Chapter 1
Seeing Things: Heritage Computing, Visualisation and the Arts and Humanities

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Abstract Digital technology and visualisation play an increasingly large role within the strategic framework of the Arts and Humanities. This is not in itself unexpected given the nature of research in these disciplines but the need to obtain and process large amounts of data, to gather this from disparate locations and then to link and disseminate this information in a manner that challenges researchers and informs the wider public which is both a challenge and an opportunity. Digital technology in Heritage is at the forefront of such a development through its relationship with large scale or pervasive visualisation and emerging human–computer interfaces with efficient algorithms for the processing, analysis and access of linked large-scale datasets. The "Big Data" worlds created by Arts and Humanities and Heritage research are proxies through which we may access the past and also make sense of the world in which we live. In this context therefore, the state-of-the-art applications presented in this volume provide a snapshot of our current position in this exciting new research landscape. The collection of chapters presents digital technology as part of an iterative process of investigation within Arts and Humanities, encompassing data capture, processing, analysis, interpretation and dissemination via interactive visualisation. The content of this book is inspired by the themes—objects, monuments, landscapes and behaviours and each chapter presents original research associated with the exploration and application of digital visual technologies within these research domains within. As a whole, the chapters demonstrate the diversity and scale of research in the discipline, and the utilisation of a wide range of digital technology to facilitate research on the frontiers of digital heritage.

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Trace Science then, with Modesty thy guide;
First strip off all her equipage of Pride,
Deduct what is but Vanity, or Dress,
Or Learning's Luxury, or Idleness;
Or tricks to shew the stretch of human brain,
Mere curious pleasure, ingenious pain:
Expunge the whole, or lop th' excrescent parts
Of all, our Vices have created Arts:
Then see how little the remaining sum,
Which serv'd the past, and must the times to come!
The proper study of Mankind
~ (Alexander Pope 1688–1744).

The role of computing and visualisation has rapidly been established as a strategic issue within the Arts and Humanities.[1] Such developments are not unexpected as the need to mine and process the increasingly large amounts of Arts data held in disparate locations, and the need to satisfy our increasingly complex academic aspirations, have inevitably pushed us towards the greater use of technology and a reliance on visualisation to make sense of the world in which we live.

The ubiquity of technology and its formative role in social and academic arenas is also driven by the increasingly Rabelaisian appetite of contemporary society for visual imagery, and again the role of visualisation has emerged as an integrating theme across the Arts and Sciences more broadly (Greengrass and Hughes 2008). This may be particularly clear in relation to heritage studies and the manner in which the past is being appropriated through the creation of vast, and increasingly interlinked, digital archives. Indeed, largely because of this, the pervasive nature of visualisation and, perhaps, the fetishisation of visualisation technologies have itself become a significant research issue. In both Social Sciences and the Arts there is an appreciation of the impact of technology on society and social agendas. These trends may also be encouraged by the increasing financial support for studying in these areas, driven within the UK at least, by research funding agencies who see the digital agenda as one in which they may demonstrate wider social impact.

The reasons for research interest in digital humanities may be complex but this does not deny the significance of these technologies for our society. We daily experience imagery that is cascaded as a proxy for reality (e.g., IMAX documentaries) or that are provided as explanatory guides to processes that transcend the capacity of individual comprehension, e.g. the MIT SENSEable City Lab's visualisation and tracking of 'senseable' household trash across the United States. We generate experiences and novel social groupings through gaming and

[1] See for example the scheme for the British Arts and Humanities Research Council's "Digital Transformations in the Arts and Humanities" and "Digging into Data" initiatives.

immersive environments (Cole and Griffiths 2007), experience elevated social status (Ducheneaut et al. 2006, p. 7), trade commodities and, in the case of the Bitcoin, and Second Life Linden$, even engage in parallel economies and currencies through these digital spaces (Jonas 2006). Increasingly our mediated world is visualised and interacted with via small and large digital displays that have penetrated the fabric of society to the extent that the boundary between the virtual and the real has become fuzzy, and, for better or worse, digital imagery has increasingly become a substitute for reality (Bugeja 2005; Yee 2006). For heritage, visualisation technologies provide powerful tools that can invoke the sense of presence (Lee 2004), a psychological state where, "virtual objects are experienced as actual objects in either sensory or nonsensory ways", or "a state of consciousness, the (psychological) sense of being in the virtual environment" (Slater and Wilbur 1997). In some sense, Baudrillard's "precession of simulacra" may have been achieved and experiential reality may now be deemed to have been realised without any prior basis in reality (Baudrillard 1983; Ch′ng 2009). It is no surprise, therefore, that understanding the position and significance of the virtual, via the proxy interface of visualisation, is increasingly recognised as a high priority for heritage professionals or that the wider theoretical content and significance of apparently abstract digital processes has been debated at disciplinary and social scales (Gregory 1994; Pickles 1994; Tilley 1994).

The process of visualisation itself, however, does not exist without a prior reality. Whether or not any existing data may be used as a visualisation, the act itself requires an increasingly complex mix of technologies to achieve verisimilitude or be applicable to heritage issues. As such heritage specialists must be concerned with how technology itself develops. Whilst it is widely appreciated that technological developments follow certain trends, for instance that observed by Moore (1998), there are other, equally important, "laws" linked with Gilders (2000) and Metcalfe (1995). The better known Moore's law suggests that the processing power of a microchip doubles every 18 months and, effectively, the price of a given level of computing power halves over a similar period. This has implications not only for processing speed, but also for other information storage devices—integrated circuits that stores millions of transistors and capacitors, such as the storage capacity of computer memory (Chip 2005)—and also imaging devices that deals with pixel data (Myhrvold 2006). Gilders's law states that the bandwidth of communications systems triples every 12 months—three times as fast as the growth of computing power suggested by Moore's law whilst Metcalfe's law asserts that the value of a network is proportional to the square of the number of connected users or nodes on the network. This means that the increase of nodes or users in a telecommunications or social network increases the value or usefulness of that network in terms of the ability to communicate and disseminate information.

The changes predicted by Moore, Gilders and Metcalfe will be of vital importance in heritage computing. As technology grows in a nonlinear fashion, our ability to gather and store large amounts of data and the capability to speed up the processing of information using parallel and distributed computing approaches, will grow at an exponential rate but bandwidth and the connectedness of networks will also change rapidly—and this will have significant impact on how researchers work and their links into wider digital communities. At the time of writing, the authors already collaborate using a Cloud service that manages the distribution and sharing of files—changes on an author's documents are instantly reflected on the computer of a collaborator. Mobile telecommunications coupled with GPS (Global Positioning Systems) and Web 2.0 features (O'Reilly 2007) are also providing the means to crowd-source using geolocation services, share and distribute information beyond the academic community, all within either a 2D or a 3D virtual world. The future of the connected Web will provide a host of services that will provide heritage information as personalised learning with meaningful subscribed content pushed to users via the Semantic Web (Antoniou and van Harmelen 2008). The Semantic Web (or Web 3.0) provides a base for intelligent software agents as service providers that learn our behaviours and automatically deliver collated information for users. As the establishment of hardware infrastructures matures, the software that sits on it will become increasingly intelligent and complex, it will enhance our user experience (Ch′ng 2013). At a practical level the significance of such developments can be gauged in the exponential change within the Birmingham computer group which, 15 years ago, was served by a local network of 26 PCs and a server that, eventually, boasted 4 gigabytes of storage and 64 megabytes of RAM. The capacity of much of that system could be replicated now in a single large workstation. The system today includes some 32 individual work stations, is supported by an in-house licence server, storage and render farm with 16 terabytes of storage, connectivity via 48 optic fibres including s dedicated link to the web and a 1Gbps link to the BlueBEAR cluster and *c.*150 terabytes of user disk space (BlueBEAR 2012). The theoretical peak performance of the compute nodes is 848 (cores) * 2.2 (GHz) * 8 (floating point operations/cycle), at 15 TFlop/s. The capacity of the current system has been transformed not simply by raw computing power but by connectivity and bandwidth. The top 500 High Performance Computing Systems of course, boasts greater computing power. As of writing, the world's fastest super computer–China's Tianhe-2 (Milky Way-2) operates at 33.86 petaflop/s, the equivalent of 33,860 trillion calculations per second, with a theoretical peak performance of 54.9 petaflop/s.

Having made this point, we must consider whether heritage studies actually need access to such powerful systems. Fortunately, such justification is relatively easy to provide. It is clear that many Arts disciplines operate at an interface with natural sciences and where this happens there is a natural propensity to generate large amounts of spatial/numeric data. Archaeology and its relation to landscape is an obvious example of a situation where a traditional arts discipline has been transformed by large-scale digital data sources, most notably generated by remote sensing, which have no existence other than in a digital format. The heterogeneous nature of Arts data also generates a requirement for data discovery and data mining at a monumental scale. Corpus linguistics can be cited as a discipline in which the whole of language may be considered an appropriate area of study. The requirement for a range of complex visualisation technologies for the purpose of representation, interpretation, restoration or aesthetic display increasingly demands high resolution modelling in areas such as architecture and art history which demand fidelity of representation. This cascades for many Arts disciplines that have an almost constant engagement with the general public, the media and creative sectors at a visual level. Ultimately, real-time exploration and the complex nature of individuals, societies, agency or action cannot be performed without such support. Human existence always carries the notion of a "being in the world" and the implication of a complex entanglement of relations between people, objects and environment (Dreyfus 1990; Hodder 2012). Such studies are infinitely complex and, usually, only one act within a larger, iterative process of collection, selection and manipulation of data that never actually ends (Fig. 1.1). Data and interpretation now cascade in a manner that was never realised previously and these networks will merely expand as computer systems become more powerful and, perhaps more importantly, all data becomes interlinked. The process of heritage computing is therefore a highly complex act and no individual part of the process, from data collection to interpretation, is independent. The debate, within archaeology at least, concerning the legitimacy of visualisation as an isolated output emphasises such a position (Exon et al. 2000; Gillings 2001; Wheatley and Gillings 2002) (Fig. 1.2).

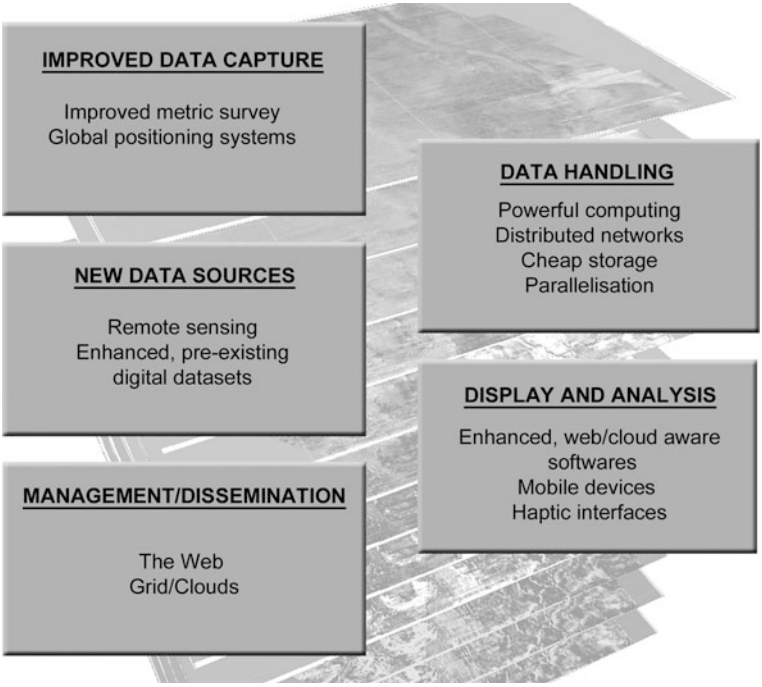

Fig. 1.1 The technology context of digital humanities

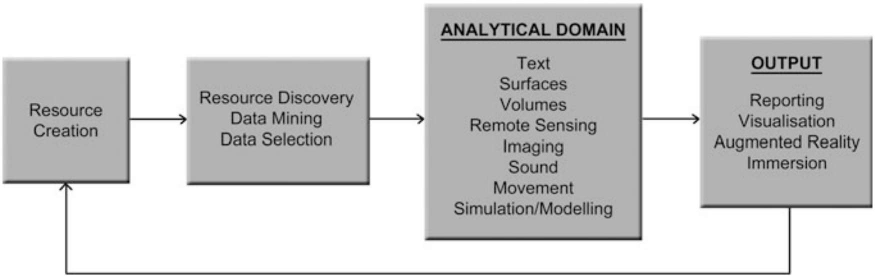

Fig. 1.2 Primary activities in E-science (reprinted from Ref. Gaffney 2008)

Consequently, the current volume presents interactive visualisation only as one part of an iterative process of investigation within the Humanities along with data capture, processing, analysis, interpretation and dissemination. This does not, however, suggest that any specific process is generic. The challenge of Arts and Humanities computing, following Alexander Pope, is that its subject is humankind. Whilst we can create entities that approximate reality, we cannot create reality itself—past or present. Specifically, the issues of scale dependant behaviour within the context of Arts and Humanities computing certainly come to the fore and the issues relating to the selection of representation remain an issue throughout the sections of this book (Lock and Molyneaux 2006). This should be evident in the organisation of papers in which is linked to both scale and process. The first Chapters are inspired by objects both in terms of data capture (Chapman et al. Chap. 2 and White Chap. 3), the organisation of data (Ch′ng et al. Chap. 4) and their representation and accessibility within increasingly complex sensory environments (Creed, Seville and Sears, Chap. 5). The study of monuments provides an equally complex arena for analysis or display that may cross temporal and physical scales. The capacity of monuments to communicate a variety of messages, perhaps at the same time, to change with time and to retain social values which may be highly contested, should be apparent to most observers (Bradley 1998). The complexities of adequate data capture for monuments (Santagati et al., Chap. 11) go hand-in-hand with studies that examine the evocative nature of monumental heritage. There should be ready parallels between the processes by which the mausoleum of Diocletian, a Roman emperor famous for his persecution of Christians, was transformed into a cathedral (Gaffney et al.) and the contemporary issues of representation of modern concentration camps (Sturdy-Colls and Colls, Chap. 7). At the landscape level, the issues of communication remain profound and transcend technology as a study in its own right.

Mapping is always contentious and multivariate in semiotic terms and these issues exponentially proliferate with technology itself (Edson 1997; Pickles 1994). The issues of mapping historic data and what these represent may become more problematic as the opportunity to integrate and analyse historic graphical, textual or numeric data increases (Ramsey, Chap. 8). This become explicitly contentious in heritage mapping at a supranational scale which brings with it issues relating to ownership and opportunity. In developing regions, how can our digital product support communities that may feel a deep connection with the heritage landscape and a wider society that may believe itself be philanthropic, but seeks to benefit from economic development of indigenous cultures (Kokalj et al., Chap. 9)—"Science without conscience is the soul's perdition" (Rabelais 1955). The future may be mobile but the use of mobile technologies both to collate information from respondents within the landscape (Shaw and Challis, Chap. 15) or to inspire an infinite number of interpretations of abstract rock art within the landscape (Areti, Chap. 10) or design space, is challenging for most heritage practitioners. What will happen as experts loosen their authoritative hold on data? Who owns the past has been debated before (Yoffee and Sherratt 1993), but the issues have never been so relevant as now. Today, data cascades through society, rather than learned societies, and how we construct our record, or record our understanding, is becoming a battlefield. Whilst in the past it may have been sufficient to understand the observed, the individual, or the society under study, today we are as likely to give as much weight, and occasionally more, to the observer when considering the results of humanities computing. If so, the increasing complexity, and adequacy, of our models will fast become an issue. Even the simplest societies challenge technology to provide an adequate representation of the past. Whilst the past as a foreign country is a cliché in heritage literature, the capacity of technology to reveal habitable landscapes that are physically beyond the reach of archaeologists and historians, rather than simply represented indirectly by the chances of survival, taphonomy and "time's arrow", present novel challenges in reconstruction (Fitch, Chap. 14). The potential for Complex Systems Science and the application of agent-based modelling within a multiagent systems framework is gradually coming to the fore in these and other, related contexts and there is a well established literature which remains to be tapped by Arts practitioners (Holland 1995; Kauffman 1996; Lewin 1993; Mainzer 1994; Miller and Page 2007; Mitchell 2009; Pagels 1988; Waldrop 1993). These are supported by emerging journals on complexity from large publishers (Complexity, Wiley, Journal of Complexity, Elsevier, Complexity, Springer) and numerous conference proceedings on the topic. There is increasingly an appreciation that Complex Systems Science is important if society and its understanding of its economic, scientific, cultural and political components are to advance. Heinz Pagel, in *Dreams of Reason* (Pagels 1988) provides a direct statement: "I am convinced that the nations and people who master the new sciences of complexity will become the economic, cultural, and political superpowers of the next century". Also, when asked what the next century will be, Stephen Hawking replied, "I think the next century will be the century of complexity" (Stephen Hawking, January 2000). How then we should anticipate this brave new world of Complex Systems Science and how is the study of complex systems relevant to the study of present and past heritage?

Complex Systems Science studies systems that have a population of interacting entities that are strongly coupled in analysis. These systems exist in every hierarchy of our universe, from the molecular level to populations of organisms within ecological boundaries and from society to the global environment and planetary systems. Complex Systems Science complements, but moves on from, reductionism; it explores and attempts to link macro-level properties of systems such as emergence and self-organisation (De Wolf and Holvoet 2005; Halley and Winkler 2008; Holland 1998) with interactions between individuals at a local level. The study of complex systems includes the by-products of society such as culture, economy and technological developments (e.g. the Internet, Social Networks and etc.). The principles of the study of complexity are similar across all complex systems and attributes at the micro level are similar to those that are in the meso and macro levels. This is the reason why complexity theory is appearing in many fields and where the maxim that "the whole is more than the sum of its parts" can be held (Aristotle, Metaphysica 10f–1045a). Complexity modelling and simulation via agent-based modelling can help us understand phenomena in ways that are impossible using traditional means—the distribution of wealth within a society, the emergence of social groups, population movements in climate change, the development of culture and the evolution of landscape use, among many examples. An appreciation of the "entanglement" or complexity of social and natural environments has recently come to the fore in a publication by Ian Hodder (2012). However, whilst such processes may be described in conventional terms it is unlikely that the complexity of the analyses that he proposes can be understood through traditional means (Hodder 2012). Complex Systems Science, ABM modelling and interactive visualisation is more likely to be essential in this field for hypothesis testing and for generating new knowledge within this emerging area of study rather than traditional methodologies.

In an increasingly mediated world there are real opportunities for transforming research in the Arts and Humanities, and for engaging the 'Net generation' (Tapscott 1998), 'Digital Natives' or 'Digital Immigrants' (Prensky 2001) through informative, media-rich and interactive learning and teaching styles (Prensky 2006). The penultimate group of papers in the volume builds upon and expands this area. Ch′ng and Gaffney (in Chap. 12), and Murgatroyd (Chap. 13) provide examples of ABM applications in prehistoric and historic contexts. These papers demonstrate that whilst many researchers may question the capacity of historic data sets to provide the answers we need about the past, it need not follow that data, even if it exists, is necessarily the answer. However, our emerging capacity to simulate human agents and their place in the world can provide different insights into very traditional questions. Finally, as consumers of digital data and interpretation, how will we relate to wider society in the future? What will our data collections look like in the near future and how will we access them (Richards, Chap. 16)? How will we react to the scale of data availability (Thwaites, Chap. 17) and will the mediated display continue to rule the passive visitor or will the visitor be in control?

Finally, the last paper draws together some of these themes and consider what may emerge in the future. In some senses the views here are generated by the experience of many of the authors who work or have worked within the Visual and Spatial Technology Centre (VISTA) at Birmingham. This is not coincidental, given the nature of technical development within academia and the relative size of the national communities engaged with heritage computing up till now. However, the success of VISTA at Birmingham was essentially a product of the people employed and the vision they displayed rather than simply the technology used. Technology was always adapted or developed on the terms of the Arts and Humanities. Pope's poem at the start of this introduction assertively states that the proper study of mankind is (wo)man. This was always the goal of the VISTA group and our appreciation that the Arts truly require resources capable of modelling exponentially expanding data sets and the complexities of human action. There was never a loss of nerve in respect of ambitious research development at VISTA in this respect and more recent developments, such as the Birmingham Digital Humanities Hub, largely represent an extension of these tenets. The torch may well have passed on from the archaeological technology team at Birmingham to a broader heritage grouping but we hope that the wider vision of VISTA has not been lost for the Arts—"the glory, jest and riddle of the world"! (Pope 1734).

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