currents* and *Dichroic Wade* make the digital network explicit and accessible to gallery participants who are able to see the changes in the outside landscape evidenced here, as well as interact to change that representation of the landscape through their own movement in the space. Moreover, interacting with the weather data through local movement makes it possible for people to reconsider their relation to the immediate space and natural landscape outside.

Reflecting on Interaction, Emergence and Differentiation

My practice, research and engagement with emergence theory have led me to think about interaction in terms of openness, unpredictability and variation. They describe the rich space of potential interaction we have with one another in conversation, as well as in the physical world more broadly. They can be explored through models of emergence, ranging from simulating it within the digital domain, through to positioning a participant relative to the digital domain in rich and creative ways. In an emergent interactive art system, a participant could, for example, perceive new patterns such as a flock of birds moving as one, or an emergent butterfly shape from intersecting, moving glass reflections as in the *Dichroic Wade* evaluation. Or, as one participant with *Of me With me* was found to do, they may unexpectedly play a 'chasing' game with the drawing system (see also Seevinck 2017).

Participant interactions that are surprising or creative are important to me. They move beyond the dominant, HCI paradigm that prioritises efficiency, control and predictability; and away from an understanding of interaction as a procedure with 'action-reaction' implementations. Emergence can facilitate this move. The theories of emergence can explore depth and nuance in interaction.

I've come to think of interaction as a differentiated quality. In creating interactive art systems, I've worked with fundamental, or concrete, aspects of interaction such as the *light*, *response* and *gesture* described here. I've also looked for their internal subtleties and 'textures'. Light, for example, was explored in terms of reflection and transmission, informed largely by the materiality of the dichroic glass; while unfolding gestures were revealed through the lens of emergence theory.

Engaging with interaction in poetic and granular ways can provide interactive artists and designers with new, creative understandings. It can also inform more articulated experiences of digital art interaction in our increasingly hybrid everyday.

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The Illusion and Simulation of Complex Motion

Fré Ilgen

I am a human being who tries to understand the nature of being human. What seems to match my own person best is creating art and exploring knowledge. Because creating art and exploring knowledge has led me to focus on the approach, process, contents and communication, the medium in which I create is the least important, although every chosen medium is taken quite seriously. In summary, I am an artist creating paintings and sculptures, suspended, on the wall and free standing and, sometimes, I experiment with a computer.

In my current art practice, I am intrigued by creating visual appearances or entities that emerge in certain clustering of coloured, curved and rectilinear shapes and forms. These are always juxtaposed into compositions that suggest (simulate) a high order of complex motions. When I start a new piece, I have no precise idea how it will look or what it should look like. While making it I have to figure out its own 'logic'. A work of art is recognized as such by me and I call it finished at the moment when I have found its logic. This emerges out of my interaction, combining thought and bodily action, with the chosen material and an immediate and intense reflection on reality, as I understand it. Creating a work of art is an intense experience of life itself. Creating complex clusters of shapes and colours that are just individually different and in their context, seem to make sense but that cannot be de

scribed exactly in words, seems a close simulation of life itself.

My artistic development started with surrealist painting, later developing a gradual interest in geometric compositions and discovering the art and theory of constructivism.[1] Slowly I reached beyond constructivism through an emerging interest in the interrelations between object and self, between perception, action and thinking, and, finally, evolving a serious interest in possible reasons for our desire to create and admire art and our desire for beauty.

Discovering, studying and exploring the analogies between art, science and philosophy have proved to be rewarding and have become as important to me as creating works of art. Exhibitions, learning people's response and experiencing how people handle my works of art in their own environments had a tremendous

L. Candy et al., *Explorations in Art and Technology*, Springer Series
on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_25

influence on my thinking. After many years of working, exploring and travelling in and through a variety of countries in Europe, Asia and North America, I have noticed the importance of being exposed to a variety of different cultural influences—both historical and contemporary. It certainly helps you to put one's own thinking in a larger perspective.

Artist Residencies

The artist-in-residency I participated in at C&CRS in 1996 was an exciting experience that led to a crucial turning point in my artistic work. Because, in my sculptural work, I present a simulation of motions to the viewer, I was invited to experiment with a Virtual Reality (VR) system in which I could create actual motion in a computer-simulation. The experiences and results of my participation have been described before (Harris 1999; Ilgen 1996; Ilgen 2004). I was teamed up with Roy Kalawsky and his assistant who were experts in the VR technology available at Loughborough University.

Although I had never worked with VR before, I had some ideas about the kind of motion and basic geometrical shapes I wished to explore. As could be expected, we initially lost some time because of difficulties in communication due to the differences in vernacular and viewpoints of the different professions, Roy being a technical scientist and me an artist. For instance, I preferred to start working in a non-referential black VR space and Roy tried to convince me of the need to have a space with a floor, walls and a ceiling. After evaluating the process, we decided that I relatively quickly learned how to handle the VR joystick, because of my experience as a sculptor in manually handling forms and shapes every day.

If a suggestion might be made for an improvement in this kind of artist-in-residencies, it would be that there should be more time for the artists to work with the support staff as well as the computer. The sorting out of technicalities seems to absorb quite some time, leaving relatively little time for actual creative work.

The impact on my own work since then has been quite clear. First, it started me thinking a lot about the very new perspective a computer simulation (especially in immersive VR) provides on visual illusion. It also brought me to really consider the importance of manual handling as an essential aspect of our creative process and as a thought-enhancing activity. Secondly, it led me to start exploring both these aspects in new works. I developed paintings directly derived from the VR experiment, showing tremendous coloured space with only one or a few floating coloured bars. I called these 'virtual paintings'. Later this concept became unified with my sculptural concepts, leading to reliefs with real and with 'virtual' shapes. These I call "augmented reliefs". The most recent step has been to unify this relief-concept with my more calligraphic and spontaneous studies of colour splashes on paper. It should be added that the short and intense experience with VR also led me to develop much more complex simulations of space and motion than I ever did

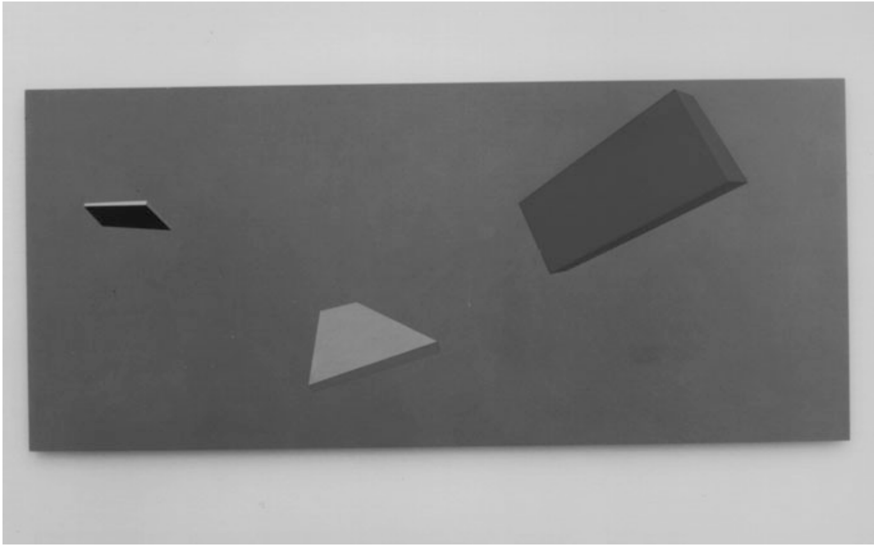

Fig. 1 Hey Joe, 1997 virtual painting © Fré Ilgen

before. It has that much changed my perception that since then I also perceive paintings of other artists in a different way. I view the canvas of a painting not so much as a flat surface anymore, but as a window into infinity comparable to a computer monitor equipped with a three-dimensional program (Fig. 1).

Reflections

It is, of course, impossible to predict where I will go next. I only suspect my works of art will become even more complex and hopefully, as such, to become even closer to life and the essence of ourselves. It is quite interesting to notice that 'illusion' as a concept in Occidental culture always is something to avoid at all costs, but since computer-technology has introduced the notion of 'simulation' this was immediately accepted as a positive concept. This change of words for in fact the same phenomenon certainly allows us to understand the importance of illusion/simulation in our everyday perception: for example, the illusion/simulation of change, space or motion. This is something an artist like Wassily Kandinsky was aware of with his concept of creating space in our perception in front of the painting, or as Frank Stella explored in his similar concept of a 'working-space' of a work of art, enveloping the observer.

It is my conviction that digital technologies are very important for any art practice. However, unfortunately people always tend to polarize and exaggerate.

I of course mean that fanatic believers in digital technologies propagate that these new media just replace any traditional means of creating art. The 150 years old history of the medium of photography has shown that a new technology may add important creative possibilities without ever really excluding painting or sculpture. It will take a few years more before the artificial hype about the proclaimed new media will abate and when notions like computer-artist or video-artist will be abandoned as labels altogether. It is the same as using labels like oil-painter or stone-sculptor in modern art. Although such specialization does exist, the contemporary artist chooses any medium and material that fits the concepts he or she wishes to explore. Because, for the average artist, it is difficult to have access to the right equipment and professional support, it is necessary that there are institutions that can provide both. It is important that these institutions stimulate a great variety of artists to explore and experiment with digital technologies, even though their normal practice does not necessarily seem to demand this (Figs. 2 and 3).

Because many professional artists do know what they do and what they would like to explore with digital technologies, and do not always have much time available, it will be important to develop an efficient and effective setup procedure. Much time is lost on preparing the technical equipment while the artist is present.

Fig. 2 No quarter, 1996, suspended sculpture © Fré Ilgen

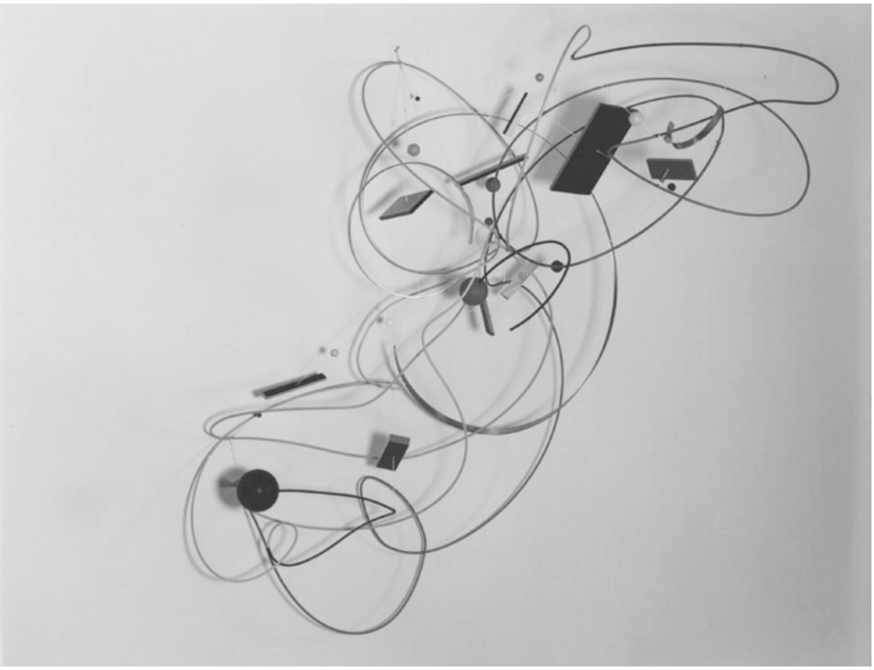

Fig. 3 Rave-on, 2000, wall sculpture © Fré Ilgen

This kind of talk should be done prior to the artists' visit. The artist is, for instance, present for a period of only three days, during which time he can work intensely with a good technical staff and hardly any preparatory discussions. One could imagine that artists will be approached on a regular basis by, for instance C&CRS, based on this institute's assumption that the interest of such an artist in digital technologies could exist. This implies reaching out, doing some active acquisition, instead of waiting for people to apply to come. At the same time, of course, it should be possible for artists to approach the institute directly to work with digital technologies.

For the future, I think it would be a very good idea if institutions like C&CRS could arrange for the leasing of equipment and technical support to artists, both for work in their own studios as well as for exhibition purposes. It is my conviction that it will become even more important in the near future to provide essential and realistic information about the opportunities and restrictions implied by using current digital technology and what will become available in the immediate future. The sooner one can overcome the hyperbole the more interested artists will be in digital technologies.

Current Practice and Technology

Since my participation in the C&CRS artist residencies in 1996 my practice has evolved. After some years realizing large commissioned, abstract sculptures, a string of international exhibitions, including biennials (e.g. Tagore 2015), and publishing two theory books (Ilgen 2004, 2014), my own artistic development led me to pick up semi and full figuration in paintings and sculptures I define as "Contemporary Classic" (Figs. 4 and 5). This shift from geometrical abstraction to semi and full figuration resulted from observing other people's viewing of art, in combination with my focus on understanding the natural components involved in experiencing art, supported by neuroscience. From 1996 until today my interest

Fig. 4 High prized woman, 2017, stainless steel, bronze, paper clay, paint—H119 × 52 × 50 cm, collection ulla and Heiner Pietzsch © Fré Ilgen

Fig. 5 Mindfields, 2017, oil on canvas, 175 × 250 cm © Fré Ilgen

in the simulation of complex motion has continued. Since my childhood, the Baroque has fascinated me. In earlier years, my artworks were more analogous to the Baroque in abstraction, whilst in recent years, they have been more directly inspired by the pictorial powers and figuration of the Baroque.

Technology always plays a role, but in my case, like crafts, a limited and supportive role, albeit quite influential. During the creative process, I often make digitized pictures and video recordings, playing with editing and handling lights and contrasts, helping me sort out next steps. The artworks though are executed in oil paints on canvas, or in various sculptural materials, like stainless steel, paper-clay or bronze.

For reading about my critical views on the perceptual differences between the artistic media labelled as traditional and as new media the reader is kindly referred to my books listed in the references. Two new books are currently being prepared for publication 2017–2018 about the art market and about the experience offered by works of art.

End Note

1. *Constructivism* is a direction in abstract art started in early twentieth century by artists like Malevitch, Mondriaan, Gabo, etc., which views the world as constructed of certain universal and elementary units that function as building blocks for the perceptible world. It is an artistic development arising from

nineteenth century knowledge in science and philosophy, such as Non-Euclidian geometry, Schopenhauer's ideas on the will and nature of things, colour theories, metaphysical interests in other cultures (esp. Hinduism and Buddhism) and the emerging importance of particle physics ideas on space/time.

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LocalStyle > Forward

Marlena Novak and Jay Alan Yim

Facing the complications of the Anthropocene,[1] collaborative efforts are more critical than ever; practitioners from all disciplines must focus on sustainability. The vital relevance of this engagement is cleverly presented in “The Collapse of the Western Civilization”, a novella set in 2393. Though anthropogenic inventions can be regarded alternately as either root causes or needed solutions, we believe that art utilising technology can empower others to envision ways to move forward (Oreskes and Conway 2014).

Switched >ON<

[Novak:] Looking back over various phases of my career, a thread runs through them: I have long been interested in the social and philosophical implications when one realizes that ‘seeing is not believing’ since it is within the limits of our perceptual framework that we interpret and act within the world. Before I embraced a digital toolset, my traditional artistic training had foregrounded the structural knowledge gained while enrolled at Carnegie-Mellon University; its affiliation with the University of Pittsburgh Medical School gave us access to critical resources to learn anatomy firsthand. The seeds for later collaborative efforts involving technology were planted by friendships with CMU faculty scientists, and an early 1970s film project involving an industrial T-3 robot choreographed to Shostakovich’s Eighth String Quartet. A diversion that determined a significant direction in my art practice found me living and working at sea for the better part of 1983 as one of only seven crew members aboard a 120-foot sail cargo ketch. Experiences during this journey—including thirty days under sail without sight of land (and surviving

The original version of this chapter was revised: Author name has been updated. The correction to this chapter is available at https://doi.org/10.1007/978-1-4471-7367-0_39

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_26

two life-or-death situations)—instilled deep respect for the environment and a private commitment to addressing global concerns in my art.

Near the end of the millennium, I was presented with a pair of opportunities to utilize time-based digital media; the expanded potential transformed my practice, re-orientating its centre with the computer as my primary tool. Grants from Northwestern University's Center for Interdisciplinary Research in the Arts and Loughborough University's Creativity & Cognition Research Studios fostered the development of two projects in succession. The first, *Thresholds* (1998), a live performance with a poet, an improvising cellist, and digital video projection, premiered at the Mary and Leigh Block Museum. For *Dancing Cranes* (2002) I invited composer Jay Alan Yim to collaborate; this marked the inception in 2000 of localStyle as a collective platform.[2] Exploring perception in both visual and now sonic domains was a clearly articulated bridge between my previous work and the context that we would henceforth pursue.

[Novak and Yim] *Dancing Cranes* entered both museum and corporate collections and has had a wide screening history in Europe and the USA.[3] A survey of our projects since then might be divided into those addressing socio-political issues via formal strategies, content, or both, and projects that address our relationship to nonhuman others (and what we can learn from those encounters). However, this turns out not to be a neatly chronologized oeuvre as both preoccupations are intertwined.

The Terrain of Political and Socioeconomic Fracture

The confluence of water, wind, electricity, petroleum, capital, data, transport, and power inspired *Fluid Mechanics Remix* (2001/2007),[4] a video work with sound. The title references the branch of physics studying the behaviour of anything that flows. These flows are entangled because our economies rely on water as both commodity and transportation medium for people and goods. Modern container shipping revolutionized the speed and profitability of global commerce, but even in the sixteenth century the incentive to maximize the efficiency of moving high-value materials led to constructing a brine pipeline in Austria's bucolic Salzkammergut. Connecting Hallstatt's mine through the locks at Lauffen to the Ebensee factory, the pipeline intensified extraction, as salt has been crucial for millennia, not just for food preparation and preservation, but for making paper, leather, aluminium, and countless other products. *Fluid Mechanics Remix* juxtaposes this past with our present: unsustainable industrial development confronts us with urgent climate and ecosystem concerns, producing environmental turbulence. The sound design was intended as a reenactment, by 'mining' the audio files embedded in Windows XP and OS9 and remanufacturing them.

Responding to a commission from the Chicago Cultural Center's Site Unseen Festival with *Cite Unscene* (2007), our proposal took the form of an immersive audiovisual installation. The centrepiece was a grand marble staircase, converted into a video projection surface that would nevertheless be used by audience members, compelling them to become part of the work. An antique perambulator concealing wireless speakers was positioned at ground level; twelve additional speakers were placed around the periphery. Sergei Eisenstein's Odessa Steps sequence from "Battleship Potemkin" was chosen as the trigger for interviewing colleagues using their individualized concerns as content was a way to sidestep our biases (Eisenstein 1925). The pram careening down a flight of stairs amidst a hail of gunfire is burned into our filmic memory, underscoring the project's theme: something vulnerable, precious, and urgently needing protection. Our interviewees voiced concerns ranging from ecological topics such as apian colony collapse disorder, deforestation, and global overpopulation, to the loss of safe spaces for closeted subcultures, presidential overreach, and militarized regime change. Computer transcription decoded melodies and rhythms from human speech; that data was electronically orchestrated and recombined with the original voices, emanating from the carriage and the surround system. Imagery in each segment of the 27-minute video-loop reinforced those concerns. A recurring visual palimpsest superimposed footage of the marble stairs from nearby Union Station, which Brian DePalma had chosen for his own Eisenstein tribute in the climax of "The Untouchables" (DePalma 1987). This 'doppelganger' on the Cultural Centre's stairs created an intervention fusing both sites and multiple scenes into an unstable cinematic citation: viewers ascending and descending had to literally 'watch their step'.

We encountered disruption on an enormous scale during a 2008 research trip to Iceland. The North American and Eurasian tectonic plates are separating at the rate of two millimetres per year: at Thingvellir, Iceland is being formed in the shadow of a towering, kilometer-long basalt cliff. This phenomenon provided the springboard for *∼plicity* (2009), a live performance piece combining music and video, created for Tel Aviv-based ensemble Musica Nova at the request of artistic director Amnon Wolman. Having had long acquaintance with his politics and desire for Israel to find a progressive solution for Palestine, we understood that tension in the Middle East was intractable, and thematized it: unrelenting forces are pulling continents and people apart, counterbalanced by a reciprocal yearning to draw together, build bridges across divides, and strengthen community. The title indicates the complexity of these relationships and strategies for negotiating the precarious Rift: implicit, explicit, complicit, duplicity, multiplicity. The score is a template for contingency, with instructions for both veejay and musicians, where the orchestration is variable. Players are challenged by windows of opportunity to address confrontations, shift allegiances, form partnerships, and collectively map a course through changing terrain. The veejay operates similarly with sets of curated video clips, as a structured improvisor in parallel or counterpoint to the musicians, modulating their choice of visual transformations on Icelandic footage. After *∼plicity's* premiere, Musica Nova performed it in Jerusalem and elsewhere in Israel; the work received its US premiere in 2010 by Ensemble Dal Niente.

Encounters with Nonhuman Others

Negotiating territories takes place at multiple levels, and among multiple species. The second thread that emerges foregrounds our fascination with the behaviour of animals, plants, and fungi within the world we share. Three of our more complex endeavours expanded localStyle to explicitly address nonhuman others. Even from a necessarily anthropocentric point of departure, each of these is an opportunity to reassess our own subjective bias and adopt a more critical stance.

Our audience re-entered the picture when we invited roboticist Ian Horswill to collaborate on the interactive installation, *pr!ck* (2006/2008). It was inspired by the mating behaviour of hermaphroditic Australian marine flatworms; each has two penises but no female orifices. This is one of the least common animal mating practices; marine biologists refer to it as 'penis fencing'. We saw this as an opportunity to feature the non-binary as personae with a truly reciprocal relationship. The flatworms were represented as two perfect spheres (one red, one blue) within Horswill's Meta programming environment. The virtual creatures also had two penises; circling each other, they tried to gain an advantageous position. Success resulted in the de facto father injecting their colour into the de facto mother, which turned violet before fading back to their original hue. Video games provided the sonic model: against an eerie background ambience, certain characteristics or actions—energy levels, excitement, attempted copulations, successful inseminations—would be matched by electronic audio cues. Webcam data from participants' physical motions (calibrated to require using one's entire body) redirected the invisible current of fluid the creatures were suspended within, thus deflecting their attempts to mate. Meanwhile, both creatures implacably continued their behaviour, simultaneously a duel and a dance.

Next we joined forces with neurobiologist/engineer Malcolm MacIver to develop *scale* (Novak and Yim 2017), involving live electric fish from the Amazon (Funk 2014).[5] They comprise a 'choir' whose sonified electrical fields provide the source tones for an immersive interactive installation. They use their periodically oscillating fields—with frequencies typically in the range of 100–2900 Hz—to locate food, shelter, mates, and avoid predators. Each species has a characteristic frequency, 'sounding' at different pitches. Scientists have discovered that if two nearby individuals are producing the same frequency, they engage in Jamming Avoidance Response, adjusting their fields to be non-identical. Through this collaboration localStyle learned that these remarkable fish have contributed greatly to human understanding of how the brain works, in particular decoding how they (and we) have a special neural circuit that subtracts most of the sensory data caused by one's own movement allowing each to be more attentive to their environment. Few laypeople know of them and their qualities; thus, one of our goals was to foster wider awareness of the scientific contributions of the fish and the fragility of the Amazon River Basin. The surrounding rainforest has often been the subject of ecological attention without a corresponding concern for the rivers themselves.

Perhaps the fish could serve an ambassadorial role via the attention garnered by our installation.

Twelve different species yielded a corresponding array of frequencies. The work was designed with their safety and wellbeing as paramount, with considerably larger tanks than the standard in research facilities, each outfitted with a horizontal, transparent acrylic tube for them to rest inside. A sophisticated filtration and conditioning system continuously cleaned the water, monitored the microbial level, and replicated the temperature of their original habitat; the presenting venue provided refrigerated live bloodworms, their preferred food. Each of the twelve tank units incorporated a pair of bespoke underwater sensors, a special circuit board handling sensor preamplification including a colour LED display indicating signal strength, and a loudspeaker. Signals were routed to a concealed computer system, passed through a Max patch, and returned to the corresponding speakers. The units were arranged in a 120° arc, using custom-fabricated aluminium stands connected together for stability. A touchscreen—with an easily learned user interface—enabled participants to selectively listen to individual fish or any combination, and control the relative volume. Each channel had a button to instantly mute or activate it, and a second button that added a predesigned chain of effects to that channel's signal. (This feature was included because otherwise the sonified signals were essentially steady, minimally changing tones (Fig. 1).)

Throughout its premiere at Eindhoven's STRP Festival (NL), we had many conversations with visitors, becoming the primary conduit for sharing the ecological aspects of the project. An as-yet-unrealized feature that could advance these

Fig. 1 Scale: four installation views—clockwise from upper left: STRP festival (Eindhoven NL 2010), STRP, translife triennial (NAMOC, Beijing CN 2011) © localStyle

goals more would involve designing a system for participants to record personal ringtones, in return for the donation of one euro/dollar/pound, which would go to a charitable fund protecting the Amazon. We conceptualized this during the initial development phase, as it would be simple to obtain a stereo mix from the Max patch. But designing a kiosk to handle receiving donations, archiving participants' recordings, and distributing download links to individual email addresses exceeded our ability to engineer it within the festival's timeframe, so it remains latent. During STRP, we were invited to present *scale* at the 2011 New Media Triennial in Beijing's National Art Museum of China, thematically titled TransLife, thus introducing the qualities of these fish to an audience on another continent. Experience gained as a result of this project was instrumental to Novak's contribution to the CAA Task Force on the Use of Human and Animal Subjects in Art as they developed suggested guidelines for curators, venues, and artists working with live subjects.

The next project began in 1995 in our Amsterdam base. The Eurasian Blackbird (*Turdus merula*) has a double-chambered syrinx, resulting in the capacity to produce two different pitches simultaneously, rapidly alternating between them, or generating complex chords due to intermodulation. Over several years our encounter with Dutch merels evolved into an obsession with their incredibly varied improvisational singing. While engaged in ordinary tasks we heard them singing throughout the city, finding ourselves transfixed; we responded with an interactive audiovisual project. Honouring the spontaneity of those occurrences and avoiding reflexive aestheticization of the material, we set up process-driven constraints. A series of dérives were triggered by hearing a merel: tripod deployed, camera aimed…sometimes it would remain in place long enough to be recorded, but often it would depart. The dérive continued until we heard another, redirecting us. Ultimately *Bird* (2012–14) incorporated multiple types of moving image, algorithmic sound design, and interactivity. The work then became a collaboration between localStyle and Jesus Duran, a software engineer and artist. The project evolved over three iterations—the University of New Mexico Art Museum (2012), Taipei Digital Art Festival (2012), and Amsterdam's Zone2Source (2014); these remarks will centre on the most recent.

Alice Smits, curator of the Zone2Source projects in the Amstelpark, invited us to make a version for their main venue, Het Glazen Huis (The Glass House). This space consists of a 150 m^2 glass-walled square connected by a small antechamber to a windowless 47 m^2 oval. The architectural contrast stimulated us to reconfigure the work as a transparent box housing a hexaphonic sound installation, proceeding into the more intimate inner sanctum. Visitors entered a zone of spatialized blackbird singing, with overhead sounds moving unpredictably around the space, functioning as a prelude to the more intense focus of the interactive video installation. The glass structure allowed for another level of site-specific interconnection as the flora and fauna of the park were visibly active elements in *Bird*. Upon entering the oval room two infrared cameras enabled a computer to track a visitor's movements, superimposing their position over the projection via trail-masking. Moving images explored different kinds of video and 3D animation: (1) the drift-driven cityscape; (2) closeup footage of merels; and (3) computer generated dreamscapes inspired by the birds. Each subplaylist had multiple segments; hoping to evoke the sense of unexpected encounters with merels, playlist order was determined by a non-human agent. Offstage was an unseen Virtual Blackbird, algorithmically improvising according to "experimental bird grammar": although individual notes were authentic merel samples, the algorithm tried to stay within the parameters of the phrases generally sung by blackbirds. This continuously recomposed song was what visitors heard in the Glass House. The Virtual Blackbird also analysed the tracking system data, shuffled the moving image playlist, and determined its own spatial position in the hexaphonic circle.

One person reported they hadn't consciously heard the bird before experiencing our piece, but now they heard it all the time: mediation with technological art actualized that participant's awareness. Others noticed that several winged residents in the park seemed curious enough about the sound of an unfamiliar bird to approach the pavilion for a closer look…. The next step along this path could be partnering with an ornithologist to design an experiment testing reactions from *Turdus merulus* in response to our experimental bird grammar (Fig. 2) (Abe and Watanabe 2011).

Fig. 2 Naming things, movement 5: dining tsars [Catherine the great's banquet setting, biobot reconnaissance, vigilant Haniwa horses, against the Skies of March]: black and white still from colour 3D computer-generated animation with sound © Marlena Novak

Destabilising Certitude

"Animals from higher dimensions (whose shapes change as they pass temporarily through ours during their annual migration)" make their debut in *Naming Things* (2015–16), our most recent piece. In Jorge Luis Borges' essay "The Analytical Language of John Wilkins" there is a passage where he recalls

> …a certain Chinese encyclopedia entitled "The Celestial Emporium of Benevolent Knowledge". In its pages it is written that animals can be divided into: (A) those belonging to the Emperor, (B) those that are embalmed, (C) those that are tame, (D) pigs, (E) sirens, (F) imaginary animals, (G) wild dogs, (H) those included in this classification, (I) those that move as if crazed, (J) those that are uncountable, (K) those painted with the finest brush made of camel hair, (L) miscellaneous, (M) those which have just broken a vase, and (N) those which, from a distance, look like flies.

By blurring the line between fact and fiction Borges subverts our confidence in the infallibility of mankind's efforts to make sense of the world. This passage was the inspiration for Michel Foucault's book, "The Order of Things" (Foucault 1994). As one of the Borgesian tactics that *Naming Things* emulates, many kinds of animals are juxtaposed in series, with a presumptively logical framework that is progressively destabilized by absurdity. Some of the animal representations in the twenty-minute moving-image installation are woven into the fabric of the work recurrently (albeit in different roles), thus linking disjunct passages, and further undermining the certainty of even the fictitious order.

We are left wondering if we can ever know ontologically how the world is organized. We will need to re-categorize and renegotiate boundaries between the biological and artificial, between the real and the virtual, between carbon-based and silicon-based entities, between one object and another, between hyper-objects. Actually, this re-taxonomization is already underway: traditionally, morphology rooted in observation was the basis for organizing biology. But with the advent of genome sequencing and Big Data, scientists must re-evaluate the relatedness of all living things. The fundamental distinctions are in the underlying genes, not the outward appearance: once again we learn that seeing might not be believing (Mooallem 2014). Though in *Naming Things* we have endeavoured to maintain a light-hearted atmosphere overall, problematizing our own faith in human-designed knowledge systems is a serious consideration as the search for Anthropocene solutions becomes more urgent. We see the work as just one contribution to a vastly broader project that must necessarily expand to engage technology along with collaborative practitioners from all fields of human activity.

End Notes

1. The Anthropocene is a proposed epoch dating from the commencement of significant human impact on the Earth's geology and ecosystems. More information at: https://www.schweizerbart.de/papers/nos/detail/50/87461/Making_the_case_for_a_formal_Anthropocene_Epoch_an_analysis_of_ongoing_critiques.
2. https://www.localstyle.tv.
3. The largest-scale presentations were in Berlin at Sony Center, and since June 2017 as a specially-commissioned version in Prudential Plaza's 13 × 2 m LED wall in downtown Chicago.
4. https://vimeo.com/52183618.
5. https://vimeo.com/19933816.

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Chance, Poetry and Computational Art: The Visual Theogonies

Fabrizio Poltronieri

The first time I had contact with computers was quite early on in my life. One day, when I was about 8 years old, my father came home with a mysterious looking box whose contents would change my perception and way of interacting with the world for the rest of my life. Inside that box there was a Brazilian clone of a ZX-Spectrum, a classic British microcomputer. Nowadays it is increasingly common to see children, even younger than 8 years old, programming their Raspberry PIs with Python, a programming language that is increasingly used by computer enthusiasts, scientists, artists and professional coders. The fact is that in 1985 I was living in Porto Alegre in southern Brazil, and I believe that I was one of the only people in the city, and especially of my age, to have a microcomputer. If you didn't know how to program back then, a computer's usefulness was quite limited. Therefore, practically every single day since that box turned up at home, I dedicate some time to programming. It is interesting to note that I have always perceived the act of programming as an extremely playful and creative activity, and not just as technical work. For me, programming has always been an experimental activity, in which computers are playgrounds where I have always given wings to my creativity. After my degrees in mathematics and in graphic design, it dawned on me that art would be a fertile ground for combining the two disciplines. Continuing my academic education, I completed my Ph.D. in Semiotics, with a thesis on the role of chance in computational art, and completed two Post-Doc researches on the same theme, one in England and the other in Germany.

Two elements have always been essential to me: The concept that artists who work with computers should know how to program and the influence of philosophical concepts on my aesthetic proposals, especially those deriving from the field of semiotics and logic. This strong presence of philosophical concepts is responsible for what I understand as art and for my refusal to use the term "work" to designate the products of my artistic practice. What I make are plays, with a small

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_27

number of basic rules, in the sense that Gadamer (2006) use the concept of play. To follow said rules is to play the games proposed. And in this playing there is a sacred seriousness, an absolute respect for art's role as a pathway to freedom through aesthetics.[1]

The Iconic Theogonies and the role of chance on computational art

This text discusses images that are part of my series "Visual Theogonies" (2014), which arose out of a playful game with the poem "Theogony: The origin of the gods", by the Greek poet Hesiod[2] (Most 2006). Chance is a concept that divides opinions in the field of computational art (Challinor 1971, Dietrich 1986) and has been a recurrent subject in the field of computer sciences as well (Zenil 2011). My stand in this text is not to refute either side,[3] but rather to state that chance is a key component of my practice as an artist. To demonstrate the action of chance applied in the production of programs related to computational art in a context of dialogue with poetry, I present two visual theogonies (Figs. 1 and 2) generated by software that I developed in Ruby language. This software produces images that do not have external indexes, in other words, these images are fruit of the pure manipulation by chance of a given set of data inside the computer's memory.

In order to achieve a satisfactory level of mathematical chance (see the theoretical discussion about this concept further on), my software employs two computational techniques: A pseudo random number generator (PRNG) and a true random number generator (TRNG), whose randomness is generated via atmospheric noise, a service provided by the website RANDOM.ORG,[4] and by software I programmed that measures the time in milliseconds between keystrokes on my computer keyboard. This software, coded in the C language, runs as a background Linux service, observing the keystrokes and storing the time measured on a database.

PRNGs and TRNGs are the two basic types of random number generators. PRNGs are based on computational algorithms and produce sequences of numbers determined by the value of an initial state. They are deterministic formulas for generating sequences of numbers that look random.

For the theogonies I used a state-of-the-art PRNG algorithm called WELL (Well Equidistributed Long-period Linear) (Panneton and L'Ecuyer 2006), a generator developed in 2006 that has a very chaotic nature and offers good performance in terms of randomness. Extracts from Hesiod's original poem were injected into the code to serve as seeds, or initial states, for the PRNG.

TRGNs use randomness that appears in physical phenomena, for example, thermal noise generated by resistors, noise generated by semiconductors, jitter in ring oscillators or randomness that results from nuclear decay. The data obtained from these sources is unpredictable in the sense that it has high entropy, producing

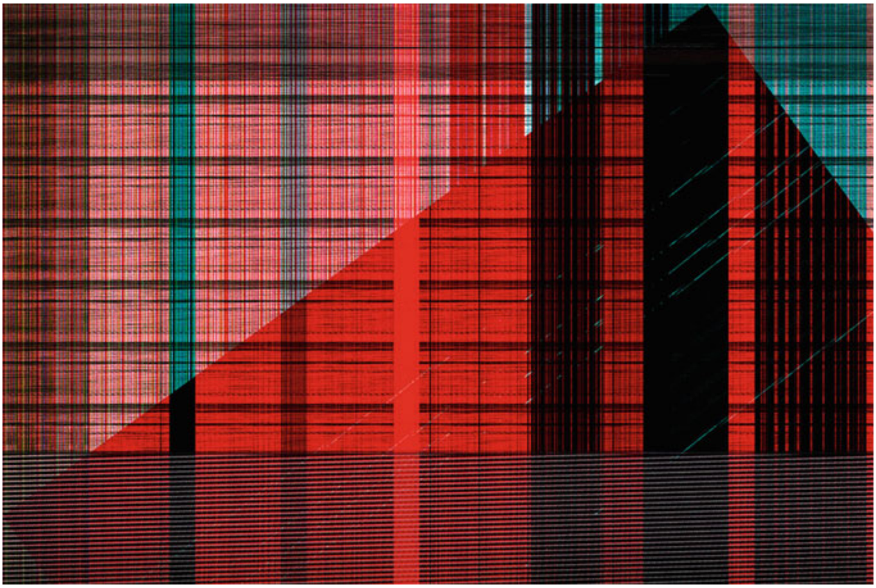

Fig. 1 ARTEMIS (Ἄρτεμις), 2014, Ruby code, Glicée print, 90 × 60 cm, Private collection—"Leto, mingling in love with aegis-holding Zeus, gave birth to Apollo and arrow-shooting Artemis, children lovely beyond all Sky's descendants."

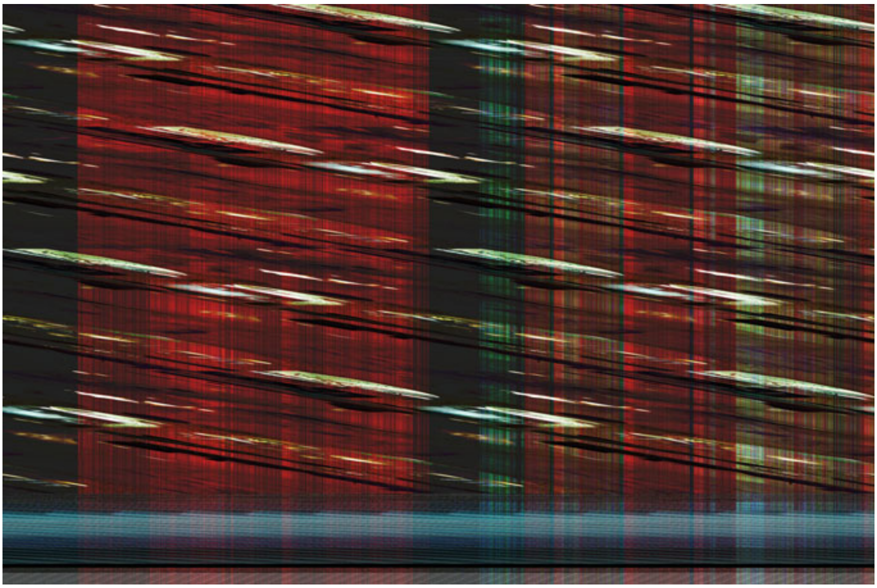

Fig. 2 CALLIOPE (Καλλιόπη), 2014, Ruby code, Glicée print, 90 × 60 cm. Victoria and Albert Museum, London—"These things tell me from the beginning, Muses who have your mansions on Olympus, and tell which one of them was born first"

high-quality unpredictable randomness (Jiang et al. 2017). However, sequences of numbers generated by TRGNs are usually costly to obtain, and this is the reason why I chose a mixed approach.

When the theogonical generator software starts, it gets two numbers from RANDOM.ORG. These numbers inform the amount of computer memory that will be used as raw material to generate a theogonie, providing the initial and final memory addresses to be captured.

Using a forensic memory dump tool called "Linux Memory Grabber",[5] the live content of my computer's RAM is extracted and manipulated by a combination of multithread actions chosen by the analyses of a mix of PRNGs' and TRGNs' numbers. These actions are finally translated into images, generating the final image.

Hesiod's poem is about the Greek gods' birth process and, as a result, the image series receives the subtitle "images of the computational god", since in this case the gods are transmuted according to the will of computational algorithms.

The programming code developed to create this series of images is a representation of the visual theogonies themselves, or even, the visual theogonies are the representation of some of the possibilities listed in the codes. It is not a mere mirror, but rather a more complex operation, since the codes give form to the images, as they are created from computational scripts. Thus, to look at and understand the programming codes involved is to already contemplate, in part, the images formed as a result of the clash of the infinite possibilities of chance with the otherness of the programming algorithm.

The software is, hence, a true representative of the Platonic iconoclastic doctrine (Plato 2007), insofar as it breaks with mimesis.

The dialogue with chance manifests itself fully in these images, since the eventualities of chance, that derive directly from its possibilities, become events based on the manifestation of possibilities that would not even be able to be inventoried in any other manner. In the code's execution occurs the presentation of the images of the "computational God", true chaos in preparation for the emergence of an organized cosmos. As a presentation of chaos, the visual Theogonies do not point to external referents, and divinity brings us the result of pure play: images that are poetic fruits of chance.

Chance and phenomenology

In order to comprehend chance, it is necessary to note that it is an ontologically indispensable concept, which is at the root of cosmic existence and is biologically and cognitively essential to man (Lestienne 1993), although many times it may still be seen as an idea that is hard to grasp and define objectively.

Aristotle (1998) had already defined the "accidental being", whose characteristics are likely to be correlated with chance. For him, the accidental being is characterized as being fortuitous or casual: it is what may not be, what is not always nor most of the time. For example, it is not, by any means, necessary for a man to be pale or nervous. That this man presents such qualities is accidental, fortuitous and casual, since they could, indifferently, be present in this man or not. However, it is necessary for man to have qualities. In the Aristotelian conception, accident is characterized by unpredictability, because there is no way to determine what provoked it or what were its causes (Aristotle 1998). The accidental being forms itself, nothing external exists that says how it should be or act. Its ultimate cause—that which constitutes the end or purpose of things and actions—is indeterminate, being constantly under construction.

How can one get to know that which does not present a defined pattern of behaviour? Regarding the impossibility of a science dealing with the accidental, Aristotle (1998) reached the conclusion that all of science refers to that which happens based on expected patterns. If this were not the case, the philosopher asks, how would it be possible to learn or teach others? There is evidence that the objects of science should behave predictably, whereas in relation to the accident and its causes there is no science.

Peirce (EP2) reminds us that science begins to be exact when it becomes quantitatively treated, because it is a network that seeks to capture what is general, letting what is small or different escape. Hence chance, classically, is not an object of science. It is art that deals with chance, as the former is something that needs no other phenomenon to exist, being completely free. What is unique cannot be reducible to reason, of which science is the traditional representative.

Therefore, I stipulate that art, chance and the accidental being are correlates, forms that existed prior to rational generalization. The time of art is a time of magic, circular and vague, marked by an eternal return that seeks to capture singular details. In this temporal modality, meaningful relationships are built without the need for any type of constraint, of cause or effect.[6] The magical, independent nature of art is essential to the understanding of its free messages and for the construction of its methods. Chance is also characterized by not being under the judgement of any kind of law, being a universe of pure qualitative possibilities, exceedingly indeterminate and free of any rules or law that determine its occurrences. As chance is ontologically real, that is, independent of what can be thought about it, it is a set of possibilities that can turn into facts at any moment, characterized by uncertainty, heterogeneity and multiplicity. Indeed, where freshness, spontaneity, indeterminacy, and open possibilities exist there lies chance that in essence is not something specific, acquiring specificity on being trimmed into something individual, when there is a clash between two or more of its infinite possibilities.

Pierce demarcated a field of studies for what is apparent to us, relating it to what we perceive, to how phenomena manifest themselves to the human mind, calling it phenomenology. Peircean phenomenology has a direct connection with chance, since the philosopher devised the concept of chance as a principle responsible for the variety found in nature and phenomenologically inventoried (EP2). The importance of phenomenology in the theoretical panorama that Peirce creates arises from the fact that it addresses the most universal categories of experience, being a quasi-science whose role is to provide the foundations upon which the rest of the philosophical disciplines are based. What Peirce calls categories are concepts that are simultaneously abstract, elementary and universal, that is, valid for all experience. In this conception, Peirce (EP2) established three categories:

- Potentiality, called *firstness*, present in that which is free, new, spontaneous and casual;
- Existence or factuality, called *secondness* by Peirce, characteristic of effort, resistance, action and reaction, alterity, negation and existence;
- Finally, generality, which Peirce called *thirdness*, characteristic of continuity, thought and law.

Given these brief observations about the general nature of phenomenology, it is possible to see that Peirce dedicated an entire category to the study of what is potentially related to chance, and which is the basis for the others' existence. It was not without reason that the philosopher named this category firstness.

Firstness is a state in which the senses appear without sharpness as there is nothing external that stresses them or tests their unity. Chance as a principle does not integrate any universal and does not belong to any kind of class. It is a fortuitous distribution of qualities like that obtained in any equiprobable experiment, such as in a game of dices for example. In this type of game there is no rational reason to bet on one result more than another.

Chance and Creativity

Chance as the property of a distribution, requires something to be distributed. This point is central to the understanding of the relationships between chance and computational structures that, although originating from a programming code, do not bring already all the results ready. The Figs. 1 and 2 presented here are worthy representative of this.

The acceptance of chance as a constituent element of the universe, and not just an indicator of human ignorance,[7] is an essential step in understanding creative processes. The understanding that the regularity observed in the universe is permeated by random occurrences was only resumed with the advances in statistical physics and Darwin's theory of evolution, from the nineteenth century onwards (Lestienne 1993). The statistical chance, recognized both in the natural and in the human sciences, gradually undermined determinism, synonymous with science since Galileo, Kepler and Newton.

Peirce (EP2) observes that creativity[8] is closely related to what is undetermined at first, and its acceptance as a real-world component has opened up a broad path to new ways of understanding reality. From this perspective, science opens itself creatively to the discovery of new connections, based on the assumption that mind and matter are connatural,[9] that is, they arise from the same principle, share the same origin and advance in the same direction, challenging the Cartesian conception that divides spirit—mind—and matter.

Unlike most philosophers and scientists of that time, for whom chance was a mere product of human ignorance, Peirce maintained, above all in a series of articles published from 1891 onwards, the thesis that chance is a real property of the universe, regardless of what human beings may or may not know about things.[10]

Furthermore, he established a hierarchy for the modalities of chance, so that we may, through his texts, learn up to three different concepts of chance which progress from a 'weak' or subjective position to a more 'extreme' one, called 'objective chance'.

The three types of any chance identified in Peirce (EP2) are:

1. Mathematical chance, whose characteristic is the independence of facts or events, prescribed by the theory of probability.
2. Absolute chance, responsible for the diversity we encounter in the world, which stems from a principle of spontaneity and novelty that violates the laws of nature, also containing a condition of dependency.
3. Creative chance, consisting of a creative function that has been operating since before the existence of laws, including the laws of nature.

Absolute chance is a modality of creative chance: the laws are originated by the work of a creative chance and, driven by a habit-acquiring tendency, become more regular, however, nevertheless subject to intervention by absolute chance that ruptures symmetries to generate differences and variety, preventing the complete determination by means of natural laws. Chance for Peirce is an absolutely essential part of his metaphysical conception of evolution in which the universe continuously improves:

> We must therefore suppose an element of absolute chance, sporting, spontaneity, originality, freedom, in nature. We must further suppose that this element in the ages of the past was indefinitely more prominent than now, and that the present almost exact conformity of nature to law is something that has been gradually brought about. We have to suppose that in looking back into the indefinite past we are looking back towards times when the element of law played an indefinitely small part in the universe. (EP1:243)

Conclusions

I start with some raw and free ideas, check how can I put them in a logical format, struggling with the computer code, and then get the ordered results. This process works as a loop, as the freshness of the 'firstness'—or chance—is always pushing for new ideas. Order, therefore, does not exclude chance, but rather incorporates it into its system. Chance has been one of the main subjects of modern art. Duchamp (Molderings 2010), John Cage (Jensen 2009) and Mallarmé (Betz 1978), just to name a few artists, used extensively chance as a creative strategy. More specifically within the scope of computational art, it is important to consider computers as members of a game of symbolic exchanges that establishes itself in a larger context, immersed in culture and susceptible to contamination by networks drive by chance. A programming code is based upon the assumption that there are things to be distributed. Based on the semiotic premise of fallibility[11], that is, that through reasoning it is never possible to reach absolute certainty, accuracy and universality, there are arguments for the consideration that even the attempt to program a computer with complete accuracy entails in and of itself imperfections and room for the unexpected.

End Notes

1. For a more in-depth discussion on this topic, see Poltronieri (2017a).
2. It is believed that Hesiod lived between 750 and 650 BC.
3. Many of the objections raise by artists regarding the use of the word "chance" to define the capacity of computers to generate unexpected situations comes from the artists' use of misused pseudo random number generation techniques. For a discussion with more technical components see Lavavej (2013).
4. http://www.random.org.
5. https://github.com/halpomeranz/lmg/.
6. For a more in-depth discussion on this topic, see Flusser (2006).
7. Peirce (EP2, 314) gives a logic explanation why chance is not a matter of ignorance.
8. For a discussion on the concept of creativity from Peircean's semiotic point of view, see Poltronieri (2017b).
9. Peirce defends this assumption through his concept of synechism, "the theory that continuity prevails and that the presumption of continuity is of enormous methodological importance for philosophy" (Houser 1992: xxii).
10. In fact, Peirce developed a whole philosophical theory about chance, named "tychism", which is the thesis that chance is really operative in the universe (Houser 1992).
11. Fallibilism, for Peirce, is the thesis that "no inquirer can ever claim with full assurance to have reached the truth, for new evidence or information may arise that will reverberate throughout one's system of beliefs affecting even those most entrenched." (Houser 1992:xxii).

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Self-portraying an Absence

Graziele Lautenschlaeger

Using the development of the performance *Self-portrait of an absence* (2016) as case study, I share here relevant issues that ground my own media art practice and its inherent cross-disciplinary aspect. The performance was created in the context of a Ph.D. practice-based research as a methodological tool and its creative process reveals the threshold areas between the technical level of scientific knowledge and the symbolic level of aesthetic experiences. The experiment also points towards the deconstruction of the dichotomous relationship between practice and theory, since the reflections provoked by it were essential to discuss subjects being articulated in my Ph.D. thesis. The article is structured in two parts: the first depicts and analyses the creative process of the performance and the second unfolds some of the relevant discoveries from the experiment in relation to media art aesthetics in its hybrid quality.

Self-portrait of an Absence

Similar to Vilém Flusser, whose writings influenced my understanding of electronic and digital media, I have a blind eye. This coincidence encouraged me to explore creatively my partial absence of vision regarding issues present in his work, namely the notions of self-translation and *Mediumsprünge* (Guldin 2010).[1] As an exercise on playing in between the abstract and concrete worlds of codes and materialities, *Self-portrait of an absence* started as a poetic experiment on the search for the possible paths between sensing and making sense in absence.

Challenging the historical dichotomy between form and function, the project consisted of an eye-tracking system programmed to generate and process sounds according to data generated from the asynchronous movements of my eyes. I took advantage of my blind eye to create a situation for triggering aesthetic experiences and dialogues with the audience. By evoking strangeness, the aim was to put the notion of absence into discussion. Among the infinite technical and aesthetical

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_28

choices, I chose to implement a translation from light into sound to mediate the translation of an intimate characteristic into a universal experience.

The idea was to perform with the embedded system in different contexts. Initially I created a performance wearing a special costume that embeds the necessary electronic devices and went to public space. By asking the passers, if they would like to hear the sounds of my blind eye, I offer a promenade under my umbrella. The shared experience of absence is then developed through different sound modes, from the introduction of the project, through different observing-listening exercises, to a more relaxed role, like *flâneurs*.[2]

Conceptualizing: Inspiration and Research Sources

I have never worked in a media art project that emerged suddenly from a brilliant idea that was just to be executed. My work process is closer to the notion of disciplinary creativity (Flusser 2008), especially because media art requires learning technical specificities for every single project.

While researching the materiality of sensors, I offered a workshop at *Besides the screen Conference* (São Paulo and Vitória—Brazil) in 2014 (Lautenschlaeger 2016). That was the very beginning of my Ph.D. research and I was studying ways for narrowing the frame of my investigation. For the São Paulo edition, it was planned to create an intervention at *Cine Art-Palácio*, an abandoned cinema building in the heart of the city, and the group decided to make something related to the audiovisual materiality of film. Addressing the intersections between Cinema and Media Art, we explored the multiple correspondences between light and sound, and we ended creating glasses embedded with LDRs (Light-dependent resistor), a microcontroller and a mp3 module programmed to trigger pre-recorded sounds.

Since the experience of the workshop, considering my background in audiovisual communication, I decided to focus my Ph.D. research on a genealogy of light-sensitive elements in relation to Media Art, structuring a thought around the possibilities of dealing with images (and per extension the imaginary) beyond verisimilitude—what has also oriented my enthusiasm to start working with media art. Additionally, my partial absence of vision was appropriate to conduct a second-order cybernetic approach. Having my own body as departing point of investigation, assuming the eye as epistemological object,[3] my role as observer would also be inevitably acknowledged along the research process. By confronting organic and machinic light-sensitive entities—the eye and the camera—part of the research was lead to a triadic coincidence: the eye, the camera and the black-box. I assumed this constellation as a challenging epistemological and relational object. Therefore, I drew attention to all the materialities and concepts surrounding the project: eye(s), physiological and cognitive issues behind vision and its variety of forms in nature, so as optical devices and machine vision. Simultaneously, I collected technical and aesthetic references of eye tracking systems and studied how to play with the confrontation I was prone to execute.

The experience of being monocular means to have a more limited sight field and perhaps a slower reflect to some circumstances of spatial perception. This last assumption is based on readings of the US-American art historian and critic Jonathan Crary (1990), who attributes the origins of stereoscopy to intertwined researches conducted in the nineteenth century on subjective vision, the emergence of physiology as a field of study and debates about the perception of space. Charles Wheatstone and David Brewster, who worked on optical illusions, colour theory, afterimages and other visual phenomena, were among the main characters behind the first spouts of stereoscopic optical devices. They are the result of investigations started around the 1820s, when physiologists were looking for anatomical evidences in the optical chiasma, where the nerve fibbers leading from the retina to the brain cross each other, transferring electrochemical pulses from each retina to each side of the brain.

As I already know what to see means, and feel adapted to the world, with no wish to build prosthesis, I was curious to know more about an unknown part of me. What a blind eye is able to do? Far from the notion of a Google Glass-like device, the aim was to grasp the symbolic level of the relationships between body and technology. On purpose, I neglect building or purchasing eye-tracking glasses for the project, due to its strongly symbolic association to corrections on "imperfect" vision. The endeavour thus became an exploration on the absence by stretching the notions of normality and deviation.

Regarding all these issues, and especially the freedom and responsibility behind the zero-dimensionality of electronic and digital media (Flusser 2008), the experiment consisted of an exercise on what happens in between sensing (light-sensing) and making sense (meaning attribution during the shared observing-listening exercises of the performance).

Concretizing: From Interface Design to Performance

Due to the technical complexity of the project, a variety of skills and know-how were required and a collaborative creative process emerged naturally through various partnerships.[4] On the technical level, personalised software was developed on the basis of other open source projects with similar purposes, such as *The EyeWriter* (2010) and The Pupil Labs. Inasmuch as possible, I made an effort to keep a do-it-yourself approach.

Decisions about interface and interaction design were directly informed by prior research and enquiries. In place of glasses, a simple metallic structure that rests on the head and holds a camera that tracks the eyes movements was used (Fig. 1). The data from the camera is sent to a Raspberry Pi[5] board attached to the back of pant braces, where the software runs. The same braces also hold five push-buttons, responsible for triggering the sound modes of the performance, and a rechargeable USB power supply, which feeds the whole system. Stereo loudspeakers that hang under my umbrella play the audio output coming from the board. My reduced

Fig. 1 Details of costume and devices from *Self-portrait of an absence*. *Photos* Edgar Zanella Alvarenga. *Source* Author's personal archive

visual field opens up a space for the participant under the umbrella, suggesting complementarity and the possibility of intimacy. The aesthetic reference for this choice was the animated short, *An eye for Annai* (2005), by Jonathan Klassen and Daniel Rodrigues.

On the programming level,[6] the eye tracking system of *Self-portrait of an absence* was built in Python language using the library Open CV (Open Source Computer Vision) and a specific technique called optical flow, which is based on the recognition of the apparent motion of objects, surfaces, and edges in a given image, calculated by the relative changes in the frames over time. In the 1940s, the US-American psychologist James J. Gibson introduced the concept of optical flow to describe the visual stimulus experienced by animals moving through the world. In computer vision, optical flow encompasses techniques from image processing and navigational control, like motion detection, object segmentation, time-to-contact information, focus of expansion calculations, luminance, motion compensated encoding, and, what was useful for this work, stereo disparity measurement (Vijayarajan et al. 2016). Another possible technique would be blobs detection, but tests with it proved to be unnecessarily complicated. Getting absolute values from the blobs positions would require a lot of power from the hardware and provide unnecessarily more precise data. With the optical flow technique, it was possible to extract relational data obtained from the comparison between both pixel matrices (left and right eye). Through this method values are generated only when and where there is movement in the image captured by the camera. A further calculation to acquire information on the angle of the difference was obtained by the cosine of the generated vector.

Besides movement detection and angle calculation, the software written in Python also sends the processed data via OSC protocol to SuperCollider, a programming language for real-time audio synthesis and algorithmic composition. The five sound modes of the performance were created in this platform. They emerged from a soundscape simulating an intervention in an urban space,[7] using the surrounding sounds as inspiration. The simulated performance in the form of a soundscape was extremely important to prevent future technical problems. Except for the introduction and farewell voices of the first and last sound modes, the other three modes were created by considering data generated from the synchrony and asynchrony of the eyes. The more desynchronized or deviated (D) their behaviours, the stronger the effects applied to the sounds being played. In summary, the sound modes created for the first version of the project were: (1) Pre-recorded voice greeting the participant and introducing the project's idea; (2) percussive sound whose rhythm loses its periodicity according to D; (3) over pre-recorded audio samples are applied bit-crushing and 'downsampling' effects, more or less intense according to D; (4) tones synthesis, including vibrato and panning effects according to D and (5) pre-recorded voice thanking the participant and concluding the intervention.

After constructing the device, training and rehearsing the performative elements was the next challenge, especially concerning the achievement and maintenance of a state of presence (Gumbrecht 2004) and becoming comfortable sharing intimate space. The project premiered in October 2016 at *Design Transfer Berlin*, as part of the exhibition and symposium *Musical instruments in the 21st Century,* organized by the 3DMIN research group.

Self-reflecting

Many philosophical connections to elements of *Self-portrait of an absence* can be made—from the human prosthetic condition (Stiegler 1998; Harrasser 2013), to the deconstruction of the supremacy of image and sight, to the translation from light to sound. However, in this paper I stress the importance and powerful effect of the feedback principle and how the body organizes the world to organize itself. While training and performing with the apparatus, I learned through the audio feedback the muscular movements to control my blind eye, in a simpler but similar way to how the artist and cyborg Neil Harbisson learned how to listen to colours (Harbisson 2012).

The muscular movements I have learned together with further research on optical devices and visual perception has compelled me to additionally associate the deviation between both eyes with a problem of spatial perception. The deviation between the eyes has no relation to the initially known limits of the visual field. It is rather closely related to the perception of visual depth, which is directly connected to the eyes' parallax. Both eyes' positions synchronise when focusing on a very close object and desynchronise when the attention shifts to the horizon or to another object placed further in the background. Through the audio feedback, I learned that I became able to move the muscles of the blind eye as if it were focusing on a close object even though no object is necessarily there.

Through the experiment, while being monocular, I learned in practice what studies on stereoscopy have been exploring since the 19th century. When Wheatstone measured the binocular parallax—the degree to which the angle of the axis of each eye differed when focused on the same point—he contributed to the understanding of the correspondences between the eyes' movements and how the physical proximity of objects "brings binocular vision into play as an operation of reconciling disparity, of making two distinct views appear as one" (Crary 1990:120).

Furthermore, to conduct an experiment on a specific feature of my body stimulated me to reflect on the interchanges between objectivity and subjectivity and to understand objectivity as a temporary fixed point that slides over and through multiple subjectivities (Merleau-Ponty 1994). Technical objects that usually serve to objectify were displaced in the context of art, where they instead served symbolic uses and the subjectivity of the artist.

In addition, working with electronic and digital apparatuses on a symbolic level, I materialize the role of media artists as bridge builders, able and obliged to bridge scientific and artistic knowledge, sensations (stimulus uptake) and senses (meaning attribution), nature and culture, abstraction and concreteness.

Regarding the thresholds between technical and symbolic elements, the meaning and operationalization of the concept of 'deviation' nevertheless had special significance. Deviation can also be a path to innovation—not in the sense of market requirements, but in that of the movement against entropy, toward knowledge construction.

Media Art: The Translation of Materialities and the Creation of Imaginary Hybrid Machines

In combination with my theoretical background, the experience of creating *Self-portrait of an absence* provided me insights in how to consider the creative processes in Media Art in general. When the light entering the eye and the camera is translated into sound in the vibrating membranes of the loudspeakers in the specific context of the performance, a new meaning is attributed to the technical ensemble being used. I have been calling this process as translation of materialities. The possibility of gathering information from all sort of material in an abstract lowest common denominator of numbers and voltage changes, and, in a second step, arbitrarily transforming them in any other possible materialities, places media art practice in the interplay between abstraction and concreteness. In this sense, *Self-portrait of an absence* became self-referential in two layers: it refers primarily to my partial absence of vision, but also to the absence of meaning initially present in the gap between input and output sides of the artwork's system.

This approach suggests the mergence between traditions from the material and the linguistic turns: Media art consists of dealing with the materiality of communication, creating technical ensembles (with machines and organisms) to generate situations and experiences that "contribute to the production of meaning without being meaning themselves" (Gumbrecht 2004: 8). While attributing symbolic layers to the work, in addition to the technical knowledge needed to execute the project, the media artist requires sensitivity to the limits and potentialities of communication between the available materials. Beyond the scope of the artwork discussed here, the notion of translation of materialities can guide other artists to reflect upon the process of attributing meaning through the organization and recombination of materials in the specific contexts they are working on. The same is valid for both critics and audience, who can use it as analytical lens to discuss media artworks.

Furthermore, regarding the in between space that the zero-dimensionality of numbers and voltage changes represent, the materiality of communication in media artworks evinces the artist's role as an important agent in the integration of organic and inorganic matter, which enables the creation of imaginary hybrid machines. Enthusiasts of a sort of 'material philosophy' (speculative design in other contexts), media artists animate and edit matter—either of life forms and/or machines. Programming exchanges of electric and electrochemical signals through the senses and sensitive materials means also to play with the feedback principle—the core of hybrid systems that frequently emerge as media artworks.

In addition and conclusively, this way of working relates to New Materialist approaches, which consider the agency of matter through material-discursive practices (Latour 1996; Barad 2003; Bennett 2010; Schäffner 2015). Thinking Media Art entails approaching contemporary artworks as relational entities. Every living entity presents its own on-going historicity and agency. They, alike the artists, are part of the stabilising-destabilising dynamics of the world.

End Notes

1. Due to his immigration background Flusser's philosophical method was strongly based on translations and retranslations. It is possible to relate Flusser's translation theory of the 1960s and his media theory from the 1980s, as suggested by the Swiss scholar Rainer Guldin in *Pensar entre línguas: a teoria da tradução de Vilém Flusser* (2010). His reflections on the media philosophy were intimately related to the concept of *Mediumsprünge,* the act of jumping from one medium to another, from the logic of one system to another.
2. *Flâneurs*: meaning 'stroller', 'lounger', 'saunterer', from the French verb flâner, "to stroll". The word carries rich associations: the man of leisure, the idler, the urban explorer, the connoisseur of the street. Walter Benjamin, drawing on the poetry of Charles Baudelaire, made this figure the object of scholarly interest in the 20th century, as an emblematic archetype of urban, modern experience.
3. Additional inspiration for feeding this confrontation was found in Foucault's text *On transgression*, when he refers to the eye as epistemological object in George Bataille's work (Foucault 1977:44–49).
4. Among the collaborators and interlocutors are: Edgar Zanella Alvarenga, Dominik Hildebrand Marques Lopes, Radamés Ajna, Caterina Renaux Hering, Amelie Hinrichsen, Till Bovermann, Lina Gómez, Pedro Henrique Risse, Jörg Klenk, Clare Charnley, Patricia Azevedo, Gil Fuser, José Cabral Filho, Stefan Schwabe, Thiago Hersan, André Pagnossim, Janaina Bernardes.

5. Raspberry pi refers to a series single-board computer produced by the homonymous British foundation in order to diffuse the basic computer science principles in schools and developing countries. Its architecture enables the connection of peripherals such as sensors and actuators. Further information is available on the foundation's website: https://www.raspberrypi.org/. Accessed Aug 30th 2017.
6. All codes and audio files developed during the project are documented at the Github platform: https://github.com/grazilaut/self_portrait_of_an_absence. Accessed Aug 1st 2017.
7. An audio recording of a walk through the Gleisdreieck park in Berlin was used as the first reference.

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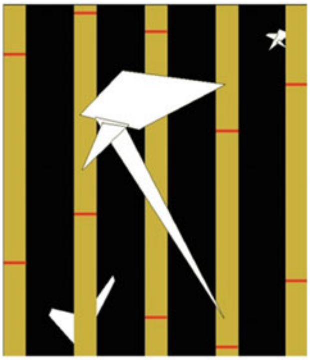
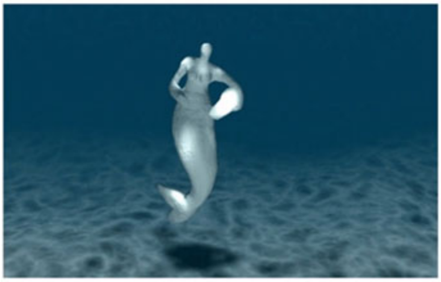
Part IV
Collaboration

Collaboration

A creative process of experimenting with technology seems to provoke questions that may not usually be asked of technology. Esther Rolinson

Why is collaboration such an important part of the new century? With increased use of more and more specialized, complicated technology, it is far less productive to be an artist delivering a monologue alone in the studio. Jack Ox





Digital art challenges not just the nature of representation in art but the traditional methods of production and represents a new creative space. Sarah Tierney

Theme: Collaboration

Linda Candy, Ernest Edmonds and Fabrizio Poltronieri

This chapter explores the nature of collaboration in inter-disciplinary art and technology projects. It draws upon the COSTART project described in Chapter 'A Million Millennial Medicis'. Other inter-disciplinary initiatives took place outside the academic context. For example, in 1996 the Wellcome Trust U.K. launched the 'SciArt' funding programme in response to a growing field of artists embarking on new projects in conjunction with scientists. Many of these initiatives are no longer active but nevertheless, the precedents were important in demonstrating the potential benefit for creative work. Communication for interdisciplinary collaboration, shared languages, cognitive styles, and the role of knowledge are all discussed. Finally, observed success factors for good collaboration are reported. The core chapter is followed by eight contributions on the subject from artists and researchers.

Introduction

Creativity often needs collaboration because creative practitioners do not always have each and every kind of skill necessary to turn ambitious creative ideas into material outcomes. The pragmatics of making aside, however, people may seek collaboration when they want to exchange ideas with people from different backgrounds. Having already had previous opportunities to work with others, they may be aware that exposure to different ways of thinking can be very stimulating and provocative. Nowhere is this more so in the field of art and technology, where not only is the use of digital tools an initial driver in the direction of collaboration, but the rewards extend beyond the pragmatics into personal and long-term benefit.

In the contemporary digital art world, collaboration is taking place between artists and artists as well as between artists and technologists and technologists and technologists. The label 'artist' covers many types of art and a 'technologist' can be anything from a software programmer to a hardware systems and electronic devices implementer. Sometimes, artists act collectively and give this a single name to

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on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_29

indicate shared responsibility and ownership; sometimes the technologists are much more than assistants to the artist and are actually creative technologists with their own artistic profile and activities. Given the many kinds of collaboration across different fields and disciplines, it is always interesting to ask if there are shared characteristics and whether successful collaboration has distinctive features that we can learn from and apply more generally? How are innovative ideas developed and made into artefacts in a collaborative context? How do people develop complementary ways of working together to create something extraordinary despite the fact that they often have different ways of thinking and communicating? It seems very unlikely that there is a perfect recipe or ideal model for good collaboration but by drawing on evidence from research studies, we can learn much from the experiences of those who take part in collaborative ventures whether in large or small scale creative situations.

This chapter explores the nature of collaboration in the context of inter-disciplinary art and technology. Almost two decades have passed since the foundational work for the first edition of 'Explorations in Art and Technology'. The book drew mainly on initiatives of the late 1990s when there was a resurgence of interest in the creative potential of digital technologies. At that time, the COSTART project, funded by the Engineering and Physical Science Research council (EPSRC), was an unusual provider of opportunities for research into collaborative creative practice in the UK (COSTART). Other inter-disciplinary initiatives were taking place outside the academic context but these initiatives did not always result in cross fertilisation of practices and outcomes at the time. In 1996, the Wellcome Trust U.K. launched the 'SciArt' funding programme in response to a growing field of artists embarking on new projects in conjunction with scientists (Glinkowski and Bamford 2009). Funding opportunities such as this were critical to the development of a community of practitioners who were at the forefront of a new form of interdisciplinary collaboration, leading to many examples of innovative creative work. The role of far-sighted programmes in fostering the development of experimental digital art has been a crucial element in the growth of inter-disciplinary collaboration is essential. Many of these initiatives are no longer active but nevertheless, the precedents were important in demonstrating the potential benefit for creative work.

We begin with a brief excursion into some of the initiatives in collaborative art and technology before going on to signal new developments in the field. The final part of the chapter includes a description of the studies and findings of the first phase COSTART research that was foundational to the first edition of this book (Candy and Edmonds 2002a, b).

Creative Collaboration: Research and Practice

Creative collaboration between individuals plays an important role in the generation of innovative ideas. Mamykina et al. (2002) note the challenges of interdisciplinary collaboration and a vital need to facilitate a better exchange of creative ideas between disciplines. Creative work can be very rewarding when it is performed in a social context where two or more individuals collaborate and contribute to the work (Csikszentmihályi 1996; Fischer et al. 2005). As opportunities were increased by the advent of personal computers, collaborative work grew significantly. In the 1990s, initiatives for art-technology collaboration were rather thin on the ground: the PAIR project at XeroxPARC California was a notable exception. PAIR developed an organisational strategy intended to encourage innovation (Harris 1999) and similarly that goal was implicit in the UK's EPRSC's IT programme that funded research on collaboration at the Creativity and Cognition Research Studios (C&CRS). C&CRS was a joint venture between the Art and Design and Computer Science at Loughborough University. The aim was to make art practice the central focus of the work and to give artists a primary voice. It provided an environment where artists and technologists could work in collaboration on art projects. A specific objective was to facilitate the co-evolution of art works and technological innovations from which the 'studio as laboratory' concept as described in Edmonds et al. (2005) evolved.

Research that springs from a need to know more about what happens in practice so as to be able to design better computer support systems for creativity has provided valuable insights into the nature of creative collaboration (Candy and Edmonds 2002a, b, 2003). In the initial artist residency projects and subsequent research in the COSTART project, the primary attention was focused upon realizing the concepts as material artefacts and evaluating them within the closed studio environment. There was, however, a wider audience and open public context to consider and this was addressed when the Creativity and Cognition Studios Sydney (CCS) was formed in 2003 based upon the lessons of the UK research. What followed was an attempt to embed practice and research in 'real world' environments by establishing Beta_Space at the Powerhouse Museum (now Museum of Applied Arts and Sciences) in Sydney in 2004, when the studio concept was extended and reimagined as a 'living laboratory' (Muller and Edmonds 2006). The notion that a museum could act as a working, studio, site for artists, curators, and the audience to collaborate was first publicly articulated by Alfred Barr:

> The museum of modern art. Art is a laboratory; in its experiments, the public is invited to participate. (Barr 1939)

At Beta_Space creative practitioners were able to develop artistic ideas and create new digital forms and at the same time assess audience experiences in a real live exhibition context. This unique venture blurred the distinction between production and presentation through an iterative approach to creating and displaying art works. The space was an exercise in establishing a new type of programme, one that became a model for partnership within the museum (Muller and Edmonds 2006; Turnbull and Connell 2011).

Concurrent with the Beta_Space initiative, systematic research was carried out via the CCS post graduate research programme, examples of which are reported in Candy and Edmonds (2011). A frame of reference for practice-based research methodologies and discussion of Ph.D. programmes in advancing research and practice in art and technology is also presented (Candy 2011).

Opportunities for art and technology collaboration continue to flourish in many countries and are increasingly normal within the digital art world. Whilst creative work is ongoing and organisations and networks are being supported by funding initiatives, especially in Europe, our knowledge of what makes collaboration work well in such contexts remains limited. There are lessons from anecdotal evidence to be sure but we need to achieve more than a superficial understanding of the attributes and skills needed across a wide range of creative activities. Studies of collaboration in art and technology are nowadays more often to be found in practice-based research programmes carried out by the practitioners themselves than in larger research projects. Nevertheless, these studies by artists and technologists provide valuable insights into how collaboration can contribute to long term partnerships: see for example, Rowe (2015).

The initiatives and studies referred to above have added to our understanding of inter-disciplinary collaboration. Each successive generation of artists is exploring the many ways in which digital technologies may be introduced into their practice. In the 1990s, not only were artists largely unfamiliar with the latest technologies, what was available at that time was very primitive in comparison with what became available in later years. The problem was that technologists did not always understand the needs of art and artists did not understand fully what the digital possibilities might offer. Bringing artists together with computer scientists was an adventure that involved the risk of complete incomprehension on both sides. A critical question was whether people from such disparate backgrounds and experiences would be able to communicate with one another sufficiently well to make the collaboration successful. Examples of research into communication in collaborative work is presented below. For a more comprehensive set of recent research studies see Candy and Ferguson (2014).

Communication for Collaboration

Collaboration refers to the process where several individuals work together towards the realisation of a shared goal. On the other hand, communication refers to the specific process of sharing and transferring information, ideas and knowledge. Communication is a critical component that conditions the outcomes of collaboration but good communication can at times be difficult. Challenges can vary whether the collaboration occurs within a Community of Practice (CoP) where there is a history of shared learning (Wenger 1998) or a Community of Interest (CoI) (Fischer and Ostwald 2003) where histories, skills and knowledge are very varied. Collaborative projects with teams of experts from different backgrounds and different skills, working together are instructive. In some creative industries, people who come from a similar background and collaborate can, nevertheless, have different working practices and bring different kinds of expertise to the process.

For example, in the context of film scoring, whilst composers and filmmakers are part of the same movie industry, they have different educational backgrounds and specialist skills that heavily influence the way they work creatively and determine the terms of reference used, i.e. the technical jargon of the given field. Julien Phalip's research into collaboration between a film director and a composer showed how practitioners overcome potential hurdles arising from such collaboration and the kinds of strategies that work well in these situations. Phalip's aim was to establish an understanding of how to establish common ground within a community of interest, and in doing so to match the efficiency in communication that communities of practice benefit from their shared history (Phalip 2011).

Yun Zhang studied collaborative styles of an interactive art team building on the foundation work of the COSTART project. Her approach was to carry out an observational and 'non-participative' study of how creative ideas were developed and implemented and provides an understanding of the communication patterns between people with different kinds of expertise and roles in the process. She identified five communication modes in three different forms (Zhang and Candy 2006, 2007; Zhang 2011). It was found that the technologists' contribution to creative ideas extended across all the different modes, but when it came to 'computer or interactive tool mediated' mode, they led the conversation more often than the other types of mediation.

We can continue to learn from previous research about the attributes and skills needed for inter-disciplinary collaboration that provided the foundations for the studies referred to above. In the following sections, we return to the art-technology residency studies that first informed this book. The methodology and findings are described with reference to more detailed source material and other articles that document the research. There have been some minor changes from the first edition but the substance remains as it first appeared in the edition of 2002.

Studying Interdisciplinary Collaboration

Art and technology projects provide an opportunity to try to understand just what the ingredients of successful creative collaborations are. This section describes some of the characteristics of collaborative work that were identified from the COSTART residency studies. Here we examine the way the information was collected and analysed followed by a discussion of some implications for collaborative creativity. We concluded that the idea of providing supportive environments for art and technology needs to be broadened to encompass the establishment of ongoing collaborative relationships that are fostered by the organization.

How can we study art and technology collaboration? How can we learn what is appropriate in terms of the environment of expertise and technology? How can we identify the requirements for new computer systems or environments? These questions require a research process that can address the complexities of collaborative creative practice in art and technology. A theoretical framework provides a route map for directing the overall aims and objectives of any research activity. For gathering information about events and experiences of real practice, appropriate methods are needed.

The question that follows from this is what are the most effective methods for studying artists working collaboratively with technologists? Artists are very individual and unpredictable in many ways. They are also inclined to be very strong-willed in the pursuit of their art and, therefore, not likely to welcome being treated as subjects in standard laboratory experimental situations. In truth, scientists and technologists are no different, it is just that they are often involved on the other side of the fence as the investigators. The methods to be used need to take account of the particular circumstances of the people involved. In research into human activities, controlled laboratory conditions are not achievable without sacrificing the context that gives them meaning. There are rich layers of meaning which are relevant to the description and interpretation of what is happening. When studies of creativity are carried out, the real-world context is an important consideration.

A starting point is to establish situations that makes it possible to ascertain the artists' needs and expectations, not only in terms of technology required, but also access to the skills and knowledge of other experts. The requirements gathering exercise is an ongoing process that informs the acquisition of new technology and access to the technical expertise. The way forward was to organize a series of artist-in-residency programmes and once in place to conduct case studies of creative projects in actual development situations as described in Chapter 'A Million Millennial Medicis' previously.

The Artist Residency Research Process

Art and technology projects provide an opportunity to try to understand just what the ingredients of successful creative collaborations are. One of the research questions that was posed was how to identify the support requirements for art and technology collaborative projects. This chapter describes some of the characteristics of collaborative work that were identified from the COSTART residency studies. In this chapter, we examine the way the information was analysed and the results of that exercise followed by a discussion of some implications for collaborative creativity. We conclude that the notion of 'support' for art and technology needs to be broadened to encompass the establishment of ongoing collaborative relationships that are fostered by the organization.

The research process begins with the collection of many types of information about the activities, exchanges and outcomes of the art-technology residency projects. This is recorded, compiled and structured in transcription records and case study reports. This provides primary evidence for the extraction of features and the allocation of feature values. The results of this exercise may be applied to individual case studies which are then compared. Figure 1 is overview of the process.

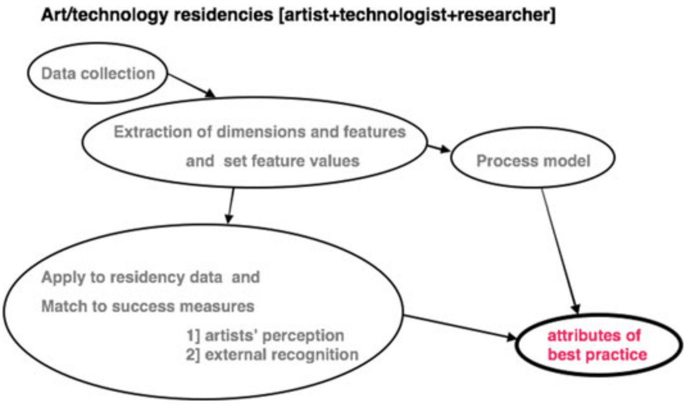

Fig. 1 The research process

Analysis Framework

The analysis framework and the mechanisms used to evaluate the art-technology collaborations are presented below. The information was compiled and structured in transcription records and case study reports which could then be analysed by different researchers. This provided the primary evidence for the extraction of features and the allocation of feature values or descriptors of collaboration. This was carried out by two researchers who arrived separately at an independent assessment. Textual data can be subjected to various forms of analysis. The one used in this case was as follows:

- The first pass over the case study texts looked for features of collaborative behaviour that relate to an existing theoretical model of creativity including cognitive style, communication, knowledge (Candy 1997).
- Values were then attached to the features: e.g. feature is, for example, approach: values are exploratory, open-ended, goal-driven, etc.
- The second pass over the texts assigned values to features for each case study
- The results for all cases were tabulated and compared (see Tables 1 and 2).

Table 1 shows the values selected for a single collaboration by each researcher. The degree of agreement is exact for two features (approach and role) and close for three (ethic, control, methods). This pattern of agreement occurred also in the Communication and Knowledge features. Further discussion of the features of creative collaboration can be found later on in this chapter. To complete the explanation of how the data was analysed, we show how each case study was compared.

Table 1 Features with values for case study 7

Cognitive style feature	Value selected-res. 1	Value selected-res. 2	Values not selected
Approach	Exploratory	Exploratory	Goal-driven
Role	Different	Different	Same/ interchangeable
Ethic	Art-Led	Neither/both	Technology-led
Control	Important	Necessary	Optional
Methods	Digital	Mixture	Traditional

Table 2 Comparison of features for all cases

Case Studies	CS1	CS2	CS3	CS4	CS5	CS6	CS7	Result ALL	Result FULL
Cognitive Style									
APPROACH									
Exploratory	***			***			***	3/7	2/3
Goal Driven		***	***		***	***		4/7	1/3
ROLE									
Different	***	***	***			***	***	5/7	3/3
Interchangeable				***	***			2/7	
Same									
ETHIC									
Art-led	***	***		***		***	***	5/7	3/3
Tech-led									
Neither/Both			***		***			2/7	
CONTROL									
Important		***	***		***		***	4/7	2/3
Necessary	***			***				2/7	1/3
Optional						***		1/7	
METHODS									
Digital	***					***		2/7	1/3
Mixture		***	***	***	***		***	5/7	2/3
Evaluation									
Viewpoint (V)	V	V	++	V	++	++	V	**4/7**	
Outcomes (O)	O	O	++	++	O	++	O	**4/7**	
V + O	V/O	V/O	++	++	++	++	V/O	**3/7**	

Comparisons Across Case Studies

In order to characterize the different collaborations, the case study data was examined for each of the above features and associated values. The researchers then compared results and compiled the features and values as tables. The results were then compared (see Table 2). The next stage in the process was to evaluate each case study in terms of two success measures: subjective and objective. “Subjective” was defined as the perceived views of the participants in the collaboration as to whether it worked well or not. “Objective” was defined in terms of recognised outcomes (e.g. exhibitions, commissions, reviews as public demonstrations of the value coming from the work done).

Having identified which collaborations were successful or otherwise in terms of the two measures, it was then possible to look back at the features and descriptors for each case study and infer which was associated with success. By combining these with success measures, the quality of the collaboration was assessed. In three cases, the collaboration was assessed as successful both subjectively and objectively. These collaborations could be described as full partnerships and are shown in Table 2.

This exercise may be used in a number of ways. The results can provide a basis for generalizing the results in the form of models of collaboration (Candy and Edmonds 2002a, b). Such outcomes provide a method for evaluating collaborations in terms of best practice. The method we have presented here is being refined for future use in the ongoing research.

Collaboration involves, amongst other things, three key areas of participant activity: cognitive style, communication and the use of knowledge. For each of these types of activity, a set of features with associated descriptors was identified and values were ascribed to each collaboration.

Cognitive Style in Collaboration

In this section, we focus upon the cognitive style area of creativity and discuss the features we identified in the case studies. The term “cognitive style” is used here to denote the characteristics of thinking and making in the creative process as revealed in external behaviour and self-evaluation. Five main features of cognitive style were identified as follows:

- the approach used to carry out the project
- the role adopted by the participants
- the ethic adopted that drove the process
- the value placed upon level of control over the process
- whether the methods used were wholly digital or traditional media combined with digital ones

As an example of the approach used to carry out a project: an *exploratory* approach involves the generation of ideas, often from small details, in an iterative manner until a clear path is determined. The process may be tentative and opportunistic. By contrast a *goal driven* approach means setting a well-defined goal at the outset of a project and carrying it through with minor deviation only.

The notion of an art-led or technology-led "ethic" arose from observation of the different priorities given to domain-oriented concerns. For example, in the art-led case, the importance of audience awareness or personal engagement and, in the technology-led case, finding the right solution first time or using best fit technical solutions.

The following quotations are direct quotations from the participants in the research: the artists, technologists and observers. They provide viewpoints on which the evidence of the feature values of cognitive style, knowledge and communication are based.

Approach: Exploratory versus Goal-Oriented

"A's approach to her work, is very developmental and hands-on, which essentially means that whilst she has a rough idea of what she wants to achieve, her ideas constantly develop as she produces the work." (Observer)

"Sometimes I believe I've resolved the problem with A but the next time we talk it seems he meant something else. It seems difficult to impress upon him the need to look at the problem logically and be very specific. This is not his fault but the problem must be expressed in sequential logical terms." (Technologist)

Role: Complementary versus Different

"The main focus of the collaboration was on a personal level rather than a goal in that we talked together about various things on a very personal level and it became apparent that our interests were very complementary …." (Artist)

"The work with A has been extremely enjoyable. It was a feeling as if we were both working together at times, gently changing roles, where I would suggest to her something from an art point of view and she would suggest to me things from a technical point of view." (Technologist)

"This was a collaboration in which the participants had separate background concerns driving their own art practice that, in turn, informed the individual contributions and direction of the collaboration." (Observer)

Ethic: Art-*Led versus Technology-Led*

"T does not think like an animator." (Artist) "One of the main things I have found working with artists is their feeling that the resources are unlimited and bear no cost. I agree that they want high resolution for their work but with a little bit of technical understanding they could have the image they want and keep the cost down." (Technologist)

Control: Important versus Necessary

"Trying to adjust thinking to work more closely with programming … I want to make unexpected or unplanned patterns of animations but still control overall style. Discussed with T about the control that I could have over final work—Defining *all* the images would limit the sense of unpredictable growth and ‘unseen’ images evolving.” (Artist)

“T raises question, ‘how much control do they want over the sound?’ A. replies ‘as much as necessary’. T says ‘At the moment we’ve got absolute control over all the visual information … the reason that I wrote the code is that I wanted to have complete control over the sound which was why we had to go down to that low level’. (Technologist)

Methods: Traditional versus Digital

“Both were more comfortable with their preferred techniques and were not able to adopt the perspective of the other very easily. In this situation, a traditional animator wished to explore the possibilities of augmenting conventional techniques with computer-based ones for which purposes an expert in computer-based modelling was essential. This meant that the blending or migration of techniques such as a frame-based approach to a digital one proved impossible. At the heart of the problem, was a lack of a shared vision of what the end result should look like.” (Observer)

These quotations are examples of viewpoints by artists, technologists and observers, taken from notes and log books, that were used to identify features of cognitive style for each art and technology collaboration. The same procedure was applied to communication style and the use of knowledge as shown in the following examples.

Communication *in* Collaboration

Six features of collaborative communication were identified as follows:

- whether openness of communication was adopted by both parties or was restricted to one or none;
- whether the relationship existed only for the residency or was ongoing; whether the language as demonstrated by terminology used, was shared or restricted to one or other individual;
- whether the exchanges took place in a continuous manner or only intermittently;
- whether there was mutual flexibility in respect of the way communication was used;
- whether the process of arriving at an agreement involved affirmation of each party towards one another or was an agreement to differ.

Examples related to the problem of not having a shared language are shown below. In the first, the technologist thinks he is using too much technical language and in the second, the artist needs more understanding of the software application’s procedures for development. These form part of a lengthy series of exchanges between the two collaborators during which they struggled to arrive at a common view of both requirements and software capability to achieve the artist's goals.

Shared Language

"We are now looking at lighting. I seem to understand what type of effect she wants with lights but I am not able to explain to her properly that lighting does not work in this software as she thinks it should. Maybe I am getting a bit too technical in my explanation." (Technologist)

"Having to re-do all drawing as once the objects have been manipulated, I cannot change the number of segments. This aspect of workflow is so important and it would be good to have had more of this pointed out as I am currently repeating tasks and I feel the process is getting messy. Maybe needed some more of the overall philosophy of the development process in relation to this particular software". (Artist)

Knowledge in Collaboration

The features of the use of knowledge in collaboration are concerned with:

- how each party to the collaboration acquired and used the knowledge required to carry out a specific task
- whether there was sufficient technical knowledge to achieve the tasks
- whether there was shared domain knowledge (art or technology)
- whether research proved necessary or not
- how critical the inter-dependence of the knowledge between the collaborators was to the success of the collaboration.

The quotations from the case reports that follow illustrate the features related to the artist's level of technical knowledge and the effect of this on the amount of support needed. A related feature was a need for further research despite an already high level of technical expertise on the part of the artist.

Technical Knowledge and Level of Support

"So far the initial idea that A would be a 'safe' artist to support is proving to be less simple than first thought. He has needed more constant presence to get started: O was drawn into it: he commented on lack of learning strategies." (Observer)

Need for Research and Learning

"In spite of the unusually high level of technological expertise in comparison with other artists taking part in the residency programme, particular gaps in the artists' knowledge about software and hardware meant that, on several occasions, they had to spend a great deal of time learning about the technology before they could make progress … some software required for the piece had to be learnt from scratch." (Observer)

Success Factors for Collaborative Creativity

The COSTART studies brought out several issues about the nature of art-technology co-creativity. In particular, we need to recognize that the artist may be seeking more than access to technology and expertise. Being able to develop a partnership, as distinct from having an "assistant" relationship was a significant plus point for the success of collaborative projects between artists and technologist.

Learning new skills and techniques is an important facilitator for creative practice. If the artist does not have the skills or the time to learn them, the role of a human collaborator is essential. Some artists may want to take full control of the reins of the technology because it is pivotal to the way they work whilst, for others a temporary need can be met by a technology assistant. However, technologists with little knowledge of art practice do not easily make good collaborators. Artists need collaborators who understand or are empathetic to their need to exercise control for themselves. Working through and with the eyes and hands of the person who provides technical expertise is not right for the core creative activities, although it might be acceptable for the more mundane ones.

Seeking a Partnership

One of the interesting things we observed was how much further the artists themselves wanted to extend the supportive relationship of their assistants. A significant number were looking for more than technical knowhow but rather were seeking a partner for an artistic exploration. For that to work, the assistants needed to engage more actively in the creative process and to resist imposing a standard technical solution. Likewise, the artists needed to be more open about their intentions and to be prepared to reveal tentative ideas that would normally remain hidden until they reached a more mature state.

Complementary Interests for Mutual Benefit

In a true partnership, complementary interests exist even where the outcomes by each individual may differ. Indeed, one of the most successful ongoing partnerships operates in such a way as to serve convergent interests but, at the same time, produces quite distinct artistic outcomes. In this way, the partners are able to achieve mutual benefit but, at the same time, retain ownership of their individual achievements. To be able to enjoy such mutual benefit, requires the relinquishing of individual control of the creative process: having differentiated but complementary roles appears to be best suited to achieving that end. Having a respect for differences in methods is also important to a successful partnership. The trick is for the people concerned to be able to identify in what way their differences in approach can benefit one another.

Art-Led Versus Technology-Led Partnership

Where the partnership is perceived as art-led by both parties, this seems to lead to better collaboration. The technology-led situation, on the other hand, may place the non-technologist at a disadvantage both in terms of control of the creative process and the eventual outcomes. If the implications of adopting a particular technology solution are not fully understood by the artist, then it may not be possible to steer the direction of the work to suit, resulting in a loss of artistic control.

For the technologist, the disadvantage of a technology-led assistant model lies in a lack of ownership of the project. This may occur even as they are providing critical input to the process through such contributions as software programming design. Where the relationship is of the assistant type, it is more productive if the artist explicitly acknowledges the value of the technologist's contribution and actively tries to learn from it. In some cases, the danger of one-sidedness for the technologist may be overcome if the artistic problem to be solved provides a sufficiently interesting technical challenge.

Sharing Knowledge

An effective working relationship exists where both parties exchange knowledge resources in order to progress the work and resolve difficulties of both a technical and artistic nature. The sharing of knowledge is an important facilitator of creative collaboration. It also depends upon the parties having complementary skills rather than at the same level. A partnership that aims to be self-sufficient must also know its limits and be willing to carry out the necessary research when the knowledge is insufficient. Indeed, self-sufficiency in technical know-how, or at least the quest for it through research, can be in itself a stimulus to creative thought. Being able to learn through knowledge sharing is beneficial and it particularly applies where having direct contact with a new way of thinking stimulates the generation of options. In one such case, as the process of programming became clearer, the artist was able to understand more fully the basic logic. This enabled her to consider more carefully her options and how the aesthetics of the piece could operate.

Communication Skills

Naturally the ability to communicate well with others is an important part of the collaboration process, but art-technology collaborations have particular requirements. For successful partnerships, being able to have a longer-term relationship during which trust and confidence can be built up, has real advantage. A communication barrier may manifest itself in a whole variety of different situations, bringing with it frustrations and problems. For example, a high degree of openness and flexibility and a willingness to engage in discussion with one another in a whole-hearted manner, facilitates the partnership whereas a lack of flexibility may indicate that there are unspoken differences about the way the project is developing. Difficulty with the language of communication sometimes reflected a different way of thinking about the problem in hand and how to go about solving it. Developing a common language (particularly when discussing technical issues) that both parties can understand and work with is essential if anything useful is to be achieved. Where an "assistant" style of collaboration operated, there was more difficulty in finding a shared vocabulary.

Requirements for Art and Technology Collaboration

A major lesson that came out of the first residencies was to do with the concept of "support" itself. In responding to the demand from artists for technological facilities and expertise, the preparation for the residencies concentrated on two things:

- the technology: the required software packages and hardware devices needed to carry out the artists' projects
- people with the technical skills to enable the use of that technology.

For the technology, we had an established base of 'high-end' computing equipment, network facilities and a repertoire of office and drawing software as well as specialized packages for 3D modelling and a position sensing system. Where a specific piece of technology was needed, it was acquired for the purpose of the residency. Whilst a number of the artists had well-developed skills in the use of some technology, because the projects were set up with a view to exploring *new* digital forms, we anticipated the need for help from experts in the more advanced technology.

For the experts, we turned to a sizeable network of willing experts at the university. We envisaged artists driving the projects and technical people supporting the process in response to their requirements. This did happen, of course, and the programmers, in particular, found their skills were in twenty four hour demand for the duration of the residencies. The support provided was, in fact, never really enough but there was no doubt that the artists appreciated the time and commitment that was given. That said, support for specific activities such as programming or digital video editing, was only part of the story. The idea of supportive environments for art and technology needs to be broadened to encompass the establishment of ongoing collaborative partnerships that are fostered by the organization.

A summary follows of a basic set of requirements for support for artists and desirable characteristics of technologists that can be viewed as essential for a successful partnership in this field. Further studies will explore these requirements and consider their relevance to other domains.

Artists need:

- heterogeneous resources for a broad range of needs
- access to high end facilities and tailored digital systems
- access to appropriate human expertise that is communicated well
- an ability to reflect and learn from technologists.

Technologists need:

- good communication skills as well as technical skills
- an ability to *listen* and learn from listening
- an ability to suppress the urge to promote a course of action that is technically feasible but not artistically valid.

Successful collaboration can be learned. Based upon the experience of this research, some basic requirements for sound and productive partnerships are:

- devise a shared language
- develop a common understanding of artistic intentions and vision
- engage in extensive discussions and "what if?" sessions
- give time to establish the relationship and recover from mistakes.

A number of artists have continued their association with the C&CRS and new people have joined. To be successful over time, creative partnerships needed appropriate organizational support. An environment for art and technology collaboration involves much more than the choice of which technologies and technical skills are needed, vital though that remains.

> The main support I observe artists needing is that of people support. It is not enough to have systems that artists can use, they need real contact with people who understand the technologies and that can effectively communicate with the artists. These people would be more than technicians. For the best results they would need to be sympathetic to the artists' concerns and not just interested in solving technical problems. (Artist)

Conclusions

Collaboration and artistic practice are not always easy bedfellows. The artist is sometimes perceived to be a 'difficult' person to work with because of the primacy of ownership of the artwork and an uncompromising concern for every detail.

Nevertheless, artists often seek partners to help them realise their artworks and, increasingly, collaboration with technologists has become pivotal for many. Even where artists have acquired some technological knowhow, there are many levels of expertise that require years of training and a high degree of aptitude to be effective, especially when it comes to accessing the latest techniques. This often poses a dilemma for artists who wish to retain complete authorial control over the design and making process. Using tools about which you have little understanding, can place the artist at a disadvantage when it comes to assessing whether or not you have what you were seeking. Getting the most out of having a partner to help you realise your intention, may depend heavily upon your ability to communicate what you want as well as the trust and openness that is between you. There are skills to collaboration and the success factors often depend upon people's willingness to acknowledge the contributions of others.

The results of the COSTART studies are relevant to our understanding of the nature of collaboration. Art-technology collaborations benefit from a partnership model of collaboration. The assistant or support model of collaboration is also needed but for different purposes. The quality of the type of collaboration can be assessed in terms of its durability and stimulus to creative thinking. It follows from all this that learning *how* to collaborate successfully is very important and cannot be assumed to be a natural to everyone. Of course, we can facilitate it by making the environmental conditions more than sufficient but we need to be more aware of the critical human issues at play. For any organizations wishing to promote collaborative creativity, attention should be paid to ways of developing learning strategies for successful collaboration. Referring to the longer-term nature of the personal creative process, Harold Cohen said:

> Creativity is not a random walk in a space of interesting possibilities, it is directed. The difficulty in tracking how the individual proceeds is that it is directed less by what the individual wants the single work to be than by what he wants his work as a whole to become. (Cohen 2002)

This implies supporting a sustained process. For sustainability to be possible in the context of digital creativity, that can only be achieved within an organizational context that is appropriate to a special kind of collaborative partnership. Therefore, understanding how good partnerships evolve and flourish is very important for developing creativity enhancing environments.

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Making Light Sculptures in Suspended Space: A Creative Collaboration

Linda Candy

'Splinter' 'Thread' and 'Melt' are light sculptures that are intended to evoke disintegrating structures and at the same time, create an environment for viewers to contemplate movement and patterns of light in space (Phoenix Interact Labs 2014). At the core of these artworks is light and movement. To achieve effective lighting control throughout that met the artist's intentions for each work, expert technologists were identified and recruited. The development process for these works required the collaboration of several technologists who worked with the artist on the design and implementation the technical systems required. There were four key collaborators who contributed to the lighting control technology and the programming of the control systems as well as the installation in the gallery space. Face-to-face meetings took place during which connections and dependencies between the different aspects were discussed and problems addressed. In addition to those key participants, there were important contributions from gallery staff and research advisers as well as consultation with vendors of materials and products.

This article describes insights into art-technology collaboration by the author acting as a participant observer of the work in progress. The artist, Esther Rolinson and the team of technologists: Sean Clark, Dave Everitt, Graeme Stuart and Luke Woodward, collaborated in the design and construction of the technological system necessary to realise the full dimensions of the artistic vision. They each contributed to the development of a customized lighting control system and a program for driving the patterns of lighting movement. The artistic concepts and technological solutions were arrived at through extensive discussions and emails, in which hand drawings, computer generated images and prototype lighting behaviour interfaces played key roles in mediating the communications. The study data consisted of the records of conversations and interviews with the four main technologists in the team as well as the comments and documented reflections of the artist herself. Observations about the nature of successful art-technology collaborations are discussed with reference to the conclusions from that earlier research.

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_30

The Light Sculpture Installations

The first two works to be installed, 'Splinter' and 'Thread', express aspects of an imagined landscape: suspended shards and clouded air; the third installation, 'Melt2', adds the dimension of a fluid vertical forest. The artists' aim was to create immersive installations that invite close engagement between the audience and artworks. In a sparse dark grey walled space, the viewer encounters a cluster of 35 shards of different sizes, hovering in space—this is 'Splinter'. Each shard is suspended by fine wire from the ceiling and anchored to a wooden base designed to enable connections to a light control box underneath. The effect is of the immediate aftermath of an explosion and it is as if the shards are frozen in time and space, but only briefly, for the stillness is broken as the work begins to glow softly. Muted colours appear as the lights fade up and are bleached out by the intensity of the white. Through the darkness, it becomes apparent that the lights are changing in intensity as they move. The movement and light levels build steadily and sometimes diminish to almost nothing before another sequence of light pulses through the form. It then returns to its still state and builds in intensity again (Fig. 1).

In the adjacent space, separated by a high wall, the fibre optical 'Thread' casts a fine dusting of scattered light above the heads of the visitor below who is drawn deeper inwards. It is as if this is the aftermath of an explosion of bright light as it dissipates into nothingness. 'Melt2' is constructed from white, semi-translucent, architectural mesh: its long thin strips are tensioned between the ceiling and floor. Here the viewer walks into a softly lit maze of clean linear planes. The stark forms are animated as light 'blows' through them, reminiscent of shards of light shining down through cloud. The assembled forms create overlapping geometries that build and dissipate as the lights fade up and down altering their surface opacity. The light moves in rhythms from slow sweeps across the space to roaming illuminated trails passing from one cluster of forms to another. Numerous possible routes around the structures offer the eye continuously varying scenes from dense shadowed forest to open graphic drawing. The other viewers in the space become the inhabitants of the landscape.

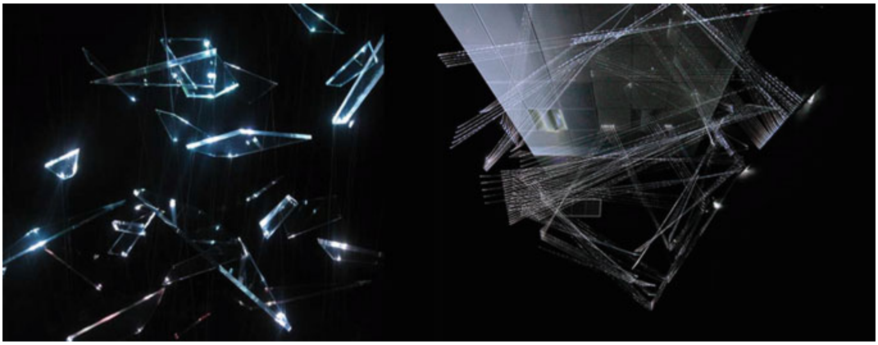

Fig. 1 'Splinter' and 'Thread' 'The Cube Phoenix Square ©Stephen Lynch Photograph'

Art-Technology Research Context

Art and technology projects provide an opportunity to identify the ingredients of successful creative collaborations. The project described has a history in earlier research. The artist whose work is described took part in the COSTART studies into the nature of art-technology collaboration (Candy and Edmonds 2002a, b; Mamykina et al. 2002).

In following up this artist's work over fifteen years later, we have a rare view of how creative collaboration in art-technology research takes place over time. The longitudinal viewpoint is invaluable in that it is possible to observe the same individual working with different people. The 2014 work took place at a time when the use of digital technologies in art was at a more advanced level than in the late 1990s. These contextual issues should be borne in mind when attempting to draw comparisons. The danger of over simplification is all too present. However, it is nevertheless an interesting exercise to return to the previous results and try to see if any of them appear to stand in the present situation, or at least to have some resonance with the kind of collaborative work going on today. In the following section, some of the issues identified previously are summarised and extracts from cases studies are provided to give a flavour of those outcomes in relation to current concerns.

The COSTART studies revealed several issues relating to the nature of collaboration: for example, the quality of collaboration can be assessed in terms of its durability and stimulus to creative thinking. Six features of collaborative communication were identified as follows:

- whether openness of communication was adopted by all parties or was restricted to one or none;
- whether the relationship existed only for the residency or was ongoing;
- whether the language as demonstrated by terminology used, was shared or restricted to one or other individual;
- whether the exchanges took place in a continuous manner or only intermittently;
- whether there was mutual flexibility in respect of the way communication was used;
- whether the process of arriving at an agreement involved affirmation of each party towards one another or was an agreement to differ.

Effective communication with other people is an important part of the creative process. For successful collaboration, a relationship during which trust and confidence can be built up, has a clear advantage. From the models of collaborative creativity that were derived from the COSTART studies, it appeared that the *partnership* model, as distinct from the *assistant* model, was better suited for this purpose.

Certain characteristics of communication appeared more often in the partnership as distinct from assistant model of collaboration. For example, a high degree of openness and flexibility and a willingness to engage fully in all available communication paths facilitates the partnership model of creative collaboration. A lack of flexibility possibly stems from a difference in perception about the nature of creative process. Partnership compatibility arises from mutual respect and trust rather than from simply liking the other person. The quality of the experience does not appear to be a result of the temperament of the personnel involved. Trust in each other's capability, whether it is artistic or technological, appears to be more important, as is sensitivity to other's agenda and approach.

In the context of the current study, the success of the previous collaboration was because the primary collaborator understood the artistic process well enough to help the artist define the technology requirements without compromising her preferred method. That understanding was also present in the technologists working with the artist in the later project. Whilst the personnel had changed the artist's preference for working with technologists with artistic inclinations did not.

> Working with someone who has a knowledge of the process of making an art work and programming seemed to allow many different ideas to emerge when at times the direction or desired outcome was not clear. (A in COSTART)

In the earlier COSTART residency, with exposure to new forms of digital technology, the potential for enhancing her creative process through better visualization techniques, was apparent to the artist. However, a critical problem at that time was how to have access to the technology without sacrificing artistic control. That problem resurfaced in the later project, which is perhaps indicative of its enduring character for artists more generally. The following quotations from the COSTART study are pertinent to the discussion that follows. In her earlier project, A described the main concerns underlying her work as "The relationship between architectural/light structures and programming".

> Aiming to make sensitive environments or architectural additions to environments. Continuing interest in how we experience spaces, travelling through them, resting and traces left in places …

In the current project, those concerns are expressed as:

> My intention is to make objects and architectures that invite reflection on each persons' relationship to the places they inhabit and remember.

The artist's ideas evolved during the COSTART residency, particularly the aesthetic qualities of her work in relation to the possibilities of the technology and this continued in the current work.

> I want to make the familiar patterns of movement that I experience in the everyday visible, such as the motion of water or the simple act of breathing.

This was made possible by the collaboration with technologists whose task was to provide the means to control the lighting patterns. That process required close communication between artist and technologist in the transformation of her 'poetic descriptions' into a programmable specification for lighting behaviours.

That transformation depended upon effective dialogue.

I've been thinking about things like: how can I communicate the precise ideas I would like to achieve and be hands off (the computer). This has definitely included going through an instinctive creative process in drawing images in grids which was like an animation story board—then breaking this down and reforming it as programming idea.

The technologist too reflected on the issue:

> What I tried to do was help A to be able to convert her ideas into a way of thinking that was modular.

In the later project, the collaboration between artist and technologist started similarly with conversations based around the artist's initial ideas, sketches and drawings, some hand drawn and computer generated and with the grid as a structuring method. These acted as conceptual tools for exploring options for 3D sculptural realizations for the artworks envisaged for a future exhibition. This exploratory process was analogous to a research project where many ideas and questions are tabled, discussed, assessed and discarded until a reduced set of possibilities emerges. For the technologist, the process began with listening to the artist explain her thoughts and probing more deeply in order to gain a clearer picture of the envisaged artwork.

Creative Collaboration

The many roles for the lead artist undertaking a collaborative project is nowhere more apparent than in the development of the three light sculptures 'Melt, Splinter and Thread'. These are works of immense power aesthetically that is made possible by a set of technological components that have been tailored for both the works themselves and the physical space into which they are installed. In order to achieve this, the artist had to be prepared to embrace collaboration as a working method.

If an artist engages others in a personal artistic journey, she has to be clear about the implications for her practice, including the risks as well as the benefits. In this case, the need for bringing others into the project was unquestionable but the full implications of what that would mean were not obvious at the outset. Setting challenging goals meant having to manage a team, a process that she found less congenially creative than drawing and making solo work. This kind of dilemma is faced by anyone whose artistic ambitions outstrip the capabilities of the individual artist working in a studio on art made by a single hand using a single medium. Of course, it is possible for artists to hire assistants for those tasks beyond their expertise. However, there is often a considerable degree of uncertainty about how the artwork can be realised, coupled with a desire to learn as much as possible about the construction techniques in order to control the outcomes, as well as to gain knowledge for future artworks. These are the circumstances when an artist is impelled towards a journey of exploration and learning to realize a vision for the works. That journey is best undertaken in good collaborative company.

The more recent collaboration group was composed of creative technologists who had previously developed their own artworks or contributed significantly to the work of others. They were also in parallel working on other creative projects as well as teaching and in one case completing a Ph.D. Interviews were conducted with the four core members and it is interesting to note just how experienced and highly qualified they were. A number of observations about the collaborative process for the development of the artworks described above are discussed below:

- Learning through Shared Teamwork
- Creative Co-ownership
- Risk of Conflict
- Artist control and partner influence on decisions.

Learning Through Shared Teamwork

The collaborative process in a creative project involves learning, adapting, constructing and exploring options in response to the sharing of ideas. An underrated aspect of collaboration is the changing nature of the situation as people learn from one another and develop a shared way of communicating. The collaborative process in the project referred to represents very effective teamwork with the artist acting as a hands-on producer as well as maker. She directed the team firmly but always in a persuasive manner and they were unfailingly diligent and responsive. The collaboration is an example of a high degree of commitment on the part of the different members of the team influenced by the artist's vision and drive, and shaped by her attention to the fine detail of the making processes. The success of this kind of teamwork seems to depend very much upon the artist treating participants as collaborators rather than technical assistants. This is harder work for the artist in a certain sense because it demands more explanation, more engagement with the people concerned and there is always the danger that this could take effort away from the main game which is already heavy duty when it comes to physical and intellectual not to mention emotional commitment.

Creative Co-ownership

From the outset, the artist was excited by the opportunities for creative exploration provided through working with highly skilled and enthusiastic partners. At the same time, she had to keep the project manageable and within a small budget. The resource constraints were an ever-present consideration if the project was to come to fruition. The cost of partner time was an unknown quantity and the very nature of the process adopted meant that it was almost impossible to predict effort costs. Having access to people who shared a curiosity driven agenda was important because this kind of collaborator was likely to be willing to give more effort than they were directly paid for out of pure interest and an opportunity to learn things that might benefit their own practice.

To achieve the most from a collaborative project, all parties need to have a role that is clearly defined and yet provides a degree of challenge that is satisfying. What we call intrinsic value as opposed to extrinsic value such as monetary reward is a fundamental aspect of successful commitment to collaboration. An important attribute that the lead artist brings to a successful collaboration is sensitivity to the value of each person's contribution to the process. This has to be achieved without sacrificing the degree of ownership they might prefer to exercise over the eventual outcome. The attitude of the artist to what each member of the team is contributing is an important factor in eliciting greater readiness to commit time and effort well beyond monetary reward. Being treated as a collaborator, rather than an assistant, was cited by one as one motivation for his own involvement. In addition, the experimental process that gives rise to opportunities for exploring new ideas and technical options has a particular value in that it provides opportunity for learning new ways of working—this can lead to acquiring knowledge that might prove useful in his own creative work in the future.

The search for suitable collaborators with intrinsic motivation who also have the right skills match, meant that throughout the project there were a number of people brought in at different points, some of whom lasted whilst others did not. In the end, a core team of artist plus four collaborators handling the lighting, materials, programming, electronics and installation requirements, was established. This group took the project through to the opening event in October 2014.

Risk of Conflict

The risk of conflict arises in most complex projects but this one appeared not to suffer significant difficulties in that respect. That is not to say that there were no problems at all and there were times when there was confusion about allocation of roles and tasks as new people came on board. The artist's approach to the expression of dissent was probably influential in resolving potential conflicts amicably. By inviting others to give voice to concerns, this allowed potential breakdowns to be "dissipated" (she felt). In other words when an issue arose, it was acknowledged explicitly, rather than suppressed, and this diffused the situation. This way of handling the complex nature of events when several people are working on the same project can be a way of making sure others in the team gain personal value for their commitment. That is not the only reason why this project was relatively free of conflict.

Artist Control and Partner Influence on Decisions

Having artistic control is often one of the most difficult aspects of collaboration for an artist to handle. There are risks when producing artwork that depends heavily on expertise beyond the artist's knowledge and where the approach being adopted is forging new ground technologically. It becomes even more risky for the eventual outcome if artists do not invest time in talking through the options proposed to the point where they feel comfortable with accepting or rejecting alternative solutions. In the case under discussion here, the artist was often faced with technological solutions that required extensive exploration and evaluation: for example, the selection of lighting. Two types of lighting technologies were considered, both of which were eventually used in the project but for different works. The first option was to use DMX theatre lighting that would illuminate the artwork from outside by having lights that would surround it and illuminate the surfaces There would be nothing on the surfaces themselves apart from the suspension wires. The second option was to use LED lights that would illuminate the individual parts of the sculpture. The eventual decisions were taken on the basis of intensive analysis and more importantly evaluation based upon physical models.

Features of Collaborative Communication

The features of collaborative communication identified in the COSTART studies can be revisited in the light of the project described here. Of the features of communication mentioned above that best served good collaboration, it was apparent that all were present but with variants. The first feature, openness of communication, was adopted by all parties; the second, regarding the common language used, every effort was made on the part of artist and technologists to explain the terms of reference and to move towards a shared understanding. This was not to say the languages were identical but rather there was an explicit recognition of the differences and the need for 'translations' in certain circumstances and for particular purposes. The third feature, continuous or intermittent communication, was present in both types: here the intensity of the level communication was facilitated by email with imagery, a feature not available to the collaboration fifteen years ago.

A key feature of the process was the way the artist took responsibility for all key decisions including the materials and technological ones, with due recognition of the advice provided. Thus, whilst agreeing to differ was not observed explicitly, such was the understanding within the team about the necessity for artistic control to reside with the artist, that disagreements rarely arose. For the artist, collaboration is much more than managing the contribution of skills to the construction of the work. Bouncing ideas around with sympathetic knowledgeable people has immense value to creative thinking and yet, there is always the risk of being sidetracked by that very process. Artists working collaboratively as in this case, have to be conscious of such possibilities, and at the same time, be confident enough to embrace those exchanges at the same time as holding to the truth of their artistic vision.

Conclusions

The article has explored the nature of art-technology collaboration by comparing two projects conducted 15 years apart. Features of communication from the earlier research study were related to a recent example of collaborative working where the artist was present in both cases. Whilst the context, the technology and the art itself were different, features of the earlier collaboration were found in the later project.

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Drawing Spaces

Esther Rolinson

This article draws on the original 'Shifting Spaces' of the first edition and goes on to describe current explorations through drawing and 3D sculpture. The collaboration process that was a feature of my practice from the very beginning has continued further as I have expanded my interest in the choreography of movement in structures. The core of my art practice is making light installations through a drawing process. It is an exploration of states of being and a sense of connection between things. Over the last 20 years I have made large-scale works and exhibitions internationally. These vary from architectural light works such as 'Align', Lewes Library (2005) to digital video projections, 'Supple', British Council, Berlin (2000) and performance installations, 'Machine for Living' (2001). I have made numerous permanent works in the UK and have recently exhibited examples of my drawings and light works together for the first time at Waterman's Gallery in the exhibition 'Gravitate', London (2017). In 2016, I was awarded the first CHI2016 Art Prize in San Jose, California and the Lumen Digital Art 3D and Sculpture Award with the work 'Flown' (2015). Examples of my drawings and prints relating to my installations are held in the V&A Digital Art Collection.

My works range from small drawings and light boxes to immersive light environments and surfaces. These are often extendable structures that can be adjusted to fit their environment. They evolve from detailed systems of drawing and go on to be constructed through my handmade practice and manufacturers. I gradually extend the process to work with teams of skilled practitioners and in collaboration. I research and coordinate how the works will come to fruition and show them in many setting from light festivals to art galleries.

Exploration of technologies and materials is integral to my work. During my degree, I roved between art departments, from one experiment in photography to another casting acrylic. Retrospectively, I see it was connections between objects and where they were located that interested me. This changeable quality applies broadly to my practice. I work in a variety of spaces, often in small bursts with a number of things evolving at the same time. I alternate between intense detailed drawings and practical experiments. There is an oscillation between silent practice

L. Candy et al., *Explorations in Art and Technology*, Springer Series
on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_31

and extensive communication with production teams and collaborators. I create consistency through the underlying concept. In each body of work, I observe and protect a conceptual 'core' as it passes from drawings to materials, structure or light. Within the process of collaboration, I am aware of how this core is worked with and expanded upon.

Art Practice 1995–2017

In my art projects of the 1990s, I investigated simple architectural structures, such as walls, roofs, stairs and columns using building materials such as sheet glass and steel, installed as sculptural installations. My intention was to heighten the viewer's awareness of architectural and natural forms and patterns of human and elemental movement. Alongside structural installations, I worked with light, either with architectural or theatrical lights or with projected digitally manipulated animations and images. From the start, I have been interested in the idea of 'sensitising environments' by combining responsive structural materials, such as 'Priva-Lite' Glass, (which turns from opaque to transparent on receipt of an electrical current) to create animated surfaces that can be programmed to form an evolving manipulation of light. As an example, 'Light-Decks' (Rolinson 1999) a publicly sited piece that was commissioned by the holdings company, COMPCO, as part of their re-development of the Aquarium Terraces in Brighton, England, consisted of a series of twenty-four light-boxes embedded into wooden decking in a wave formation. Each box contained fibre optics that changed colour at approximately walking pace. As people promenaded along the boardwalk washes of coloured light rhythmically pass under their feet. The piece utilized the structure of the wooden decking and aims to hint at the presence of water flowing underneath it, as on a ship or pier. A full history of my artworks from that time can be found on my website (Rolinson Rolinson 2017).

The Drawing Process: Rule-Based Creativity

Drawing is at the centre of my art practice, from quickly rendered sketches to detailed meditative pieces, three-dimensional structures and drawings on computer. It can be both a measured and instinctive activity. The drawings contain rules and use practiced skills in various materials such as traditional methods like pencil and graphite. Recently I have started to apply the same rules to movements, marking out the drawing structures in physical space. I rehearse movements in all kinds of ways such as large flowing ink marks, walking and folding materials. By doing this I aim to know the movement deeply so that I can build structures following the rules with fluidity. As the built forms are extensions of two dimensional structures I consider all my works as drawings whether they are part of a building such as

'Trace Elements' Electric Wharf, (2005) or as forms etched into granite in *'Flow' Musgrove Park Hospital Taunton,* (2013).

I draw with specific goals towards projects and without direction as part of daily art practice. The drawing is a meditative process in which to explore sensations, structures, movements and connections. I use simple combinations of lines in repetition to build up complex forms. These construction rules enable disassociation from conscious thoughts, allowing spatial patterns and movements to emerge. Some structures conclude like solved puzzles, '*Breathing the Breath of Others*' (2013), whilst others have the potential to grow infinitely such as '*Attraction*' (2016), pencil crayon on inked paper. The drawings are the blueprints for three-dimensional works and are pieces in their own right. I understand and plan structures through them. I extend drawing into three dimensions. I refine forms until they can be reconfigured in many ways as kits of parts. These 3D drawings become materials in themselves to build structures in response to an environment.

Over the past two years I have worked extensively with construction rules to render out textures and forms by hand. The rules are often simple, denoting types of shapes movements or orders of colours. They can be interpreted flexibly and act like a skeletal structure providing reference points rather than limitations. I find working with constraints in this way allows a free flow of creativity. The drawing structures are forms and rhythms with some understandable systems inside them. I am also curious about the complex human behaviours they contain and how these might be identified. I see connections between the drawings and algorithmic patterns. In the drawings to some extent unpredicted patterns emerge by carrying out a series of predefined actions. As I work I notice how different formulas behave and also how I can control and deviate from them.

A key development was using a rule based drawings *'Shaken' pencil on paper* (2015) as the basis of '*Flown*' (2015), a large-scale light installation commissioned for the Illuminating York Light Festival. It is a delicate textured work of crossing lines. From this I made further drawing to understand the possible forms and supporting structures. I extended the process into three dimensions making many hand folded acrylic forms for the final work. *'Shaken'* was also shown in the exhibition *'DP Henry and Beyond' LCB Light Depot* Gallery*, Leicester* (2015) curated by Sean Clark. It included works made by drawing machines with mine as an exception. These were examples of works that have a machine-like quality and might be interpreted by a computer.

As I research structures the choice of technology informs the work. The materials give form and volume to light and I find the best fit for each work. In the process, I push at technical boundaries and test extensively. I learn about techniques from manufactures and through experimentation. I am looking for the most succinct solution regardless of how high or low tech it is. This then influences the whole process creating purposeful constraints that shape the work. This search for precise effects raises technical challenges. For example: The prototype work '*Melt*' (2013), made with creative technologist John Nussey, was constructed from liquid crystal glass panels that switch from opaque to transparent as a current of electricity passes through them. I wanted the glass to have the appearance of dissolving and asked if they could fade slowly. This was new to the manufacturer but John was able to do it by switching the glass on and off very rapidly to give the illusion of a fade.

Coming forward to the present day, a current project *Revolve* (2017) commission by Curve Theatre, Leicester shows how drawing and materials influence each other: I began by drawing vertical yellow lines to represent LED strips lights that had been decided as the light source. I then surrounded these using a simple construction rule to create shapes in grey textured pencil crayon. At the same time, I researched materials, including metallic meshes. I chose one that was the same colour and texture of the grey pencil. Knowledge about quality and rigidity of the mesh influenced how I drew the rest of the image. I refer to this drawing to establish how it will work in the installation space. Each stage of development from pencil drawing to installation, influences the materials and technology. How a work is embedded in its environment is crucial. In public art works the focus is on understanding the relationship between materials and technologies in the work and at the site together.

Simplicity arrived at out of complexity reflects an enquiry into orders inside apparent chaos present in all my works. At the start of any work all the choices around forms, materials and movement are fluid. Gradually some aspect of the work such as a movement or shape guides the rest. At the end of the process a method emerges that expresses the original complexity succinctly. The shapes and patterns I draw are my own exploration of sensations and are records of movement as well as descriptions of spaces and forms. Light is a material that can expresses movement and has been a consistent material used to choreograph and reveal actions. I like its immediacy as it changes static objects, showing everything in a state of flux. Our senses are very much affected by light; we are literally woken up by it. I want the movements to be like familiar sensations that the viewer can understand through their own felt senses.

Collaborative Ventures

An enduring feature of my practice has been an interest in and, at times, requirement to collaborate with other professionals. As each project demands new skills, it is necessary to communicate the ideas structural engineers, programmers and lighting consultants and manufacturers. I find this process develops my practice both practically and conceptually. In the 1990s, I made two collaborative works with choreographer Carol Brown. ‘Shelf Life’ was a four-hour gallery installation which toured in Britain and Europe (Rolinson and Brown 1998–9). Throughout the installation Carol was suspended on a two-metre high Perspex shelf with steel legs. Another work, ‘Machine for Living’, was is a large-scale performance installation constructed from a series of thirteen steel panels measuring five metres high that, when lined up, form a ten-metre wide wall (Rolinson and Brown 2001–3). As the performance unfolds, relationships are drawn and divided between the performers creating a ‘human architecture’. The audience is able to navigate around the performance area, moving as and when they desire, at times viewing through the perforated structure experiencing moments of both proximity and distance from the performers. These works explored the relationship between the body and architectural forms, drawing attention to the extremes of scale between them, attachments to space and the memories held by architecture beyond the experience of the individual. I also worked collaboratively with the landscape architects, Freemont Landscape Architects, on creating a landscape that included unusual structures and landforms without creating a hierarchy to a specific feature. The boundary between hard and soft landscape and 'artwork' has become entirely blurred creating the potential to make a work that is a detail of the global site.

In 1998, I undertook a residency at the Creativity and Cognition Research Studios as part of the COSTART project [COSTART Project]. 'Digital Garden' (Rolinson 1998) was a project proposal intended for an externally sited structure that uses sensors to detect factors such as rain wind or heat, interpreted through a grid of Light Emitting Diodes' (LED) within curving glass forms. I worked in the main part with Michael Quantrill and with Colin Machin of the Department of Computer Science at Loughborough University on the use of LEDs (Machin 2002). 'Digital Garden' expressed the activities of nature that we may sense but cannot see. It makes the invisible, visible. It interprets information from the elements and mimics the process of organic growth, expanding and decaying in response to the nourishment and erosion of the weather. It uses light as its cell structure and builds fluctuating patterns within its outer skin of glass.

My objective was to explore the project concepts in relationship to available technologies and gain a greater understanding of the information I needed to supply to a programmer. Mike Quantrill was an ideal person as he practices as both artist and programmer. We talked at length about the extent of control I could have over the images. I did not want to constrict the potential of the technology by defining images too specifically but, at the same time, wanted the programming to revolve only around central visual themes. During the residency Mike, Colin and I sketched out a number of programming and structural possibilities and established a working method that illustrated how the animated screens might appear. It was useful to know that this type of project was practically possible but potentially very expensive. The 'Digital Garden' was developed significantly during the residency through our mutual interest in patterns occurring in natural forms. It was particularly valuable that Mike also had a visual art practice and was willing to explore the project ideas alongside the possibilities for the technology. Our discussion raised questions around the structure and sequencing of events in the animated light panels and gradually drew the use of the technology and overall project concept closer together. In particular it was useful for Mike and I to discuss the project and then spend time individually evolving ideas through drawing and programming before bringing them back together again. In this collaborative approach to making work and have found that the dialogue assists in developing the project beyond the initial concept.

The incorporation of digital technologies into a physical fabrication, either as a controlling or evolving device, is an opportunity to create a layer of information that the structure alone cannot provide. The experience of the COSTART residency (COSTART 1997) clarified the potential role of the digital technology to expand upon the original project concept, meshing together the control and form of the work. Over the past five years I have worked experimentally with technology and programming to create more sensitively controlled light works. I see programming as a complex material that can interpret and extend light movements. It is a way to analyse the structures of movements inside the drawings with the intention of making connections between physical and programming structures.

My exploration in using programming directly in relationship to forms became more focused in the works '*Melt Splinter and Thread*' (2013) supported by Arts Council England and De Montfort University, a series of sculptural installations around the notion of disintegrating structures. '*Melt*2' is a vertical forest of forms, '*Splinter*' a shattering surface and '*Thread*' the barely perceptible presence of dust in sunlight. They are contemplative spaces made with the intention of engaging with the viewer's understanding of form and movement. The key works in experimenting with technologies were '*Splinter and Thread*'. Both were drawings rendered three dimensionally. '*Splinter*' is a burst of acrylic shards hovering in space. The acrylic fluctuates in fades and pulses with muted colour changes and variations in quality of movement '*Thread*' is an ephemeral architecture reminiscent of dust in sunlight made from sanded fibre optics attached to LEDs. To create subtle light movements in lines, lengths of fibres were connected to individually programmed LEDs. The works were developed over two years with a team of artist technologists including Dave Everitt, Sean Clark, Graeme Stuart and Luke Woodbury all of whom had a great understanding of creative process, were experienced with working towards a goal with unknown specific outcomes. Sean Clark's role was to interface between the software and hardware making recommendations on both. Graeme Stuart came on board to carry out the high level of programming required and Luke Woodbury constructed the electronics. The focus was on achieving my creative aims and each person on the team contributed to the final work and my understanding. Our aim was to utilize the subtle control that a programmed system afforded whilst visually prioritizing the physical experience through form and materials. Drawing developed in my practice during this time to explore states of being, felt sense and patterns of movement (Fig. 1).

Reflections on Collaboration

Partnerships and collaborations are a necessary part of my practice on different levels and time spans. Large-scale light works require teamwork, with assistants and collaborators, including manufacturers, artists, consultants and programmers. When I visit a factory or workshops I often meet skilled makers and thinkers. Creativity is in many processes, but not necessarily recognised. I relish discussing how to use tried and tested skills, perhaps slightly differently. It is often shared

Fig. 1 'Splinter', Light installation, acrylic and programmed LEDs. Photograph courtesy of the artist

enquiry that achieves the work. I feel that besides drawing, my skills or 'material' as an artist is communication.

Collaborations have come about by meeting practitioners 'en route' and sometimes being paired with artists and designs by commissioners. Choreographer Liz Aggis suggested collaboration with choreographer Carol Brown in her role as Director at Brighton Dance Agency. We made formative work together that remains a resonant creative experience. A different example is '*AirWave*' (2004) Bracknell in which the brief was to collaborate with Prior, Manton, Tuke Powell Architects. I would describe this more as a design team consultation with specific end goals rather than a mutual exploration. But, the dialogue was interesting and we were all pleased with the work.

In '*Melt Splinter and Thread*', through discussion and development of visualisation models with Dave Everitt and Sean Clark, I gained an understanding about programming possibilities. To achieve the animated lighting, I envisaged required expansion of my field of knowledge around patterns such as flocking, flowing and crowding. Ideas of movement patterns described through texts and drawings were translated into a set of behaviours that could be used to animate the physical piece. The software created subtle and complex movements and established clearer connection between drawing and programming.

Collaboration with Sean Clark came about over about three years working on '*Melt, Splinter and Thread*' and '*Flown*'. Gradually, a common ground around systems of connection surfaced. We started to work more creatively together in the refinement of '*Flown*' following its premiere at the Illuminating York Light Festival. In the first version, it used the programming from Melt, Splinter and Thread. Sean Clark was an important part of the technical development and installation process. With the aim of taking it to the Art CHI Exhibition, (CHI 2016) we decided to detail 'Flown' further. New programming was developed more specifically to the nature of the piece as an extendable structure. It had its own set of simple behaviours and changed colour and pattern in response to light, humidity and temperature in its' immediate environment. The light movements were soft and subtle with a sense of the work breathing. The work now extended the principles of connections from drawings to physical form, behaviours and responsiveness. Following this, '*Flown*' was awarded the Art CHI Prize CHI 2016, San Jose, California and the 3D and Sculpture award, Lumen Global Digital Art Prize 2016.

Further work with Sean Clark is evolving and reflects our conceptual thinking. We are two individual artists and our systems of work interconnect and enrich the other whilst remaining their own entities. There is a broad spectrum of collaboration between us, with some shared goals and also different desired outcomes. There is a common motivation to put art into a broad set of contexts where anyone might experience it without prior knowledge or understanding of the project or art itself. The dialogue gives me greater understanding of my practice which is a fundamental benefit beyond sharing of skills.

Over the past year and half, I have been developing a series of works '*Gravitate, Signal and Facets*' through a series of drawings. With funding from Arts Council England, I am beginning to translate these into three dimensions. The process is informed by investigating construction systems inside my drawings, extended this into physical structures, lighting technology and programming. A key part of this process is development of work collaboratively to explore hand and digital drawing processes as a way to deconstruct the forms and gestures through a gesture capture app. This is motivated by the ambition to translate the movement inside the drawings and forms into light sequences that can be part of the new installation works. It furthers an ambition to make works in which movements, sensations and forms unfold from the same source in drawings. It is slowly unearthing more than could be predicted, revealing subtle connections between human and digital process.

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Collaborative Practice in Systems Art

Sean Clark

My creative work is concerned with an on-going exploration of flow and connectedness. After completing a Computer Studies degree at Loughborough University in 1988, I worked as a researcher at Loughborough and then Derby Universities. I have always been interested in the intersection of art and technology and it was while at Derby University in the late 1990s that I began to move from being a computer scientist who often worked with artists to feeling comfortable seeing myself as an artist in my own right.

Much of my work at this time was concerned with the Internet, multimedia and Virtual Reality—what was collectively referred to as "new media". My output included CD-ROMs, live performances, club events and websites, with my first gallery-based piece being Flow in 2000, a collaborative installation at the Q Gallery in Derby with Geoff Broadway. Since then, I have developed my own digital arts practice that combines screen-based, installation and printed work. I have exhibited nationally and internationally, winning the Art.CHI and Lumen prizes in 2016 for the collaborative artwork *Flown* with Esther Rolinson.

I am typically described as a "digital artist", and many of my skills certainly fit within this field. However, it would be more accurate to say that I am a systems artist, since my interests are primarily related to the systems-like nature of the world around us and I see the systemic behaviour of my artworks as being their primary characteristics.

From Art Systems to Cybernetic Ecologies

From my earliest creative output in the late-1990s to the present day I have referenced "systems" concepts in my artworks. This was initially manifest in the type of audio-visual materials I used in my live and installation work, with natural and ecological images often being combined with diagrams and anatomical drawings to suggest the different ways of knowing the world.

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_32

As I began to consider how I could engage with systems concepts in deeper ways, I started to create work that aimed to behave *like* systems, rather than simply looking like, or alluding to the systems worldview. These 'Art Systems' are designed to interact with their viewers and their environment and evolve over time whilst maintaining certain rules of construction.

This concept has been developed further to the point that I now aim to construct "Cybernetic Ecologies", collections of digital and non-digital artworks that interact with their audiences and each other. Cybernetic Ecologies are inherently collaborative, opening the opportunity for multiple artists to collocate artworks that can interact.

Collaborative Practice

When I reflect the development of my creative practice it becomes clear to me that collaboration is a key part of how I work. My very early work took place in club environments. Such activities typically involved a group of people—musicians, artists, VJs and other performers—working together to produce the event.

My first installation, *Flow* with Geoff Broadway in 2000, was a collaborative piece. Similarly, my first self-defined "Art System" work, *A Choreographer's Cartography* at The City Gallery in Leicester in 2005, was an interactive artwork with poet and writer Raman Mundair that evolved in response to the viewers. Similarly, the first prototype "Cybernetic Ecology" in 2012 was an exhibition entitled *Symbiotic* in collaboration with arts group Genetic Moo at Phoenix in Leicester. Six co-located artworks (three by myself and three by Genetic Moo) were installed in the exhibition space and were able to listen or watch each other as well as respond to human initiated changes in the environment (Fig. 1).

Development of a New Aesthetic

Given the important of collaboration in the development of my art practice it is not surprising that when, following the *Symbiotic* exhibition, I decided to undertake a review of my aesthetic that the early showings would involve collaboration.

Up to and including *Symbiotic* my artworks were largely video-based and used video capture, processing and feedback to create their structures. However, despite being a successful exhibition, I wanted to focus on understanding the nature of the interaction between the artworks. This led me to consider moving to a more minimal and algorithmic approach to the construction of my artwork.

Pioneering artist Ernest Edmonds supported my change in aesthetic direction by giving me insights into his creative practice and invited me to work with him on the creation of *ColourNet*. In this piece, I created a self-organising grid of colours running on a viewer's mobile device that was connected through the Internet to one

Fig. 1 The *Symbiotic* exhibition in 2012. An exhibition of connected artworks by Sean Clark and Genetic Moo. Photograph courtesy of the artist

of Ernest Edmonds' *Shaping Forms*. This was as part of Ernest Edmonds' *Light Logic* exhibition Site Gallery in Sheffield in 2012 (Edmonds 2012). It was later shown as part of the CHI'2013 art exhibition in Paris (Clark and Edmonds 2013).

A variation on this idea (Fig. 2), in which two screen-based grids are placed side-by-side and with different organisational rules exchange colours via a web service, was included in the *Automatic Art: Human and Machine processes that Make Art* exhibition curated by Ernest Edmonds at the GV Art Gallery in London, 2014 (Devcic 2014).

Collaborations with Esther Rolinson

In 2013, I was given the opportunity to work with artist Esther Rolinson on her exhibition *Melt*, *Splinter* and *Thread* at Phoenix in Leicester. Esther Rolinson's work combines light installation with drawing and she was initially looking for technical support in creating the three new light pieces. This working relationship continued with Esther's next piece *Flown* at the Illuminating York Light Festival later in 2015.

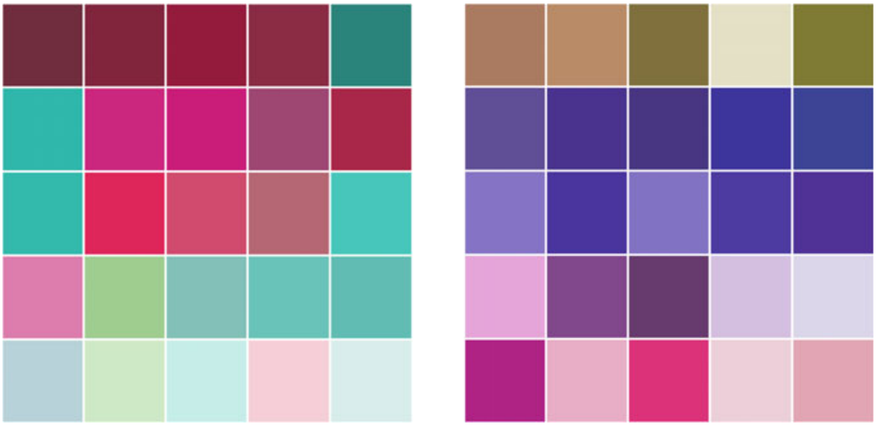

Fig. 2 When shown a screen-based digital artwork the left-hand and right-hand images constantly exchange colours and order them in accordance with their own internal rules. Images courtesy of the artist

While working with Esther it became clear that, despite our very different creative histories, we had a great deal in common. In particular, there was a shared interest in systems and the relationships between "parts" and "wholes".

I also found the almost "algorithmic" process Esther used to create her drawings very interesting. Indeed, I playfully included her work in an exhibition of machine drawing I curated in Leicester in 2015.

Despite the algorithmic and intensely repetitive processes used in its construction, Esther's drawing work is also very personal and very "human". It clearly could not be the work of a machine and the handmade nature always shines through. This is especially apparent in the three-dimensional structures that often emerge from the drawing process.

When the opportunity was presented to show *Flown* at the CHI conference in 2016 in San Jose we decided to rework the lighting system to include some of the ideas relating to responsiveness and connectedness from my practice (Rolinson and Clark 2016). The artwork was made to respond to changes in light, humidity and temperature levels and was able to exchange information with other copies of the artwork (or, potentially, any artwork in a cybernetic ecology). Presented as a collaborative piece, this version of *Flown* went on to win the 2016 Art CHI prize, and then the Lumen Prize for 3D/Sculpture in London later in the year.

As the partnership has developed we have exhibited other joint artworks, such as *Signal* (Clark and Rolinson 2017) and I continue to work with Esther in both collaborative and supporting roles. Unlike some past collaborations, this process is continuing beyond a single piece of work and consequently issues such as attribution and ownership of work raise themselves. Our solution to this is to maintain a creative dialogue that gives us space for individual and joint practice.

Our work has recently taken an interesting direction with a focus on capturing the act or *gesture* of drawing. I am developing a suite of software tools that are able to capture and replay Esther's drawings on an Apple iPad. This work is still in its early stages, but one goal is to allow Esther to use the drawing captures as the basis for lighting sequences in future light sculptures.

Reflections on Practice

When reviewing over 20 years of creative practice for this article it becomes clear to me that two things are central to how I work—collaboration and reflection. Key steps in the development of my practice have involved collaborators, be it my first gallery exhibition in 2000, with Geoff Broadway; my first interactive gallery piece in 2005 with Raman Mundair; *Symbiotic* in 2012 with Genetic Moo; *ColourNet* in 2012 with Ernest Edmonds; and *Flown* with Esther Rolinson in 2016.

Collaborations are always different, but patterns can be seen. Many of my early collaborations involved me providing the technical input to a project, but as I have developed as an artist this has given way to much more of a collaboration between equals. While my background inevitably means that I have technical skills that are valuable in a collaborative project, later projects have been more evenly balanced in terms of me bringing new concepts to the work, this is particularly true of the most recent work with Esther Rolinson.

These periods of collaborative work are often punctuated with periods of reflection. Be it my early attempts at bringing my interests in systems and digital art together informally, or through more formalised periods of research, such as during my MA, *thinking* about what I am *doing* is clearly important to me.

My current focus on Cybernetic Ecologies has emerged through quite intensive reflection as part of a Ph.D. programme. This research took the form of a series of make-exhibit-reflect cycles (centred around three gallery exhibitions over a five year period), with only the third cycle yielding the fully developed Cybernetic Ecology concept. Collaboration is also now key part of my practice since I believe that Cybernetic Ecologies are more interesting if they feature work by multiple artists.

I said in the introduction that although I happily accept the label "digital artist", I see myself as more of a "systems artist". The fact remains, however, that I *do* use digital technology in most of my work. While I could consider enlarging my palette and may do so in the future (systems artists work in photography, paint, video, landscape art and many other areas), I actually find digital technology particularly well suited to creating the type of work that interests me.

The ability of a digital art system to react immediately to stimuli makes it particularly well suited to creating connected artworks that behave like systems. In fact, I have come to believe that this is the key affordance of the *digital medium*. In a world where almost all art involves digital technology of some sort it is the ability of the digital artwork to *behave like a system* that makes it different from art that simply uses digital technology in its construction or distribution.

End Note

1. *Flow*, and all other artworks by Sean Clark mentioned in this article are extensively documented on his website at http://www.seanclark.me.uk.

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Creativity, Technology and Collaboration Towards Hoped-for and Unexpected Serendipities

Anthony Rowe

Using three projects by digital arts group Squidsoup (www.squidsoup.org) as examples, this article maps out a spectrum of collaboration within digital media arts, ranging from serendipitous encounter to entwined collaborative development towards a shared goal. The examples show that these collaborations can easily produce unexpected results but these results often have significant value as original, cross-disciplinary offerings.

Squidsoup—Arts Practice and Background

Squidsoup is a digital media arts group, specialising in creating hybrid, immersive and responsive experiences that occupy physical and digital space. Members include artists, designers (graphics, interaction, 3D, games), musicians, researchers, creative technologists and coders. Since its formation in 1997, the group has evolved through a variety of structures, sizes, approaches to funding and production, personnel, and reasons for being. However, one constant throughout its existence has been an attempt to fulfil at least some of the potential promise of digital media to create extraordinary and evocative experiences. Since its inception, we have been searching for ways to create new forms of immersion, intuitive interaction, to encourage suspension of disbelief and the embracing of augmented and enhanced physical experiences. From initial explorations into VR panoramas and the possibilities of the CD ROM, to recent projects involving volumetric visualisation in physical space or the use of bioluminescent bacteria to visualise immersive soundscapes, the ambitions have remained similar. However, the technical and other expertise and inputs required to realise these projects has been very broad, encompassing artists, designers, musicians, architects, academics and researchers, biomedical scientists, performers, creative technologists and engineers, coders, and a range of clients and commissioners from arts organisations through advertising agencies to government departments and commercial companies.

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_33

Fig. 1 Evening/morning: Four Tet and Squidsoup, 2016. Image: James Lane/Future Sun. Image: Anthony Rowe

There is much pressure in digital art circles to pursue the 'new': that is, to use novel and cutting-edge technologies in original ways, as this is an established route to creating newsworthy work with a significant 'wow' factor. Indeed, this is a process that has been going on for millennia, as each new technical innovation is subsumed into the creation of cultural experiences—for example, in the case of immersive art experiences, the history from Roman frescoes to tech Mixed Reality experiences (Grau 2003). In recent years, the creative possibilities of emerging digital technologies have been unfurling at an accelerating rate, to the extent that digital artists are under significant pressure to keep up with the technology, and develop ever newer technical approaches. Although very exciting, these circumstances can result in immature work that has not had the space to develop artistically—or even becoming showcases for proprietary technologies rather than cultural experiences or artworks (Fig. 1).

Artworks and Meta-Projects

Many artists, Squidsoup included, protect themselves from this breathless technological leapfrogging by focusing on specific artistic criteria (thematic, aesthetic, affective) to develop their work, rather than pursuing technology-led ideas. Clearly, any digitally-based artwork will be using relatively recently developed technology, but the technology need not be the focus. In the case of Squidsoup's work, the technology is simply a tool—in other words, a means to an end.

Squidsoup's working process has resulted in a series of groups of works, where each work within the series uses similar artistic, creative and technological approaches to attempt to achieve specific artistic and research goals. We call these *meta-projects*. Individual projects within the meta-projects explore the possibilities of the approach in different ways, different circumstances and to different ends. The projects also feed off each other, benefitting from technological similarities, but also from reflection on the strengths, successes and failures of prior iterations, and in fact collectively steering the path of development of the meta-project. These meta-projects can last ten years or more, resulting in a range of outcomes that cover research and experiments through to mature artworks, projects, theoretical frameworks and commercial products.

As at 2017, three current Squidsoup meta-projects are *Ocean of Light*, *The Autonomous Pixel*, and *Bioluminescent Media*. These are briefly described below, with reference to one particular artwork that emerged from each meta-project. The development of the artwork is discussed in particular in reference to how it fits within its meta-project, and also how it emerged as the result of interdisciplinary collaboration (Fig. 2).

We Are Not Alone is the first output from Squidsoup's most recent meta-project, *Bioluminescent Media*. The ambition is to explore the creative possibilities of using bioluminescence as a source of light in digitally controlled artworks, particularly in the area of volumetric visualisation and immersive experience. The light emitted by bioluminescent bacteria has a delicate blue-green hue, and is of a quality very different to that emitted by LEDs, lasers or even incandescent bulbs. Being the first output of the project, *We Are Not Alone* was the result of open-ended experimentation. The luminescence is triggered through agitation, and early trials involved an array of small vials filled with bioluminescent bacteria in liquid media that, when touched by passers-by, would naturally illuminate. However, we discovered that much larger volumes of media, when agitated, created stunningly beautiful and

Fig. 2 Bloom by Squidsoup, Kew Gardens, 2016. Image: Anthony Rowe

delicate patterns of luminescence that evolve over time. These slowly morphing volumetric forms and patterns then became the focus of the project, in terms of creating a (digitally-controlled) method of agitation that would trigger the patterns, and also as the inspirational ambience for a highly spatialised soundscape to accompany the visuals. The final piece consists of a 40 cm diameter suspended glass sphere which contains the bacteria. An Arduino-triggered air pump blows controlled bubbles of air through the bacteria from below, creating the abstract bioluminescent forms. The spatialised musical composition both places the gallery in an ambient soundscape, and also creates the illusion that the bacteria themselves are producing sound (see www.squidoup.org/wana).

We Are Not Alone was a collaboration on two fronts, quite different in nature:

(a) *Sonic collaboration* (with Natasha Barrett). The soundscape consists of three complementary forms of spatial sound. The choices, both technical and aesthetic, were based on detailed discussions and trials, musing over the emerging forms from the media, and what we were trying to evoke with the piece. Additionally, experimenting with ultrasonic speakers enabled us to create the impression that the bacteria themselves emit sound, as the highly directional soundwaves bounced off the sphere and towards any viewer looking at the bacteria (Fig. 3).

(b) *Microbiology* collaboration (with Siouxsie Wiles, Auckland University, and facilitated by Brian Robertson and Colleagues, Imperial College, London). The second form of collaboration was scientific rather than creative. Dr Wiles provided the bioluminescent bacteria that she had developed as part of her work in immunology and microbiology education, along with advice and support on

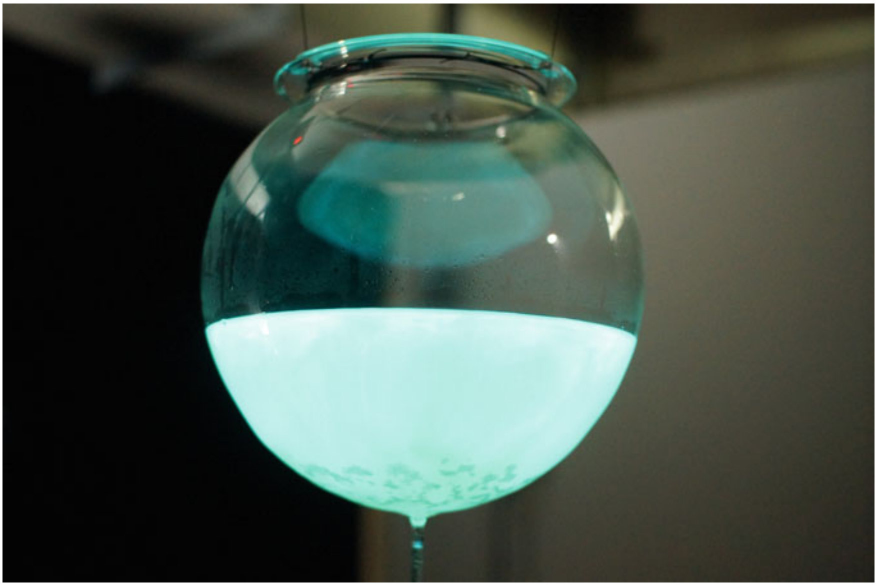

Fig. 3 We Are Not Alone. Squidsoup and Natasha Barrett, 2015. Image: Anthony Rowe

maintaining the culture, optimising luminance and so on. Further explorations were supported in the UK by Imperial College, London.

The work was publicly exhibited in Oslo as part of Oslo LUX 2015, and awarded an Honorary Mention at Prix Ars Electronica (2017). As is to be hoped at the beginnings of a line of enquiry such as this, the work highlighted various avenues for further exploration. In this case, the aspects of particular interest for further development include the participation of microbiologists and others to formulate alternative media that keep the bacteria alive and luminous, yet have improved clarity. It also involves finding ways to reduce the effort required to maintain optimum bacterial illumination (this currently involves regular replenishing of the food/media, and siphoning off of bacteria). These issues could be reduced using biology (genetic selection) or by finding mechanical means to feed the bacteria. At a creative and experiential level, a single bioluminescent sphere, whatever its size, falls short of the aims of the meta-project, which is endeavouring to create controllable media spaces using bioluminescent media.

The Autonomous Pixel: Bloom (2016)

The *Autonomous Pixel* meta-project focuses on a decentralised approach to digital media, but still within the scope of creating large scale and potentially immersive experiences. We regard an Autonomous Pixel as a point of light (or other form of digitally mediated output) that has a degree of autonomous processing ability; an awareness of where it sits within a larger array, yet able to process data and inputs, communicate, and produce its own responses.

Bloom is the third iteration of the meta-project. It was preceded by *Remembrance* (2015) and *Field* (2016). All three projects consist of spherical lights on flexible fibre stalks, with each unit also containing other technology, such as an accelerometer and processor, within the sphere. The point of the project though is not about the individual unit per se, but rather to reflect upon the overall effect as a form of emergent behaviour. The three projects each had in the region of 1000 individual units, each responding in real time to various environmental, spatial and temporal factors.

With *Bloom*, the units consist of LEDs, a speaker, Wi-Fi-enabled processor, accelerometer and GPS unit. The units can communicate with each other and with a central server—they therefore inhabit a virtual network, effectively creating a responsive symphony of ‘Internet of Things’ enabled devices. This collectively creates a dynamic datascape, able to respond individually to choreographic commands from a central server, but also able to respond to human interaction and to the calls of other devices—creating a dynamic and responsive digital overlay covering a large outdoor space.

Bloom was an international and multidisciplinary collaborative project in the broadest sense, involving four countries in three continents, vastly different types of organisation with very different skillsets. Artistic and project development was led by Squidsoup in the UK, but other parties, integral to the development of the idea and the technology used, included the University of Technology Sydney (Australia), a small hardware development company (Digistump, Washougal USA), two technical manufacturers (in Shenzhen and Guangzhou, China) and an international world leader in networking (Xirrus).

The project involved a large technical jump from previous iterations, creating a lot of unknowns and risks. Predictably, development was not entirely without issues (mainly in terms of production), but it never-the-less ran continuously for six weeks during late 2016 at the Royal Botanical Gardens, Kew, and then moved immediately afterwards to Canary Wharf (also in London, UK) as part of their Winter Lights festival.

Each collaborating party fulfilled their part of the project. However, cultural (both across disciplines and nations) and linguistic differences caused some unexpected issues and mismatches that needed to be resolved at high speed. For example, as a result of having two factories building and assembling components for the project, the items arrived in separate parts in the UK, meaning that 1000 units needed to be manually assembled and weatherproofed at high speed (and untested) just days prior to launch. Yet these stresses and strains should also be seen as key advantages of collaborative processes. In much the same way as the use of emerging technologies has an often unpredictable effect on a project and on the creative development process through the uncovering of both limitations and unexpected affordances and capabilities, so too does the clashing of minds and priorities involved in collaboration.

It is also worth noting at this stage that an artwork's commissioner, or client, may be to some degree a collaborator, in-so-far as they often have a key role in defining the scope of a work. In the case of *Bloom*, the commissioner (Culture Creative, a UK production and event management company specialising in light festivals) defined the budget, location and the flow of people through the piece in discussion with us and to optimise the effectiveness of the work within the realms of what was possible.

Ocean of Light: Evening/Morning (2015-6)

Evening/Morning was a series of four live concerts with DJ Musician, Four Tet. It emerged from the *Ocean of Light* meta-project. The meta-project has been running since 2007, and produced numerous works that between them have been exhibited over 40 times on five continents. *Ocean of Light* uses large, suspended walkthrough arrays of individually addressable LED 'voxels' (points of light in space) to create immersive visualisations that occupy physical 3D space. The resulting experience can be regarded as an alternative form of Mixed or Augmented Reality (Milgram and Kishino 1994), where three-dimensional digital forms and architectures are visualised using the LED array, mapping a volumetric digital overlay onto physical space. Originally developed to create immersive, responsive installations (such as *Submergence* (2013, 2016) or *Aeolian Light* (2014)—see for example www.squidsoup.org/submergence), we became very interested in seeing how the same approach would work in other environments, in particular as part of a live performance, and whether it could be used to begin to challenge the boundaries between performer and audience, as well as between the physical and the virtual.

Three of the four Four Tet events occurred in conventional stage venues (at Manchester International Festival, Sydney Opera House and London's Roundhouse), but the fourth event took place at the ICA (London's Institute of Contemporary Art), where there was no formal stage. Four Tet performed on a low riser in the centre of the theatre, surrounded by the suspended LEDs. The audience was allowed into the LED space, very close to the performer and also within the LED array. This meant the audience was also immersed within the dynamic light visualisations, creating a clear breach of the boundaries between audience and performer, performance and installation.

The collaboration process here was simple and organic. Terms of reference were agreed, very loosely, at a single meeting a few months prior to the concerts. A rough set-list was presented, although the musician was clear that what he plays at a given performance is to a high degree improvised and unpredictable. Each event was also affected by the ambience of the venue and audience, and so adaptability and flexibility were key. The aim of the collaboration was to be flexible, responsive and to anticipate intriguing juxtapositions in the meetings of these two separate works. It was felt imperative that the collaboration must not impede the creativity of either partner, or restrict their ability to improvise in the moment. A reliance was, therefore, placed on serendipity: that through the overlaying and intertwining of two separate creative processes, interesting and unpredictable synergies would emerge.

Summary

The three examples above describe individual projects that occurred at different points within the developmental path of what I have called meta-projects, series of works that collectively form a body of iterative exploration of a specific theme. *We Are Not Alone* is a work at the beginning of a meta-project, *Bloom* somewhere in the middle, and *Evening/Morning* took place ten years into development, and as such, is a relatively mature output from a meta-project. There are several other projects that could have been used as examples of collaborative practice with the meta-projects described, these are therefore merely exemplars, or illustrations of the processes that have emerged in Squidsoup's collaborative creative practice.

Conclusions—On Creative Collaboration

Several recurring themes emerged in the collaborative projects discussed. It should be noted above all that Squidsoup is itself a collaborative practice. This paper has focussed on external interdisciplinary collaboration, but the relationships within

Squidsoup are also collaborative, dynamic and interdisciplinary, and involving personnel that work both within and without the Squidsoup group.

Whatever the nature of the collaborating partners (be they a collective, university, private company or other), each will have their own cultures, priorities and methods of working. The goal of creative collaborations whose aim is the production of a specific project or artwork is to harness these differences, get the most out of them for the project, steer them towards the project goals without stifling them or limiting their input.

In Squidsoup's collaborative art practice, the following themes and lessons have emerged:

Hierarchy: technology is viewed as an enabler, a tool or means to an end. It can also be a source of inspiration, and will of course have an effect the final outcome, but it is not an uninhibited determiner of creative direction. Art that uses technology still needs artistic priorities, or risks becoming technological showcase.

Level of co-development: there is a difference between collaboration and co-development. A collaborative project is often thought of as a group of people working together in the same room, or at least in frequent contact with each other. In the examples above, I suggest that, particularly in the case of more mature projects, collaboration can consist of parties that meet and discuss only infrequently, and produce work whose components are developed quite separate from each other (albeit with the collaboration seen as a goal from the inception). Other forms of collaboration of course need to be in depth—in particular when developing the technological platforms that will be used for multiple individual projects. These are not two discrete forms of collaboration but a spectrum. The degree of co-development needs to be defined per project, based on the needs of the project and the nature of the collaboration—but high levels of co-development are not necessarily beneficial, as they can inhibit flexibility and serendipity.

Flexibility *and Serendipity*: All of the collaborations discussed above have spawned surprising synergies, affordances, abilities and opportunities, and surprisingly often through misunderstanding and unexpected developments. The examples suggest that looser creative collaborations can foster an increased likelihood of serendipitous and unexpected benefits. Flexibility is needed to capture these possibilities, and see them as such, rather than as merely methods to overcome limitations and resolve technical issues. Yet, it is always a balancing act. Too little flexibility and creativity and serendipitous discovery suffer, but too much flexibility can easily have an adverse effect on the artistic integrity of a project.

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Collaborative Creation in Interactive Theatre

Andrew Johnston and Andrew Bluff

This article describes the collaboration between the authors, two digital artist/researchers from the Creativity and Cognition Studios at the University of Technology Sydney (UTS), and the Australian based physical theatre company, Stalker Theatre. This collaboration has been under way since 2011 and has resulted in the creation of five major works that have toured internationally. Here we focus primarily on the most recent of these, two complementary performance works for children: a physical theatre show and an interactive installation. These works were inspired by Ethel C. Pedley's classic Australian children's novel, *Dot and the Kangaroo* (Pedley 1929), in which a young girl becomes lost in the Australian bush. She befriends a mother kangaroo and, after eating some magical berries, the two share a fantastical journey, during which the little girl talks to a number of native Australian animals and learns of humans' negative impact on the natural environment. Both the theatre show and the interactive installation explored the ecological themes and narrative of the novel and featured large-scale interactive visuals that responded to physical movement.

Stalker Theatre and UTS began collaborating in 2011, when David Clarkson, the Creative Director of Stalker approached Andrew Johnston, who had expertise in the use of interactive technology in live performance. Initially, the focus was on the use of interactive technologies in live physical theatre performance, and the potential of various technologies such as motion tracking[1] and photogrammetry[2] was explored in a series of workshops. The general pattern of development was for Andrew to sketch up some rough prototypes based on previous discussions with David and other artists and on his own past work. These prototypes would be shown in a small studio at UTS, and performers would dance with them in order to get a sense of their potential.

As the worked progressed, we began showing the work publicly, but only to small audiences of 20–30 people, in order to gain experience with the technology, get audience and performer feedback, and provide impetus to further development. As the ideas for a larger scale performance gradually took place, funding was obtained from local arts bodies to enable larger scale experiments in bigger venues.

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_34

Workshops, which typically ran for 2–3 weeks, began with performers improvising with prototype interactive systems which had been developed beforehand. As the workshops progressed, performers would develop a set of movements or moods which seemed to work with different settings of the interactive systems. Likewise, the digital artists developed a 'palette' of pre-set interactive system states which were effective and well-matched to particular choreographies.

As the show moved towards its final shape and the scale and complexity of the work increased, Andrew Bluff joined the team. The development workshops culminated in the creation and performance of *Encoded*, an hour-long dance and physical theatre work exploring the relationship between humans and the digital worlds they create and inhabit. *Encoded* was well received and went on to tour nationally and internationally for several years.

Technology

The software system used for both the theatre show and the interactive installation is an evolution of the fluid based particle system developed for the initial 2012 work, *Encoded*. An infrared camera and optical flow algorithm is used to process any movement in front of the projection screen and apply appropriate forces to a virtual fluid simulation. As the performers or participants move about the stage, they effectively 'stir' the virtual fluid which ripples and flows in response to this physical movement, carrying with it a mass of digital particles.

While the core of this interactive system remained unchanged for *Pixel Mountain* (2013) and *Frameshift* (2016), a substantial series of technical upgrades were added to create a large 360° interactive play-space for *Creature: Interactions* (2016) and expand the visual palette for children's storytelling in *Dot and the Kangaroo* (2016). An attraction system was implemented where particles could loosely stick to the vertices of 3D models, allowing simple images to 'emerge' from the abstract particle system. Bullet,[3] a rigid-body collision simulation, was added to the system allowing 3D particles to semi-realistically bump, rub and spin when in contact with one another. The particles can be attracted or repelled from the source of physical movement and, when combined with the collision simulation, this effect strongly resembles a flocking algorithm. A range of real time visual effects (such as blurs, trails, masking and lighting) were added and a layered compositing engine was built to combine the interactive particle graphics with pre-rendered video and visual effects in real-time (see Fig. 1). A network architecture and projection stitching capability was also added to enable multiple cameras and projectors be combined in a unified 360° display. These upgrades enabled the landscapes and characters to be portrayed with a diverse interaction style and more literal visual aesthetic in *Dot and the Kangaroo* and facilitated an immersive 360° presentation of *Creature: Interactions*. For more information on the system's use for interactive storytelling and immersive interactions within these works see Bluff and Johnston (2017a, b).

Fig. 1 The particles are composited with the pre-rendered landscape to interactively tell the story of *Dot and the Kangaroo*

Observations and Reflections

The ongoing collaboration between UTS and Stalker Theatre can be considered successful in that it has produced five internationally toured productions, been well received by audiences and critics and resulted in several research publications. During this time, we have observed and reflected upon a number of aspects which have largely defined the nature of this collaboration. These observations represent both the authors' and Stalker Theatre's approach to the collaboration and how they may interrelate. These findings have emerged through semi-structured interviews with the artists, directors and performers of Stalker Theatre and are presented in conjunction with self-reflections from the perspective of the authors.

When considering the characteristics of the collaboration, and what has made it successful, it is immediately apparent that there is a high degree of respect and understanding between Stalker Theatre's Creative Director, David Clarkson, and the digital artists Andrew Bluff and Andrew Johnston. Naturally, a degree of respect is expected between professionals in different domains. It should, of course, be the case that those working on technical aspects of any creative project have a sense of the nuances and history of the art form they are engaged with—although there are, unfortunately, more counterexamples than there should be.

When a collaboration is based on 'commissioning' work—where an artist enlists a technologist to develop digital systems for example, or where a technologist hires an artist to show off a new technical development, there is a risk that the outcomes are not satisfying creatively or technically. We feel that the collaboration in our case is based on an unusually high degree of cross-domain 'sympathy'. The digital artists, while they have a background in music rather than dance or physical theatre, have a strong sense of aesthetics and an understanding of performance and art history. Conversely, creative director, David Clarkson, studied astrophysics at university for some time before going on to work in theatre. As such, while he is not a software developer, he has an implicit understanding of the essential aspects of digital technology—what it is good for, and where its limitations lie.

It has been argued that more effective movement-based interaction design results when designers become experts in movement (Hummels et al. 2007), and our experience suggests that this is indeed the case. However, while we agree that designers in this area should have a high degree of sensitivity to, and awareness of, movement, time pressures can present a formidable boundary when in comes to mastering all aspects of a multi-disciplinary project. While we certainly would have liked to participate in the yoga and dance warm ups as a means to immerse ourselves in the physicality of the performers' world, it simply was not practical with such a short development period.

In this collaboration, our sensitivity to movement came about largely through being present during warm ups and rehearsals, and this co-location was critical. While a large amount of technical preparation, coding and design work took place before workshops there was still a significant amount of technical work to be done in the room, as performers developed movement strategies and skills. This had immediate concrete benefits, because rapid feedback on design ideas and technical features could be gathered directly from performers, and it fostered longer term benefits with the digital artists and performers developing an understanding of one another's working methods, challenges, skills, limitations and artistry.

Technology as Fragile, Megalomaniacal Beast

We have previously discussed the fear that many technologists encounter when working with artists from traditional domains: that the technology will have a tendency to dominate and detract from a more directly human, physical artistry (Johnston 2015). While this fear still exists, outright resistance to the use of digital technologies is gradually fading as the number of successful works grows.

During interviews in which Stalker's team members were invited to reflect on their experiences, a counter conception of the digital technologies emerged: that of the 'fragile beast'. While the digital artists acknowledged the possibility of their creations exhibiting domineering traits, they also had a clear understanding of their frailties. They saw the long chains of function calls, large protocol stacks and gaffer-taped cables and marvelled that the whole assemblage worked at all.[4] Far from having a unified, simplistic set of character traits the assemblage of technologies was complex and changing over time. The implication is that we are describing a network of collaborations between humans and their technologies

(Latour 2005; Latour and Porter 1996). The technologies have embedded within them scripts—literally in the form of computer code, but also inbuilt design attributes which afford certain activities and inhibit others (Akrich 1992). In effect, these characteristics mean the technologies shape and influence the behaviour of the creative team in the same way that human participants do. Like the other participants, they must be enrolled in the project, convinced to contribute ideas, support others and be coached to perform reliably in rehearsal and performance.

Just as (implicit) distinctions between ‘artists’ and ‘technologists’ is unhelpful, characterising digital systems as ‘technologies’ to be used as passive carriers of the creative intentions of artists (digital or otherwise) is misleading. Following Latour, we argue that the digital systems can instead be more helpfully seen as full participants in a complex collaboration involving all manner of humans and non-humans. The advantage of this perspective is that it helps ensure that the artistic work is not seen only as a human social construction with technologies playing a passive, subordinate role; or, conversely, as a technology-driven work in which humans merely play the roles allocated to them by designers. In short, it promotes a symmetrical view in which human and non-human actors are considered on equal terms.

Given the framing of digital systems as participants in the collaboration, we now consider the strategies that were used here to ensure they were effective contributors. Given the fears that some performers had of the digital systems’ domineering traits, much attention was given to establishing trust. Just as the digital artists benefited from being present in the rehearsal venue as performers warmed-up, sketched ideas and rehearsed, the artists benefited from being in the room as the digital systems were being set up, configured, tested and refined. During this time, they were able to familiarise themselves with the behaviour and appearance of the digital systems, play with them and generally get a fuller sense of their character, including the megalomaniacal traits, but also their fragility and dependence. Ensuring that the digital system was present and interacting during the collaborative development allowed the movement artists to learn the capabilities of the system through playful interaction (Turner et al. 2005) and facilitated moments of serendipitous discovery (Latulipe et al. 2011). The opening scene for *Dot and the Kangaroo*, which featured a digital hare shadowing an acrobatic actor, was serendipitously discovered during a lunch break when the digital artwork and performer were playfully shadowing each other’s movements and chasing each other around the room (see Fig. 2).

While the human artists and technologies inhabited the same space during development, the digital system required specialised lighting conditions (namely the absence of sunlight and introduction of controlled stage lighting) which became unpleasant and dangerous for the performers when learning new acrobatic choreography. This simple conflict of lighting requirements restricted the digital system’s presence during development and limited the scope of play and discovery between the performers and the interactive digital entity. We seek to rectify these lighting requirements in future productions to allow the digital performer to be as present as the human collaborators during a development period.

Fig. 2 The digital hare shadows the movement of an acrobatic performer: image courtesy Stalker Theatre

The use of physics simulations as the basis for the interactive graphics was another strategy (used widely by interactive dance works, games and installations) to engender trust by generating visual responses which were intuitively understandable by anyone regardless of their level of technical interest or expertise. The physics simulations helped bring the projected animations into the physically grounded realm of dance/physical theatre, as opposed to interactive systems which require performers to move over particular spots to trigger pre-recorded video playback for example, which arguably demand that performers engage in more digital, discrete-push-button-style behaviours.

A further driver of the use of physics simulations was the desire to bridge the gap between stage and ‘screen’.[5] The fact that the pixels in the projections moved in physical ways helped to bring them into the physical world of the stage and the human performers. Likewise, linking the physical movements of the performers to forces exerted on the fluid helped bring their physical world into the digital realm of the projections.

In an effort to maximise the presence of the interactive digital technology during the collaboration, our aim was to have all of the actual software and hardware, fully realised before hitting the floor with the performers. A number of interactive animal shapes, animated bush landscapes, audio generated interactions, live projection mapping and bird flocking algorithms were prepared using pre-recorded motion capture to find interesting interactions and troubleshoot the system before meeting up with the performers.

While this preparation was important to maximise the digital presence within such a short development period, we were cautious not to be over-prepared. The system and all of the artworks generated before entering the space were very usable and demonstrated the potential of the system in a live context, but they were considered by the digital artists as mere building blocks to serve as a starting point for the collaboration. Entering the collaborative development environment with elements considered to be highly polished and “performance worthy” may have led us to resist any changes and made us reluctant to discard them. During the production’s development, the animal interactions, flocking and particle effects changed considerably and the live projection mapping and audio based interactivity was discarded altogether.

Egoless Collaboration

A considerable portion of the collaboration’s success can be attributed to the egoless approach of all contributors, especially that of Stalker’s founder and director, David Clarkson. A leader who dictates their own ideas and agendas at the beginning of each collaboration is thought to contribute to a phenomenon called ‘groupthink’ where the communal desire to placate a superior and avoid conflict leads to poor decision making in a group (Janis 1971). In contrast to this approach, Clarkson will deliberately enter a development with an open mind and seek the input and expertise from every individual artist in the crafting of their own unique aspect of the production.

As digital artists, we were encouraged to bring interactive ideas and visual aesthetics to the productions in addition to specifying and developing our own interactive technology. Similarly, dancers would bring their own movement styles and choreographic ideas to the development period. Faced with a number of creative ideas from a diverse team of artists, Clarkson then assumes a curatorial role where he will select the best combination of ideas to realise the theme or narration of the work. These may not necessarily be the most interesting ideas, or the most polished aesthetics, but they will be the ideas that best fit the production and the team working together to produce it. While individuals could easily be disheartened or annoyed at the dismissal of their, often considerable, efforts, the artists in these productions understand that these ideas are not lost forever, but are instead waiting to be repurposed or recycled for use in future endeavours. This openness and lack of ego in direction of the project allows each individual artist more creative freedom and ultimately more agency and attachment to their own work in the productions.

Trust in the Team

The ability to have an open and egoless directing style requires that there is an incredible amount of trust placed on the entire team. The director must trust that the artists involved in the collaboration are capable of producing creative output that can fit the theme of the piece and be used in conjunction with the other elements of the show, both technically and aesthetically.

An egoless direction style can provide each artist with a great deal of freedom, but an overall lack of direction can cause stress and anxiety in the contributing artists (Steinheider and Legrady 2004). This anxiety was evident in the development of *Dot and the Kangaroo*, where the exact nature of the show was in a constant state of flux well into the short development period.

> It was so big and so confusing… it was a bit like driving blind for a long time. I just couldn't see where it was going to go. - Rigging Master (*Dot and the Kangaroo*)

This anxiety had the potential to disrupt the entire development process, but it was largely kept in check through a mutual trust between all collaborating artists. We trusted that each individual artist involved was of sufficient calibre to produce quality work within their own field of expertise and could work together as a team. This trust enabled the team to focus on actually figuring out *how* the pieces would fit together as a cohesive whole, rather than worrying about *if* the piece could actually fit, and whether each individual element would be up to scratch.

> The team was great. I never doubted that it was going to be a fantastic piece. I just didn't know how we were going to get there. - Rigging Master (*Dot and the Kangaroo*)

Artist as Family

This heightened sense of trust between the collaborators has led many of the artists working with *Stalker Theatre* to treat the team like an extended family:

> Being back in that group was kind of like family in a way, and collaboration gets deeper and more real in that kind of circumstance because you know everyone and there are shortcuts through conversation and levels of trust where we kind of know one another's work. And we needed it because there was such a short time to get that show together with so many sort of complexly relating pieces. - Costume Designer (*Dot and the Kangaroo*)

Like many functioning family units, this familiarity brings with it a certain level of conflict, sometimes even on a daily basis. Janis (1971) suggests that a lack of conflict within a group can have detrimental effects to the decision-making process and our experience in this collaboration confirms the necessity to challenge each other's ideas in order to find the best solution for the entire production. Just like family members, the artists may have had their differences and rarely held back any criticisms during development, but the mutual trust and respect allowed these criticisms to be taken constructively and not as a personal attack.

Interaction Director

During development, the digital artists were primarily working to set up and test the interactive systems, add new features, and develop and refine the palette of effective interactive system states as the overall production emerged. The scale and complexity of the systems was such that the digital artists were hard pressed to keep up with this workload, which meant that creative decisions about which interactive states to include, which features to put time into developing, etc. were largely made by the creative director. While the digital artists were actively consulted and did participate in discussions, the demands on their time meant that their level of engagement was less than it ideally would have been. We feel that having someone dedicated to the creative design of the interactive system—an *Interaction Director* perhaps—who is able to liaise with all members of the team (directors, performers, choreographers, etc.), while not being responsible for tasks relating to the implementation and setup of the system would help ensure that interactive systems are used to their best advantage. The person in this role would need a high degree of understanding of (or 'sympathy for', to use the terms we employed earlier) interactive systems—including knowledge of what areas of development they would be likely to resist (i.e. which would be impossible to implement in the available time), as well as a well-developed feel for how they are able to contribute to the overall production. They could also act as an advocate for the interactive systems and the digital artists, and free up their time to prioritise other activities. It is not necessary that this role be the full-time responsibility of one person, but it is important to acknowledge that this is a role that needs to be filled in some capacity.

Conclusion

The ongoing collaboration between the UTS based digital artists and Stalker Theatre has been a mutually enjoyable and fruitful endeavour resulting in five successful interactive physical theatre and dance productions. The trust, mutual respect, egoless approach and sympathetic nature of all artists involved has allowed truly multi-disciplinary collaboration to be realised. We hope to further strengthen this collaborative body of work with plans to reunite for a new production later in 2017/18.

Acknowledgements Our thanks go to the entire *Dot and the Kangaroo* team for such a constructive and enjoyable collaboration: David Clarkson, Lee-Anne Litton, Rick Everett, Ursula Yovich, Kate Hosking, Jordan O'Davies, Boris Bagattini, Margie Breen, Annemaree Dalziel, Alejandro Rolandi, Peter Kennard, Katherine Budd, Cristabel Sved, John Rommel, Ross Graham and Dean Walsh.

End Notes

1. Computer vision was used to detect the movement of objects (i.e. performers) in order to create visuals that respond in real-time.
2. A process where multiple photographs of a scene are stitched together to create a three dimensional representation of an environment or object.
3. Bullet is an open source collision simulation—http://bulletphysics.org/.
4. This is not to imply that the systems were poorly designed or implemented, just that they were complex and made up of many components.
5. While projections were often projected onto walls or other architectural features rather than purpose built screens, they were nonetheless generally on a flat plane behind performers.

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Collaboration, the Color Organ, and *Gridjam*

Jack Ox

Gridjam, a performance instrument, visualized real-time in the *Virtual* Color Organ, was developed and transformed through collaboration and new technology during a fifteen year process. This international performance of specially composed music performed by six physically separated musicians, reached the place where all of the people and venues were on board and is yet to be fully realised. The artist's collaboration with the scientists involved demonstrated that this project can show the potential of packet-less, global, direct connections. This article describes the origins of the Gridjam in the Virtual Color Organ and envisages its performance in a future environment.

Collaboration

Why is collaboration such an important part of the new century in art and technology creative work? With increased use of specialized, complex technology it is far less productive to be an artist delivering a monologue alone in the studio. We need each other in many different ways, and the reasons to work together are often the result of collaborative energy. When working together in the same physical lab or space with other artists, ideas spring up like seedlings and all work seems to send out projectiles of collaborative antennae. Before I joined the COSTART project at C&CRS Loughborough, I had realized that my time of production using only studio assistants had come to an end. In the beginning, the Color Organ project was named after *Quanta and Hymn to Matter,* which was also the name of the music that I was planning to produce in the CAVE. David Britton,[1] who turned out to be my first

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_35

major collaborator, was programming our project to perform only *Quanta*. It took the unexpected dropping of the first piece of music, and then plugging in of other MIDI [Musical Instrument Digital Interface][2] encoded music in order to realize that what Britton and I were creating was a musical instrument which could be played by many composers/performers. I also realized that Britton was a far more essential partner than any one particular composer with whom I would be working.

The Virtual Color Organ (VCO)

I spent more than thirty-five years working on the visualization of music so that the images reflected their sources clearly and specifically. I began this work in the 1970s when earning my MFA from the University of California at San Diego. I modified my intellectual course by earning a PhD in Design Theory at Swinburne University of Technology in Melbourne, Australia in 2015. My dissertation[3] included a literature review of Lakoff, Johnson, Fauconnier, and Turner's conceptual metaphor and blending theories. The research was a search for manifestations of these theories in science, art and design.

The 21st Century *Virtual* Color Organ is a computational system for translating musical compositions into a visual performance (Ox and Britton 2000). The VCO is an instrument, like a musical instrument, but it uses supercomputing power to produce 3D visual images and sound from MIDI files; the VCO can play a variety of compositions. Performances take place in interactive, immersive, virtual reality environments such as the CAVE (Cave Automatic Virtual Environment), and digital full dome theatres. Because it is a 3D immersive world the Color Organ is also a performance space. This interactive instrument consists of three basic parts:

1. A set of systems or syntax that provides algorithmic transformations from an aural vocabulary to a visual one; this includes different colour systems which correspond to elements of musical syntax.
2. A 3D visual environment that serves as a performance space and also the visual vocabulary from which we modelled the 3D environment. This visual vocabulary consists of landscape or architectural images and provides the objects on which the syntax acts.
3. A programming environment that serves as the engine of interaction for the first two parts. Dave Britton my collaborator created this part of the Color Organ.

Collection of Data: Analysis of Music

The first part of the analysis is to determine the structural parameters of the musical source for the visualization. In other words, what are the operating principles of the music and which data sets are necessary to collect? Does the composition exist within a diatonic/chromatic harmonic framework, or is it composed of layers of carefully chosen timbre? These two approaches mean different things, and therefore I depict them with different colour systems.

There are some data sets contained in all of the musical sources I have worked with, including the *Gridjam.* These include the patterns of rising and falling pitch levels in melodic tones, changes in dynamics, or relative sound intensities, and also the rhythmic units and configurations including the initial 'attack' of the notes and their articulations. This information exists in the MIDI files which drive the visualization in the VCO.

Creation of Corresponding Data Sets: Visual Vocabularies

Appropriate visual vocabularies must be found to express different attributes of the music; this means that there are metaphorical (analogical and metonymic) relationships between the music and images through which one can see the structural changes in the music. I gathered the images by making high-resolution photographs on location, and from these, I made well-rendered drawings that hold their character when cut into small pieces and then reassembled. The original hand-drawn images were scanned and used as the texture maps that cover the landscape models in the VCO's visual organ stop. The VCO is capable of having multiple visual organ stops. An organ stop in the VCO is the 3D immersive environment in which the visualized music will exist and also the visual vocabulary applied to the musical objects. Currently, there is still only the first visual environment and vocabulary that corresponds to the concept of a 'stop' in a traditional organ. An organ stop is a particular voice in sound. In the future, I hope to have more organ stops for use with different kinds of music. An example would be creating a landscape inside clouds where you could perform Debussy's composition called *Nuages*: this is a piece of music I already visualized through cloud images but as a two-dimensional one-hundred and four-foot painting.[4] The original music sonically emulates the motions of clouds.

The *Gridjam* takes place in the black and white, hand-drawn desert rock structures coming from real deserts in California and Arizona. My eight original drawings are the models used to construct the first three-dimensional performance space in the VCO, and they also serve as the basic texture maps for all of the musical objects. A texture map is a digital skin that covers the modelled objects in virtual reality. Each landscape image is connected metonymically with a family of instruments in the orchestra. Metonymy is a cognitive process in which one conceptual entity, the vehicle, provides mental access to another conceptual entity, the target, within the same domain, or ICM (Kövecses 2002, p. 145; Ox 2015, p. 57). Below I have given two visual examples of metonymies that connect instrument families with shapes found in desert landscapes (Fig. 1).

Each desert landscape image has a physical feature that corresponds to an element of a musical instrument. For instance, the columns of stone that form some

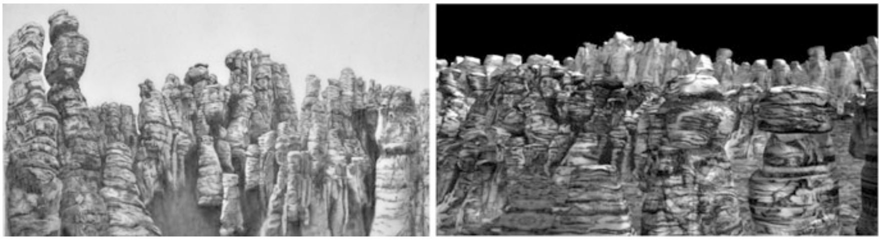


Fig. 1 On the left image is a pencil drawing of stone columns in the Chiricahua Mountains in Arizona. The shapes are similar to the basic shape of woodwind instruments. On the right, you are inside the 3D virtual environment of the Color Organ's first visual organstop. ©JackOx (1998) (See seven more landscapes that have physical relationships to the shapes of orchestral instruments, or are metonomies of instrumental families at: http://www.jackox.net/pages/gridjamIndex.html.)

landscapes in Arizona's Chiricahua Mountains seem close to the shape of various woodwind instruments, such as the clarinet. This visual organ stop is particularly appropriate for visualizing music structured through *timbre*, that is by layering different instruments together and creating a blend of their sounds. Every instrument has its timbre qualities; this can be modified by, for example, the method of playing, such as the difference between bowing a violin or plucking a violin.

Transparent Colour Systems

The VCO creates layers of transparent colour to be applied to each sound object; the colour maps either harmonic or timbre information from the source data onto each visualized sound. There are differences between music composed within a harmonic structure versus music based on the multi-layering of different instrument timbres. Music composed harmonically uses a different colour system from music that is timbre based.

The first colour mapping system I created maps harmonic movement (key changes) and harmonic quality (various levels of dissonance versus consonance). In essence, I mapped a twelve-step colour wheel onto a circle-of-fifths. This colour wheel has three primary colours: red, blue, and yellow. Three primary colours mean that colours standing directly opposite are complementary, or are opposite in temperature—one colour warm and the other cool.

A circle-of-fifths shows the structural relationships between the different keys in harmonically based music. Imagine a piano keyboard; the key of C Major includes only white keys and begins and ends on C notes that are an octave apart. C Major is at the top of the circle-of-fifths. G Major follows on the right; it includes all C Major's notes except that it changes F for F#, the black key next to F. The distance between C and G is five notes, thus its name of circle-of-fifths. As we move around the circle on the right, the next key is D, with two sharpened notes, or black keys, and so on. The circle moves to left adding flatted notes until the bottom where flats enharmonically become sharps and vice versa.

Examining the circle-of-fifths in detail shows that this arrangement is in structural alignment with the twelve-step colour wheel; therefore, it is an example of analogical mapping. The top of the colour wheel can be any colour. I like the flexibility of choosing the home-key colour based on qualitative information I have collected during analysis. However, from there the mapping from the circle-of-fifths wheel to a transparent colour carries musical key identification data, as well as harmonic quality data. The outer ring of the colour wheel shows major keys only; an inner ring of colours begins three steps behind the outer ring, mapping the relationship between major and minor keys.

Harmonic quality defines where a sound stands on the continuum running between consonance and dissonance. The VCO can visualize this data through assigning various percentages of the complementary colour, located directly opposite the original "key" colour on the colour wheel. There are six levels of relative consonance/dissonance that we have programed into this algorithmic system. However, the colour system used for the *Gridjam* is a *timbre* system, which means the colour of sound. Music in the late twentieth century is often structurally based on timbre. All music employs timbre, but not necessarily in a structural way. A vital component of music structured on timbre is the combination of specific, differentiated sounds, analogous to the way a painter can choose to use colour.

We worked on the *Gridjam* for almost a decade, during which the composer in our collaboration, Alvin Curran, changed his orchestration for the music from using four groups to six; both versions are timbre based, but differ in their instrumentation. I created a list of over 130 mixtures of RGB hues where families of instruments are represented by a set of colours in a graduated series, further modified by mutes and playing techniques visual equivalences. For the human voice, I determined that the timbre changes when the vowel sound changes, because the vocal tract changes shape as a singer voices different vowel sounds.

The Viewer's Experience in the *Virtual* Color Organ

When the performance begins, the viewer-listeners are in a world of hand-drawn landscapes, modelled into 3-D. All of the landscapes are black and white with a black sky. As the music plays a three-dimensional coloured and image-embedded geometric structure takes shape in the space over the landscape; constructed from two-dimensional pictures of the landscape images representing the instrument families that are linked metonymically. These coloured polygons each have a particular, transparent hue; I based the colour on a timbre analysis of which instrument is sounding and what the particular playing technique is at that moment. The saturation of the colour reflects changing dynamics (loud, soft, and the steps between them). These flat strips of landscape images appear up and down in a vertical space, determined by their pitch values. A higher pitch exists in a higher

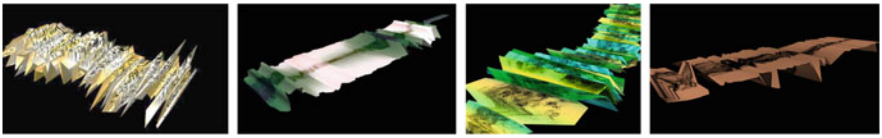


Fig. 2 From left to right—sound of thrown metal coins, a lion roaring, glass instrument played, and Maria Callas on a high note

place than a low pitch. The pitch analogy corresponds to a vertical scale. The volume (in the attack) of the sound controls the width of the image embedded polygons. After the music has played there remains a complete sculpture that we can explore further interactively. The viewer can move at will through space and touch elements of the sculpture to hear the sound that initially produced it.

I created a process for visualizing sound files played by Curran on the Disklavier piano. These files could run from several seconds to over a minute and included events such as the throwing of coins, of an elephant trumpeting or Maria Calas singing one note. I modelled over two hundred of these sounds[5] into 3D shapes that included pitch changes on the front and dynamic changes (loud and soft) on the top of each unit. When the player depresses a key, the model starts emerging until the key is released. The amount of time the key is depressed determines how much of or how many sound models appear in the virtual space (Fig. 2).

The Gridjam

The Music, According to Alvin Curran

Curran[6] describes the process for creating the music of Gridjam as follows:

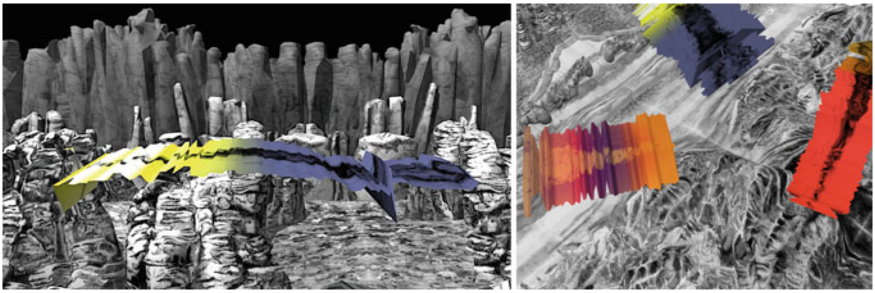
> I have come up with a plan for the musical part of this project which is inspired both by the pure fundamental “synesthetic” goals of Jack’s visual structures as by the technical and theatrical nature of the domed projection spaces, the local acoustics and “global” nature of the work itself.
>
> The music itself will be composed using a fluid mix of structured indeterminacy, synchronized composition, spontaneous music structures, and live electronic processing. But the essence of the music - whose goal is - to become interchangeable with the images is to create another set of “images” real and sonic, which is the music-theater itself. The LamdaRail communications will enable the complete synchronization of the dislocated music groups and their ability to react as if in the same room together.
>
> The choice of instruments, which represent and embrace the main musical cultures of the world - will become another prime visual element embedded in the rich texts of Jack’s desert and VR sound-objects.

The final plan of the *Gridjam* has six stations in the world and Alvin decided to use the Del Sol String Quartet (four musicians), himself on the Disklavier, and Anthony Braxton on saxophone.

For the *Gridjam*, the musicians perform together in a virtual space from geographically distributed sites thousands of miles apart. Imagine an immersive display system—(e.g. a digital planetarium dome, a Scalable Adaptive Graphics Environment [SAGE], or a three to six wall CAVE virtual environment). Enclosed in this virtual world, hand-drawn high desert walls inspired by the California-Arizona desert surround us on all sides. The desert floor is bare, except for the six performing musicians.

All six performers appear together in this shared virtual space, though in reality, each is in a different city somewhere in the world. Four of the musicians, comprising the Del Sol String Quartet, normally perform no more than a bow's length apart. Joining them in virtual space from a different physical studio is the saxophonist, Anthony Braxton, whose mastery of improvisation with an ensemble requires quick and intimate interaction. We, the audience, are immersed in this same environment, watching and listening from different participating venues around the world. The virtual appearance of the musicians is courtesy of Pierre Boulanger at the Man Machine Laboratory in Alberta. Each player will have eight stereoscopically placed video cameras around them and will then appear in the desert organ stop. Both the audiences and the players will be able to see the other players and respond to facial and body language.

Alvin Curran sits in front of a Disklavier loaded with the sounds and effects that comprise his musical palette. An assortment of computer and electro-musical devices accompany him. He may be in San Diego or Amsterdam—we do not know; we see him here in our desert, as does everyone at all the performance venues linked by the LambdaRail networks. This international fiber optical network carries 10,000 Gb/second through a direct line, with a small, predictable delay: between Amsterdam and Tokyo, the delay is the same as between the right and left sides of an orchestral stage. The virtual conductor is not a person, but a signal that synchronizes time. The music unfolds sonically and visually; the dynamic range varies from nearly inaudible, sparse sounds to discreet isolated tones, to pulsing synchronous rhythms, to clouds and walls of sound, while recorded natural sounds from animals, people, and machines provide an underlying sonic backdrop. Below, See Gridjam images showing CJ laughing hysterically, Maria Callas hitting a high note, and a shofar (from top moving clockwise). I modelled sounds collected by Alvin Curran into the objects shown inside the VCO desert organ stop[7].



From the AccessGrid to the National Lambda Rail

We began the *Gridjam* collaboration meetings on the AccessGrid[8] in May 2003, but found that the issues with multiple site conferencing/transmissions were too profound for the structured improvisation that Curran was proposing. The AG is not able to overcome the irregular delays called *jitter*. Having a delay is something every large orchestra stage has; there is a regular one second delay between the right and left sides, making a conductor standing in the middle essential. AccessGrid technology had irregular delays. It was just at this time that Larry Smarr and others at 30 universities were beginning to connect a vast network of privately owned Lambda (Light) fibre that can give a 'jitter' free performance. It seemed that *Gridjam* was in the right place and time. Dr. Smarr had gone to the University of California at San Diego to found Calit[9] and I was invited to make a presentation to get them on board in 2003.

The times were exciting, and *Gridjam* was able to connect with an impressive list of collaborators in the *Gridjam* consortium. These include the University of New Mexico with the Center for High-Performance Computing and the Arts Lab; the University of Alberta and the Advanced Man-Machine Interface Laboratory. We aldo partnered with Calit2 at the University of California, San Diego, Lousianna State University (LSU), Baton Rouge, SARA Computing and Networking Services and the University of Amsterdam with the Waag Society, the Netherlands.

Today, the NationalLamdaRail is no more; in 2011 it was purchased by Patrick Soon-Shiong from the U.S. research and education community. The billionaire was to invest money in upgrading the system. However, the NLR ceased operations in March 2014 without the promised upgrades. If we were to do *Gridjam* today, it would be over Internet2.

Reflections and Conclusions

Gridjam is both a work of art and a research project into high-performance collaborative network computing. This project progressed to the point of having people, places, music, networking. Networking scientists saw *Gridjam* as a way to provide a complex and demanding 'use case' of the sort that drives software and hardware development. Just as a major part of Christo's landscape installation art is in how the concept works its way through the many layers of social, regulatory, financial and bureaucratic obstacles, the *Gridjam* conceptual performance art project has had an impact during its evolution. In performance, *Gridjam* is a complex adaptive system at the interface of art and science.

End Notes

1. Dave Britton is a pioneer in computer programming and has a Ph.D. in cognitive neuroscience.
2. Musical Instrument Digital Interface—The system records notes played, the length of the note, dynamics, tempo, the sounding instrument, and hundreds of other parameters.
3. https://www.academia.edu/13924881/Manifestations_of_Conceptual_Metaphor_and_Blending_Theories_in_Science_Design_and_Art.
4. http://intermediaprojects.org/pages/Debussy3.html.
5. http://www.jackox.net/pages/Gridjampages/GridjamC_2.html.
6. http://www.alvincurran.com/.
7. For more on modelled sound files: http://www.jackox.net/pages/gridjampages/gridjamA_2.html.
8. http://www.accessgrid.org/home.
9. http://lsmarr.calit2.net/ California Institute for Telecommunications and Information Technology.

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Creating Interactive Art—Conceptual and Technological Considerations

Christa Sommerer and Laurent Mignonneau

In this article, we describe how we have been using and developing media technology for our art practice over the past twenty five years. We will illustrate two examples of our interactive prototypes that combine artistic concepts with technological experimentation. Before presenting them, we will give a short overview of the general context of collaborations in art and technology.

Collaborations in Art and Technology: Historical and Recent Examples

When we look into the history of art, we find countless examples of movements involving both art and science that influenced the technological and societal changes of their times. A prominent example is the E.A.T Group for conducting experiments in Art and Technology that was founded by the engineers Billy Klüver and Fred Waldhauer together with the artists Robert Rauschenberg and Robert Whitman in 1966 (E.A.T. 2003). This non-profit organization developed from the experience of the *9 Evenings: Theatre and Engineering* Event, which was held at the 69th Regiment Armory in New York City, U.S.A in October 1966. It brought together 40 engineers and 10 contemporary artists, who collaborated on performances that incorporated new technology.

A different type of collaboration between art and technology took place in the field surrounding Cybernetic Art. Cybernetics was established as the study of control and communication in both animals and machines by Norbert Wiener, Warren McCulloch, John von Neumann, Heinz von Foerster and others in 1947 (Wiener 1965). It had a revolutionary impact on media art. An important exhibition entitled *Cybernetic Serendipity* was curated by Jasia Reichardt at the ICA in London in1968 (Reichardt 1968). It was the first one which attempted to demonstrate all aspects of computer-aided creative activity. The artists represented were often researchers and engineers who developed these systems themselves.

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_36

Information Aesthetics is another interesting area where pioneering artist-scientists or scientist-artists extended the boundaries of technological developments and art. Max Bense and Abraham Moles, who coined the term Information Aesthetics, foresaw the creative potential of early computer technologies and machine aesthetics (Bense 1965). Bense's student Frieder Nake, also a mathematician and computer scientist, investigated the aesthetic potential of computers by producing plotter drawings (Nake 1974).

There are numerous examples of scientist/artists who contributed to the greater evolution of knowledge by going beyond the narrow confines of their disciplines. Peter Weibel has compiled a book called *Beyond Art: A Third Culture* (Weibel 2005), which focuses on 20th century developments in art and science in Austria and Hungary, and for example contains writings by researchers and artists who were associated with the *Vienna Circle*. This group was striving to create a unified science back in 1930.

In 1996, while working as researchers/artists at the ATR Advanced Telecommunication Research Laboratories in Kyoto Japan, we organized a symposium called ART-SCIENCE-ATR. Key researchers such as Hiroshi Ishii from MIT Media Lab, Erkki Huhtamo from UCLA, Peter Richards from the Exploratorium in San Francisco and many others presented their approaches to the associations between art and science at that meeting, which cumulated in a publication called Art@Science (Sommerer and Mignonneau 1998).

A group of engineers and artists are currently pushing the boundaries of technology and art at Tsukuba University in Japan. The Empowerment Studio, headed by engineer-artist Prof. Hiroo Iwata (Iwata 2002), has created a new branch of informatics that supplements and extends human functions and enables technology to work in harmony with people (EMP 2017). A multidisciplinary collaboration enables the creation of novel human-machine systems that defy clear categorization and bridge engineering and art. Especially noteworthy here is also the concept of Kansei Engineering (KE): it is based on studies involving elementary principles of the mind, human development, learning and cognition, as well as memory, motivation, emotion, social behavior and creativity (Nagashima 2012).

Creating Interactive Artworks: From Concept to Technological Implementation

We have been dealing with the challenges of combing art and media technology for over 25 years. Coming from a diverse background in botany, anthropology, modern sculpture, video art, electronics and media art, we consider our art practice to be trans-disciplinary. In the following sections, we will provide two examples of the artworks we have created and highlight how the use of technology shapes our creative practice.

Interactive Plant Growing, 1992

Interactive Plant Growing was our first collaboration. Combining our backgrounds in botany studies, sculpture studies, video art and electronics, we drew from our previous experience in order to create an interactive art installation. Our concept was to see how one could interact with real plants and transform this interaction into a visible form. We were inspired by the book "The secret life of plants" (Tomkins and Bird 1973) but felt we should come up with a non-scientific visual interpretation of a human-plant dialog. We therefore created an installation where living plants function as interfaces between a human user and the artwork. Users engage in a dialog with real plants by touching or merely approaching them. The electrical potential differences (voltage) between the plant and the user's body are captured by the plant and interpreted as electrical signals. These determine how corresponding virtual 3D plants (which look very much like the real ones) grow on the projection screen. By altering the distance between the user's hands and the plant, the user can either stop the growth of the virtual plant or let it continue, deform or rotate it, or develop new plants and combinations of plants. We program growth algorithms to allow maximum flexibility by taking every voltage value that results from the user's interaction into account. The virtual plants that thereby appear on the screen are always new and different, creating a complex combined image that depends on the user-plant interaction and the voltage values that it generates. The final result of the interaction is shown on the screen as a collective image of virtual plants that have been grown by several users (Sommerer and Mignonneau 1993) (Fig. 1).

Since the technology for realizing the *Interactive Plant Growing* installation did not exist, we had to invent and build everything ourselves: the hardware interface as well as the software written in C++, including the development of a special growth algorithm. We consider *Interactive Plant Growing* to be an artwork, as its main purpose is to highlight our human relationship to the vegetal world. On the other hand, human-plant interfaces, which in fact did not exist until then, have become very popular in recent years (Sommerer et al. 2015).

Flies in the Sky, 2017

In 2017, we were invited to the Tsukuba University Empowerment Studio as guest researchers. The Studio has a novel immersive display with the world's largest confined VR space, the so called *LargeSpace*. It is 25 m long, 15 m wide and 7.5 m high, with stereo projections on all four walls and the entire floor. The system uses 12 projectors, 8 computers, and 20 motion-capture cameras as well as custom-made Virtual Reality environment software (Takatori et al. 2016). It was developed by Hikaru Takatori, a Ph.D. student of professor Hiroo Iwata, who is head of the Ph.D. Program in Empowerment Informatics.

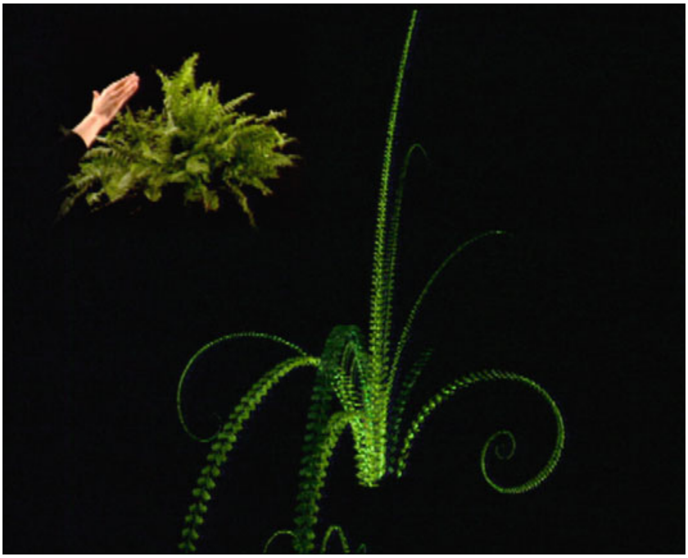

Fig. 1 *Interactive Plant Growing* © 1992, Christa Sommerer & Laurent Mignonneau, collection of the ZKM Media Museum Karlsruhe

We decided to write a new software program called *Flies in the Sky*. Its main concept was to simulate a large amount of virtual flies that would swarm around in the *LargeSpace* and react to the visitors in real time. We intended to create a sensation of unease and fascination, similar to the famous scene in Alfred Hitchcock's movie *The Birds* where people start to be attacked by big black birds (Hitchcock 1963).

Conceptually, the project is also a continuation of our interactive installation *Portrait on the Fly (Interactive Version)*, which was realized in 2015 (Mignonneau and Sommerer 2015). This work consists of an interactive monitor that shows a swarm of ten thousand flies. When a person positions him- or herself in front of it, the insects try to detect his or her facial features. They then begin to arrange themselves so as to reproduce them, thereby creating a recognizable likeness of that individual. When somebody poses in front of the monitor, that attracts the flies. Within seconds they invade the image of that person's face, but even the slightest movement of his (her) head or of parts of his (her) face drives them off. The portraits are thus in constant flux; they construct and deconstruct. The motive of the fly was used as a symbol of Vanitas, a common reference to death and decay in art history.

For *Flies in the Sky,* we started with a first simulation of around 10,000 flies modeled in 3D. We wanted to have as many flies as possible, so that they would be able to organize themselves into swarms and create interesting patterns in 3D when users were walking around in the *LargeSpace.* Laurent Mignonneau and Hikaru Takatori began to implement our software code into the existing library framework of the *LargeSpace*. This runs on a hardware system provided by the Christie Digital Systems company which is specialized in display, audio and presentation products (Fig. 2).

After the first implementations of our software, we realized that it would not be realistic to display more than 512 flies, due to the high computing power needs of the *LargeSpace*. This meant that instead of counting on the effect of a large swarm of insects, we had to choreograph the movement of the smaller numbers of flies in a way that could arouse the interest of the interacting person.

We decided to directly link the movement of our flies to the position of the interacting person, so that the flies would follow and swarm around him or her. To add complexity to the experience, we also linked the movement of the interacting person to that of clouds which we mapped onto the walls of the *LargeSpace*. This resulted in a slight feeling of distortion, which we found to be interesting and to enhance the feeling of immersion. The main control of the interaction is done by the person wearing the Xpand 3D glasses; he or she holds a custom-made tracking system that can capture his or her position and posture in 3D space. An additional

Fig. 2 *Portrait on the Fly* (*interactive version*) © 2015, Laurent Mignonneau and Christa Sommerer, at Ars Electonica Center, Linz Austria

van interface with an attached sensor was used to enable the interacting person to catch the virtual insects. In order to further intensify the sensation of immersion, we also implemented the buzzing sound of the insects, which becomes louder the nearer they come. Many visitors can interact with the *LargeSpace* simultaneously (Figs. 3 and 4).

Observations on the Relationship Between Art and Technology

Going back to some of the historic examples of art and technology collaborations described at the beginning of this paper, we can see that there have been several models for them. Some of these involved having artists create the concepts and engineers realize them. In others, artists performed both the artistic and the engineering tasks, or the engineers carried out both of them. Our approach is more closely related to the second model, as we did most of the technological realization ourselves. We have, however, created various degrees of technical complexities in these artworks. At the beginning of each project, we start out with strong conceptual research and then proceeded to develop the necessary technology. In some cases, it became necessary to invent new technology (as in *Interactive Plant Growing*); in others, we work within an existing technological framework (*Flies in the Sky*). In

Fig. 3 *Flies in the Sky* © 2017, Laurent Mignonneau, Christa Sommerer, Hikaru Takatori, Hiroo Iwata, at *LargeSpace*, Empowerment Informatics Laboratory, Tsukuba University, Japan

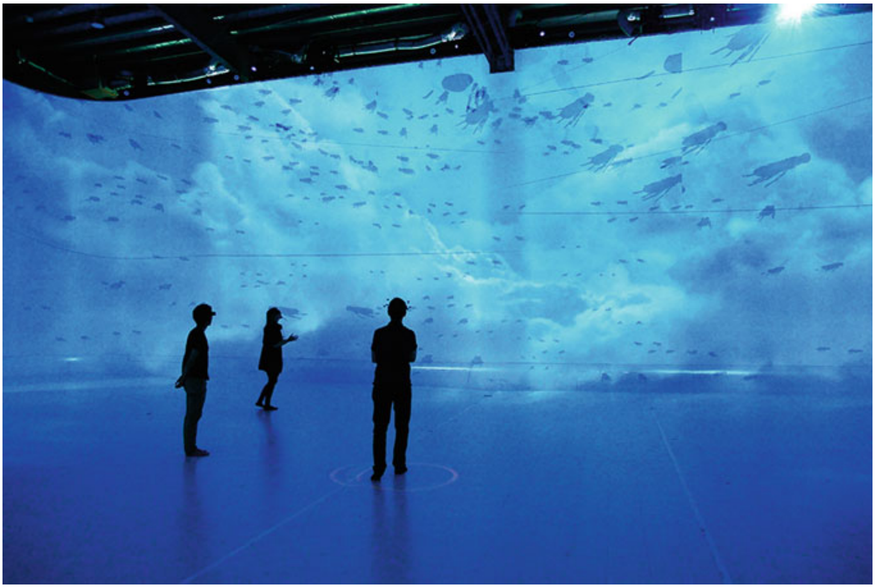

Fig. 4 *Flies in the Sky* © 2017, Laurent Mignonneau, Christa Sommerer, Hikaru Takatori, Hiroo Iwata, at *LargeSpace*, Empowerment Informatics Laboratory, Tsukuba University, Japan

our opinion, a particular technology should not be implemented for its own sake, but rather because it is suited to a particular artistic concept and capable of arousing the type of emotion we want to create.

On a wider scale, we can now see that almost all facets of our lives are beginning to be augmented by digital technologies. On the other hand, current problems involving issues of privacy, the corporate ownership of personal data as well as unsustainable consumerism make it necessary for us to engage in new types of reflections, to undertake new projects and to design innovative products, in which the "design thinks about itself as a future stage of change" (Fuller 2015: 42). As artists, we should also contribute to the development of the new grammar of change by introducing artworks that reflect on digital technologies and their role in society.

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Post Fail: IOCOSE Collaborative Failures

Paolo Ruffino, Matteo Cremonesi, Filippo Cuttica and Davide Prati

In this piece, we discuss our experience of working as an art collective. Through more than a decade of artistic practice we have developed practices of self-organisation. The habits and management of our collective also reflect our relationship with contemporary art and technologies. We have named this modality of work *Post Fail*: a mode of making and thinking about art, and our hyper-connected lives more generally, as always failing, and necessarily disappointing our expectations (IOCOSE 2015). In this text, we intend to describe and reflect on these practices, and explain how the notion of Post Fail could provide a pathway to rethink some of the approaches to contemporary media art.

Postal Failures

We started working together as a collective in 2006. The group took its current shape in a few months since our first meetings, and the four members that were part of the original formation (Paolo, Davide, Filippo, Matteo) are still the only participants in our collective. For the last 12 years we have been living and working across different cities. At the moment, we live in London and Lincoln (UK), Berlin (Germany) and Brescia (Italy). We meet three or four times per year, and occasionally for our exhibitions and workshops. However, we have never been living in the same city at the same time, and our collaborative work has always taken place on the internet. From this point of view, we are probably the only truly internet-art-collective, since we existed since our inception only thanks to the internet. It is not that we have intentionally decided to live separately. It just happened. But the accidents of life brought us to ask ourselves questions on how to organise our work while thinking collaboratively and yet separately at the same time.

Skype has been our privileged tool of communication for a long time. At first, it seemed to offer the possibility of thinking and doing things together, adapting to our schedule and making voice and video communication possible from any corner of

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_37

the world—when Skype became available on smartphones, rather than requiring bulky laptops with limited battery life, it really appeared as a revolution. However, it became clear after a few years that Skype could improve our work only to a limited extent. Our online meetings were mostly made of intermittent dialogues (which often revealed to be monologues, when one inadvertently lost connection while in the middle of an excursus). Concepts had to be repeated two or three times, because someone's connection dropped, or earplugs were not plugged in correctly, just to name two common technical problems. Google Hangouts offered a glimpse of hope, and other services promised more fluid voice and video communication. The harsh reality, after more than a decade of trying to make art through VOIP technologies, is that online communication is never smooth.

We have been trying different forms of file sharing. Dropbox, Google Drive *et similia* have been helpful in storing and retrieving files, although finding what someone else had saved in the online folders is often impossible and requires a phone call, or an email. WhatsApp allows instant messaging, although the dispersal of information is guaranteed. Emails are certainly the most used tool in our group to exchange ideas and for the planning of production and exhibitions, while Trello, a popular web based application for work management, gathers our shared to-do lists (but we are never on the same page at the same time, and there is always at least one of us missing an update on Trello). Slack, an online tool for team collaboration, appears to gather all the problems and inefficiencies of these tools in one platform. In short, after so many attempts to make art collaboratively, we have reached the conclusion that doing art online means embracing noise and disturbances as the dominant element within the work environment.

How Are We Writing This?

What we are trying to argue with this piece is that the difficulties and failures of online communication are not just a hindrance, or an accident, in our way of doing art. These are an essential part of our work, even at the most trivial level. We could explain this process by looking closely at how this piece has been written. Paolo wrote this piece on an intercontinental flight with no Wi-Fi. After landing, he shared the document with the other three IOCOSE, and then sent them an email and a WhatsApp message to remind them about the submission deadline. Eventually, Matteo paid attention to the messages, double checked this piece and suggested corrections. However, corrections arrived late, and Paolo was again disconnected. The manuscript, intended to represent the views of the collective and supposed to be the outcome of our *collective intelligence*, is best described as the result of the intermittent attention of one or, at best, two of us (Levy 1997).

Our argument (or, at least, what we managed to agree on) is that this is not just an imperfect modality of work. This is how thinking is made possible in the age of internet: by fragmenting time, assigning roles, and solving tasks. Our art tries to be thoughtful in a context where there is no time for thinking, responding to the anxiety that Angela McRobbie argues to be shared by artists who work under the regime of the contemporary creative industries (McRobbie 2001). But it is art that is *situated* within the time and space of the technical hiccups of computer mediated communication.

Post-fails

It is precisely this situatedness that we would like to reclaim, and that we try to bring to the fore. Discourses surrounding the internet, and its role within the production and consumption of contemporary art, are often too reliant on a common-sense understanding of how new technologies could have an impact on societies and cultures. While these visions are easily agreeable, they tend to describe scenarios that have no specific time or place, and outline allegedly global and universal tendencies that we allegedly share. The name usually given to this new condition, where online communication and digital reproduction of images should be taken for granted, is Post-Internet.

As Hito Steyerl suggests in the essay "Too Much World: Is The Internet Dead", the internet nowadays matters more than ever, as it is still expanding and even moving offline (Steyerl 2015). The exponential development of the internet is affecting the ways in which we use our devices and the relationships we create with other human beings, and most importantly it is affecting the lives we live in what we used to know as the 'real world'. Not only the way we use technology, but also how we think of it affects our everyday lives, and it shapes the world. The internet is affecting our lives in the present, and this happens in different manners depending on the cultural, political, and economic conditions of the society we live in.

Artie Vierkant's essay 'The Image Object Post-Internet' provides a useful introduction to what we intend to comment on, as it observes how the pervasiveness of internet is now influencing the art context. In Vierkant's text, Post-Internet art is defined as 'a result of the contemporary moment: inherently informed by ubiquitous authorship, the development of attention as currency, the collapse of physical space in networked culture, and the infinite reproducibility and mutability of digital materials' (Vierkant 2010: 3). The 'contemporary moment' is taken as a given to be analyzed and understood for what it supposedly is. Internet, in this context, has allegedly permeated the lives of a generation of artists, critics, gallerists and consumers, in ways that are probably irreversible. The author suggests that we adapt our perception and artistic production towards this new condition. Images of artistic objects should be considered as the only product that counts and circulates, thus preceding the importance of the artistic object itself. In an age when circulation of digital files is the only truly significant event, art should welcome the Post-Internet age, and digital native artists should lead the way and explore the new modes of cultural production.

Similarly, David Joselit argues that the production and fruition of images in the artistic environments has changed according to technological innovations (Joselit

2012). According to the author, this new condition has also changed the economic evaluation of artworks. He starts by quoting, in the first page, a comment that Donald Rubell, an art collector, made to the New York Times. Rubell says that 'people are now realizing that art is an international currency' (quoted in Joselit 3). This over generic statement, about what people are now doing with art, is not critiqued by Joselit, but used instead as the rationale for a new mode of art production: 'what results after the "era of art" is a new kind of power that art assembles through its heterogeneous formats' (91).

According to other authors, such as Jesse Darling, the post of Post-Internet instead indicates that art happens at the crisis of the internet, not as a successor to it. Also, Darling states that 'every artist working today is a postinternet artist' (Darling 2014). Indeed, Post-Internet can also be interpreted differently. 'Post' can also mean, maybe more simply, 'doing art after being online', as proposed by Marisa Olson in the original formulation of the Post-Internet (Cornell 2006). Post-Internet can also be seen, more broadly, as also including the new forms taken by the artistic investigations started by the net art movement, which tend to avoid replicating similar narratives of historical progression, at the cost of being less accepted by the art market (Quaranta 2015). However, what we want to stress is that the works of authors such as Vierkant, Joselit and Darling tend to generate universal narratives of temporal and technological progression. In the early theorization by Marisa Olson being online was not something dated, and it still had a great deal of importance. Olson's argument was that her own way of making and producing art was influenced by the internet even when she was not online anymore, but the timing of being connected, and the separation with offline work, were still marked as crucial. The key difference between Olson's early understanding of the Post-Internet and those of later authors, consists in the disappearance of the plurality and variety of things that internet does. Instead, more recent accounts speculate on what internet supposedly is. It should appear obvious, for example, that art is a currency mostly for people like David Rubell, quoted by Joselit, and probably also for some of his colleagues. For the rest of the world it simply is not. In other words, these stories about who and where we are now, and what we are all doing, these common-sense visions of our engagement with art and media hide the fact that someone is saying these stories, and that the act of telling is embedded in a political, cultural, economic scenario which is far from being obvious, or given.

What we are arguing is not necessarily that Post-Internet as a theory and movement, as varied and complex as it is, might work for the context of art criticism (particularly in those cases when it is presented also for its theoretical limitations). What is most worrying, for us, is how theories on the Post-Internet appear to derive from a common-sense understanding of how the world is, how it works and how we live in it. Of course, the common-sense logic is helpful when trying to make things simple and accessible to our understanding. But, within these conditions, we are going to prefer the *misunderstandings*: the failures, the disappointments, the events that complicate our expectations on what internet, technologies and human beings are doing, or could be doing.

We have named this alternative mode of doing art Post Fail. As in Post-Internet, here "post" means many different things at the same time. It means, first, that we work and reflect on what we call the after-failure moment of the teleological narratives of technological development, with regards to both their enthusiastic and pessimistic visions. In the long run, both utopian and dystopian narratives about the effects of technologies on our lives will confront with much more mundane and varied realities. Post Fail means to accept that the present and future are stories we tell ourselves, and that are formulated in specific moments and received via specific bodies that are located in history. Post Fail also means that we acknowledge the failure of many of the post-whatever theories of the last decades and of course, with a bit of self-mockery, Post Fail itself could become just the last one in the row (Post Fail should then be intended as a temporary and strategic theory). Eventually, Post Fail means accepting the failures and bugs of all the different technologies we need to employ to be able to work as a group, while leaving in four different cities.

How can we accept the ethical challenge of doing art while accepting the limitations of our own position in the world and in history, and yet still be able to say something about the other possibilities of our world? The best answer we can think of is through a metaphor, one that we always keep in mind and refer to in our practice. Making art starting from a Post Fail precondition is like being DJs at a party, but DJs who are already feeling the hangover of that same party. These DJs-with-an-headache have the imperative to keep the music going: they must take care somehow of the tension towards the collective joy of the party while knowing that, surely, everyone will leave and go in a separate direction at the very end. Doing art Post Fail means asking ourselves the question of what music is appropriate to play in such context, how to respect own one's headache while giving an interesting (and possibly enjoyable) experience.

Art After Failure

In the *NoTube* series we have investigated what could be done after acknowledging that the promise given by Google's video sharing service is unlikely to be fulfilled. The promise of YouTube is that we will be able to 'broadcast ourselves', promoting and showing whatever we want and with (almost) no filters in terms of both content and quality. Indeed, we know well that YouTube is an agglomerate of videos, most of which appear useless to many people. Many of these have zero views, and no real reason to be watched, or even to be published. The *NoTube* series is made of several separate interventions, each exploring the after-failure condition in which YouTube can be considered to be. The *NoTube Contest* [http://notubecontest.com] (2009–ongoing), for instance, is a competition where we ask participants to find the most valueless videos on YouTube. Each year, participants are invited to find videos that have no reason to exist, do not really show anything meaningful, and ultimately could have just not been published. This excludes funny videos and memes: the *NoTube Contest* is about the large quantity of videos with no significance that are uploaded every minute on YouTube, and which are preserved on the database of the online service for several years.

Another work that we have been working at in recent years is the *First-Viewer Television* [http://firstviewer.tv] (2012). In this piece, which exists both as an installation and as an online television channel, we have set up a streaming of videos with zero views. The playlist updates automatically every two hours and draws on YouTube to find video material that no one has ever watched. Whatever you see on *First-Viewer Television* is being shown to you for the very first time.

Both projects can be seen as ways of taking care of that side of YouTube which is usually forgotten, but which constitutes great part of the content available on the site. The countless attempts to 'broadcast oneself' usually do not result in anything particularly remarkable. Doing art on and about YouTube is a challenge because it forces us to question how YouTube (and Web 2.0, more broadly) is commonly understood, and how differently it could be (mis)understood.

The *A Crowded Apocalypse* series draws on crowdsourcing to critique the myth of collective participation and co-production. Rather than eliminating social and economic barriers, as it was originally hoped, crowdsourcing has been exploiting those same divisions. The after-failure momentum of these practices of online work are critiqued through of series of interventions. *A Crowded Apocalypse* (2012) collects conspiracy theories generated through micro-commissions on Amazon Mechanical Turk. *How to Make A Bomb* (2013) gathers short videos on a playlist, each one of them being commissioned via crowdsourcing and showing an almost meaningless action. However, when put together, the videos demonstrate how to create a domestic explosive. *Instant Protest* (2017) is an online service offered by IOCOSE to sell customised protests. Photos of people demonstrating in the streets are bought on eBay for $10 each, and buyers can request any slogan they like to be written on the signs of the protesters. With the Post Fail we have been trying to name a mode of producing and thinking of media art. It reflects our way of organising work, made of communication failures, interruptions and disturbances that are part and parcel of the tools we use. It also summarises the function that art has for us, for now at least. A Post Fail approach acknowledges and takes responsibility of the place and time of its intervention, accepts its limitations and yet, somehow, still tries to play the music.

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Speculative Apparatuses: Notes on an Artistic Project

Cesar Baio

Throughout my whole life, technique, imagery and the imaginary have always been closely intertwined. I am the son of artisans and, during my childhood, my father, who had already worked as an electromechanical technician. I grew up amidst paintbrushes, drawings, and experiments aimed at creating new techniques and paints. I was also always surrounded by circuits, motors and tools, and invariably accompanied my parents in their daily tasks. From a young age, I began building my own remote-control cars with precarious components, taking apart electronic toys to see how they worked and putting new cars together from pieces of junk I found around the place. Growing up in this environment greatly influenced my conception of technology, affecting my studies and practices. I believe that this way of understanding technology let me to graduate in electronics; however, it also made me quit engineering to study Arts. I graduated in media studies, which, in Brazil, comprised subjects such as social and media theories and also art history, photography, design and creative writing. This period at university also strengthened my interest in the socio-political issues connected with media and technology. This entire range of experiences and interests comes together in many different ways in both my theoretical research and in my artistic practice.

For me, technology is related to a gesture of invention, intervention, experimentation—instead of being an object of consumption. The playful nature of this attitude implies, consequently, the maximization of its ability to penetrate our sensitivity, activate our imagination and thereby, transform our understanding of the world and of ourselves. In its political dimension, this idea shifts the function and experience of technology in society, questioning the set of power relations that establishes itself in the production processes and ideologies that guide its industrial development. Ever since the Renaissance, through the Enlightenment, industrial revolutions, the Cold War and, currently, informational capitalism, science and technology have always played a key role in consolidating the existing political and economic systems in modern societies. In our daily lives, the decisions made in research and development laboratories around the world are materialised in things

L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_38

that (in)form each aspect of our life, modifying, above all, the way we give meaning to the world and ourselves.

Although we are partially aware of technology's role in today's society, most of us forget that in our everyday lives the form of everything around us ends up producing a specific way of understanding and being in the world. This means that the form given to things such as: social network interfaces, internet data traffic, the functioning of Internet search engines, artificial intelligence algorithms that drive the financial market, our cell phone's functionalities, the design of our cities, surveillance systems, and a camera's lenses, circuits, and sensors are strictly linked to the political, ethical, and aesthetic dimensions that have produced these technologies but are generally invisible.

All apparatuses from cameras to the latest computers are the result of an industrial project, and this aspect should not pass unnoticed by those who decide to work with these tools. As an artist, I have worked with video, photography and interactive installations that seek to explore the potentiality and the tensions related to the insertion of technology into society. My main interest resides in subverting the operational logic of cameras, cellular devices, information networks, databases and computerized surveillance systems in order to uncover the political, economic, social and ethical dimensions that normally remain beyond most people's visual range. This artistic gesture avails itself of tactics such as insubordination to the normal use given to industrial devices, reverse engineering, occupation of information networks, among other procedures that I use to engender what I consider to be "speculative apparatuses". By opposing the logic of technological innovation, the goal of these works is to create subversive objects that bring about debates, create contradictions in the hegemonic logic, reshape the human-machine relationship, encourage public participation, social agency and allow mankind to imagine alternative ways of representing the world and producing reality. Thus, for me, artistic practice becomes research practice, from which unfold not only works that do the rounds of festivals and museums but also texts that are presented at congresses and published in books and magazines.

Sometimes, this artistic gesture only requires a very simple action, such as deliberately changing the normal way certain devices are used, as I proposed in my video *Fourteenth Floor* (Décimo Quarto Andar 2007). In the mid-2000s, cell phones began incorporating photo and video cameras, reconfiguring the body, gestures and attention levels to our daily surroundings. The video shows recordings where I was using the phone in recording mode, but my body posture was that of someone who was on a phone call. My simple physical reconfiguration in relation to the camera that I was using—as it was merged with the telephone—radically transformed the understanding of the phone's function, of my actions and the status of my presence. I made several incursions into public and private spaces—many of which could not be accessed if bearing a camera. Lastly, I made a video with images captured in elevators in various locations around the city, addressing the everyday gestures and interactions that take place in this banal and weird means of transportation.

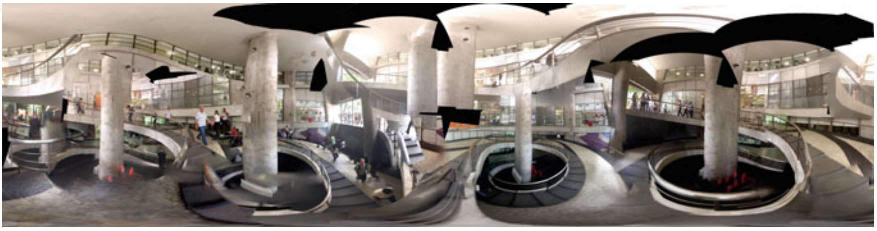

Fig. 1 Marquês de Herval Building, photograph of the series *Spaces of Failure* by Cesar Baio

I made use of these practices of disobedience towards the ways these apparatuses are programmed to be used as a strategy to disarrange that which has already been learned about these apparatuses and the social dynamics they are inserted in. This idea is echoed in the images of the project *Spaces of Failure* (Espaços de Falha 2014), a series of photographs that I have been making based on the unexpected use of panorama-making apps for cell phones, modifying the camera's axis and shifting the viewpoint during the shots. Even if this attitude maintains a defined intention and the program strives to reach its objectives, it is impossible to predict exactly how the algorithm will stitch the images (Fig. 1).

Thought of as "(counter)panoramas", these images stem from a speculation about the ways of seeing and representing that have been imposed since modernity. The learning algorithms used in these apps are trained to replicate the codes of perspective, but, by corrupting their functioning, the artistic gesture highlights the role of coding, the standardization of forms of seeing and the invisibility that marks the ever-increasing penetration of intelligent algorithms into society. It is precisely through the algorithm's failure in this stitching that one can imagine other (im)-possible spatialities.

By choosing to photograph icons of modern Brazilian architecture, I seek to underline the role of perspective as a code that is common to the regimes of representation of technical images and to the functionalist space model that guides modern urban design. The noisy, fragmentary and lacunar images, that arise as landscapes of failure, offer metaphors to ponder on the socio-political incoherencies of the construction of modern cities in the tropics.

Both in *Spaces of Failure* and in *Fourteenth floor*, the image becomes a representation not only of what is in front of the lens, but, above all, of a performatic gesture through which I put myself on a collision course with the logic of the internal operating structure of these technical apparatuses. With this poetic gesture, I aim to trigger insights that can expand the understanding of what those technologies can be, to beyond the intentions already set by the factory in its design, in the instruction manual and in the manner they are inadvertently incorporated into daily use.

In other cases, the process of reconstruction of meanings occurs through a direct intervention in the sociotechnical apparatuses, as is the case in *IOtherI* (EuOutroEu) (2008), an interactive installation in which a computerized video surveillance system is installed at the end of a corridor. The camera and the projection of the images it captures in the corridor are located on the opposite side to where people enter. Although the image of the space is sharp, the visitor's image is cropped out of the context and appears as a dark, undefined shadow. With each step towards the screen, the person sees their image a little more clearly. However, when they are about to see themselves fully on the screen, their shadow is replaced by the image of some other person who visited the work beforehand. At this point, the visitor notices that they have become part of a database created by the system.

The work makes reference to the narrow spaces equipped with CCTV by Bruce Nauman. It makes use of people-tracking technologies, automated threat detection and automatic database creation of current computerized video surveillance systems to create a platform which invites the participant to engage in self-representation. Before the selfie craze, the idea was to create a digital space to unite self-invention, the fascination with the ego and the expression of otherness.

This subversion of institutional control systems, facial recognition algorithms, databases for identification of individuals in order to create play spaces for representation is also present in the series *Collective Identities* (Identidades Coletivas) (2008). The piece is an interactive installation in which the participants are invited to photograph themselves. In the installation, a self-service camera setup is made available to the public, just like a minimalist "photo booth" which takes portraits according to the standard format of ID registration systems. However, on using the system, the participant realizes that it is impossible to take a photograph like those taken by traditional machines, as their image is superimposed with those of people who have already activated the system. The resulting photographs challenge the observer to recognize traits that can identify a particular individual. Each person's agency on what was done by the other ends up creating a palimpsest of self images which calls into question the modes of representation, the construction of identity and the production of relations through digital networks.

These interactive artworks propose a breaking down of the automation and functional rationalism that is traditionally imposed on technological apparatuses, demanding the subject's affective participation. In this regard, I agree with the relations made by Julio Plaza (2013) between interactive art and the participatory art of the 1960s. I consider these works and their relation to Brazilian Neo-Concrete Movement, especially that of Hélio Oiticica, Lygia Clark and Lygia Pape, who sought in the art object a way to trigger unique and subjective interactions from those who interacted with the work.

In the context of electronic media, participation becomes much more complicated due to the density of the political, ideological and economic dynamics that determine the industrial production of interfaces and technologies. This complexity already appears in some manner in works by artists such as Bruce Nauman, Bill Viola and in the manner Nam June Paik envisages the public's participation in works such as *Random Access* (1963) and *Records Schaschlik* (1963).

In *Good Morning Mr. Orwell* (1984), Paik brought together dozens of the most important artists of the time on a TV programme seen by 25 million people. These artists, of various nationalities, were representatives of pop culture and the avant-garde. Not without creating tensions with the alienating and politically controlling role that mass communication played, the South-Korean artist stated: "I wanted to contribute to bringing down barriers (…) TV translates everything. TV is the new Esperanto" (Paik 2016). This idea led Paik to demonstrate the viability of another functioning model for the electronic medium, based on global dialogue, on expressive participation and on the intertwining of classical and popular circuits

If art's strength lies in the production of sensitive experiences, I believe it is necessary for the ethical-political aspects to be intimately entwined with the aesthetic ones. If this does not happen, one runs the risk of making a purely formalist type of art that is displaced from reality or, otherwise, of producing a lacklustre pamphlet instead of a potent work of art. That is why I like Vilém Flusser's[1] approach to the issue, based on the concept of techno-imagination, something that, for him, would be a nomadic way of imagining (producing and understanding the world through images) in order to penetrate the system and reformulate it from within. For Flusser, techo-imagination leads "(…) to an action that takes advantage of the established situation by using purposes that are different from those of the current manipulators. Techno-imagination is precisely the ability to imagine currently manipulative ideologies and to play with them" (Flusser unpublished: 16).

Taking up Orwell and Paik discussions, if the mass media model has a centralizing character, the internet is no different. The web's supposed democracy is easily unmasked when we realize that practically everything we access goes through the networks of a very small group of corporations. Although we have the feeling that by creating a social media account, posting a photo or a comment we are establishing a global dialogue, the restrictive action of the algorithms that organize searches and feeds (Mager 2012), the multiplication of hate speech and intolerance and the predominance of the so-called "post-truth" (Harsin 2015) highlights the fact that a technical model of distributed multipoint network is not enough to create effective dialogical and horizontal social relations. Moreover, it is necessary to come up with symbolic spaces that act as devices of creative collection and dialogue on the web.

I first approached these issues in 2009, when I produced *Table of light* (Mesa de Luz), the first interactive platform for collective audio-visual mixing. The idea present in this piece is expanded upon in 2010 with *Good Evening Mr. Orwell (or Dance Everywhere)*, a small homage to Paik. Presented as an interactive and networked Vjing performance, the project creates a platform especially developed for the work. It allows images of a customised dance floor to be used, video streams to be sent and received over the internet, and "hijacked" photos and videos of social network users to be used. Anyone can watch the streaming of the event and participate in the online performance by accessing the project's website, but, to do so, it is necessary to first of all log in through a social network.

By agreeing to the terms of use, the images of the person's online account are automatically captured and become part of the artist's image bank, used in the audio-visual composition created in real time (and subsequently deleted). Artists from different places around the world, invited to the project ahead of time or who offer to participate on the spur of the moment, can send videos or make broadcasts over video calling networks.

At the exhibition site, a mini dance floor is set up with special flooring, a disco glitter ball, lighting and a surveillance camera. Besides being used in the audio-visual mixing, the images of the floor are analysed by tracking and gesture detection algorithms, so that the movement of those dancing interferes directly with the rhythm, colour and visual patterns in the final image. From this convergence of databases and live streaming arises an audio-visual composition that short-circuits psychedelia and informational clarity, making reference to both the colours, effects and rhythms of Paik's videos as well as the geometric graphing of the data visualization (Fig. 2).

The consensual surveillance techniques used in social networks become a way of putting together a collaborative, multi-sensory and global aesthetic experience. On the dance floor, the algorithms that are interpreting the images are not looking for suspicious acts but rather a harmonious movement between the bodies influenced by the music and rhythm of the audiovisual composition.

Currently, projects such as these discussions about occupation of information networks and production of public space are being taken up in projects such as *Immediate Surroundings* (Imediações) (2015) and *Ancestral Objects and* Internet *of things* (Objetos Ancestrais e Internet das Coisas) (2017), which I undertake in partnership with Claudia Marinho and undergraduate and graduate students, through actLAB—Research Laboratory for Art, Science and Technology, Federal University of Ceará. These projects have led me to have deeper discussions about how the logic present in artificial intelligence algorithms, databases and communication networks still continues to replicate many myths of modernity that update development models that increase economic inequality, reinforce social exclusion, endanger natural resources, and strengthen colonialism.

For me, these practices of insubordination to the functioning of technical apparatuses act as a means to investigate the roots of the cultural processes that,

Fig. 2 Documentation of the interactive installation and performance Good Evening Mr. Orwell (or Dance Everywhere), by Cesar Baio

solidify in these apparatuses ways of seeing, sensitivities and experiences of self and of the other that inform our understanding of the world. To uncover the organizing algorithms of these apparatuses, produce flaws in their internal logic and reconfigure them into unique aesthetic experiences has become a way of searching for insights into modes of sensitivity that deviate from the logic of current informational capitalism and allow us to discuss our ways of existing.

For me, playing with these apparatuses implies understanding circuits, lenses, sensors, cameras, networks and interfaces in their political, ethical and aesthetic dimensions. This process requires an understanding that integrates subject areas and ways of thinking from different fields, ranging from electronics and computing to philosophy, sociology, archaeology, physics, history, art theory, and so on. It also requires a playful attitude that reminds me of my childhood days. This motive, perhaps, is why my inability to see technology as something separate from inventions and the imagination (representation and project) of the world made me understand this game as a way of establishing affectionate relationships and sharing utopias.

End Note

1. Vilém Flusser (1920–1991) was a philosopher who was born in Prague but who lived in Brazil for more than thirty years. His best—known book, published in Brazil under the title "Filosofia da Caixa Preta", has been translated into fourteen languages. The English version of this book is called "Towards a Philosophy of Photography". Although most of his books were originally published in Portuguese and German, in recent years, some of his most important books have been translated into English.

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Correction to: LocalStyle > Forward

Marlena Novak and Jay Alan Yim

Correction to:
Chapter "LocalStyle > Forward" in: L. Candy et al., *Explorations in Art and Technology*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_26

In the original version of the book, author name "Jay Lim" has been changed to "Jay Alan Yim" in Chapter "LocalStyle > Forward", biographies and TOC. The correction book has been updated with the change.

The updated version of this chapter can be found at
https://doi.org/10.1007/978-1-4471-7367-0_26

L. Candy et al., *Explorations in Art and Technology*, Springer Series
on Cultural Computing, https://doi.org/10.1007/978-1-4471-7367-0_39

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