Barbara E.A. Piga
Rossella Salerno *Editors*

Urban Design and Representation

A Multidisciplinary and Multisensory Approach

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Foreword

Acknowledging the pregnancy of the built environment's sensory and atmospheric dimensions changes the way we grasp architectural and urban design, as well as the habits that govern our representation of space. We must set aside, at least for a while, the self-evidence of the planes and schemes that impose a set order, static structures, limits, and points of view. Instead, we must admit the shifting flows and envelopes our senses perceive, the changing impressions, which define the character and ambiances of projected places, allowing them to inhabit our devices. One certainly will not do without the other; the atmospheres we project will unfold in the materiality of space, in the choice of volume. But the fundamental change brought about by an approach to design based on emerging ambiances is the overturning of the hierarchy of the project's components: Its limits and materialities no longer have any intrinsic worth—petrified in some definitive architectural gesture—only of any value through the potentialities they afford once the space is invested, felt, walked through, filled with voices, colours, smells, the light of changing seasons, and the affects and stories of those who live there.

Ambiance updates itself in the articulation between the potentialities built in by designers and the appropriations or borrowings of future users and residents. To design the city in a 'potentialist' manner, architects and urbanists need other tools than those forged developing the classical or modern city. The huge possibilities offered by today's digital technology constitute an extremely rich reservoir for conceptual and methodological experimentation. They should be used by designers, policy-makers, and stakeholders, not just to reproduce the habitual formalization of the built environment more efficiently, but also, indeed above all, to renew the languages of a project, integrating temporality, prompting sensoriality, and favouring immersion.

The great merit of this book is to make concrete proposals in this direction. The authors present tools and methods capable of renewing the ways we grasp urban space by giving plenty of room for the potentialities of place to emerge. It is important that such propositions should be given substance and put into practice in contemporary urban projects, in collaboration with policy-makers, city planning departments, and stakeholders. It is the only way to assess the real value of these tools and to acculturate municipal planners to the new stakes embodied in the sensory and atmospheric dimensions of the built environment.

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Chapter 1
Introducing a Research Perspective in Urban Design and Representation

Barbara E.A. Piga, Eugenio Morello and Rossella Salerno

Abstract The chapter aims at providing a framework to the content collected in the book and, in particular, it investigates the mutual and influential relationship between representation and urban design. This topic represents the core activity and is at the very basis of the main approach developed by the research structure Laboratorio di Simulazione Urbana 'Fausto Curti' at the Department of Architecture and Urban Studies of the Polytechnic of Milan, where physical and digital simulation is interpreted as the anticipation of future urban environments from a perceptual and experiential point of view. In fact, the entire book deeply explores the topic of urban simulation from different perspectives and in an interdisciplinary way. This chapter presents the structure of the entire volume, a synthesis of the content for each contribution, and the relationship between the parts that are organized in thematic categories, namely: conceptual and experiential approaches, digital modelling and visibility studies, physical modelling in the professional practice, mapping and simulation, and frontier tools. The contributions by professionals and researchers address the topics of simulation and design from both theoretical and practical perspectives with sound references to case-study applications. By presenting the current state of the art and the possible future directions of research in urban simulation, the book aims to become a reference for researchers and professionals, but also for higher education in urban design.

Keywords Urban simulation · Representation · Urban design

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The main aim of the book is to address how Environmental Urban Design can benefit from traditional and emerging representation and simulation techniques, with particular reference to human-centered approaches in a multi-sensory perspective. This specific point of view on design was developed by the research structure *Laboratorio of Simulazione Urbana 'Fausto Curti'* at the *Polytechnic of Milan—Department of Architecture and Urban Studies*, where from the concept of this book originates. In fact, the authors of this chapter are all members of the laboratory, and contribute to its research work from different perspectives.

The urban simulation laboratory investigates the topic of human experience in the urban environment, following a phenomenological and environmental design approach. Hence, experiential simulation is an imperative to our research, and the anticipation of ungiven environments (i.e. future or lost spaces) is the core of our exploration. The link between design, evaluation, and forms of representation is the dimension where we mostly focus our attention and efforts in research; for instance, we look for innovative methodologies and reliable design tools for supporting design thinking, or for enabling a trustful and comprehensive understanding of places that are not reality yet, in order to ease their quality assessment in advance.

The first statement for our research is that the restitution of simulations should guarantee reliable and accurate outcomes, i.e. as close as possible to reality; this can be best accomplished if these simulations are the result of cumulated investigations that refer to the object of analysis. In other words, bringing together multi-sensory perspectives and environmental considerations of places can enrich the overall interpretation of space and enables to get closer to a complex reading of environments. We strongly believe, that this can be better achieved through an interdisciplinary perspective. The book addresses this matter proposing contributions by authors belonging to different disciplines that deals with the environment, namely: architecture, urban planning, ICT, and environmental psychology.

The second statement regards our approach to experiential simulation: we aim at shortening the gap between the representation of reality and reality and, hence, fostering its application in the design process, from conception to evaluation. Obviously, photo-realistic (or better "sensory-realistic") simulation requires a lot of time and energy to be produced, but the recent and rapid advancement of ICT opens up new opportunities towards our scope. Hence, innovation in our work lies in exploring the potential uses of novel tools for design. Of course, ethical questions related to the validity of models and simulations, issues related to the proper framing and assessment of visual and multi-sensory perception, are embedded in our daily work. We believe that transferring operational tools to design has still a long way to go, and novel approaches in teaching and thinking the design of spaces will emerge in the future. Of course, the process of constructing not existing realities and adding multi-sensory and environmental features to simulation represent big challenges, because today the process of accurately modeling virtual environments is still demanding, and most of the attention and time goes directly into it. Anyway, it is reasonable to expect that this problem will be gradually overcome thanks to a more collaborative and sharing approach, to accurate data provided by public administrations, and thanks to further software development that will increasingly ease the modeling phase. Having the models at hand, the relevant concern is then how to properly use them in order to improve design outcomes. The chapters present different approaches and methodologies that provide possible answers to this issue from different perspectives. In fact, the definitions of simulations presented in this book are not unique, and not all the authors share our definition of simulation; rather, the richness of the book relies in the purpose of giving back different perspectives that can be interrelated or that can be taken separately.

The strict interrelations among the different contributions and parts of the book is guaranteed by a simple but crucial question: how representational solutions can enhance an urban design approach where achieving people wellbeing is the core mission? How to grab, represent and design the atmosphere of places? Which kind of technologies and tools are available today for supporting multi-sensory urban design? How to represent and simulate current and future environments taking into account the way we experience places? In order to answer these questions in a structured way, the book is organized according to the following main thematic categories, namely: *conceptual and experiential approaches*, *digital modelling and visibility studies*, *physical modelling in the professional practice*, *mapping and simulation*, and *frontier tools*. Each part collects contributions by professionals and researchers that address the topics from the theoretical and practical perspective with references to case-study applications.

More in detail, the contributions related to *conceptual and experiential approaches* show how a mixed methodology, based on different modalities of representation and assessment, can better contribute to inform design in terms of physical structure or subjective experience. In fact, even if it is possible and useful to represent the urban environment in a geometrical form, i.e. portraying the objective metrical dimensions of the city elements, this modality is far from being lifelike, and it is hence beneficial to pair it with experiential simulation, that aims at realistically depicting future scenarios to be virtually experienced by people. Both approaches are relevant for urban design, but while the first one has a long tradition, the second one became a recognized tool only at the end of the Sixties. This modality enables to partially anticipate citizens' reactions to urban transformations, thus enabling to take better informed decisions.

Rossella Salerno traces the main characteristics of both approaches with a specific focus on the development of experiential simulation. The different ways in which the environment is represented enables to focus on different specific urban elements, and this has of course an influence on the design process and its final outcome. Geometrical representation generally emphasizes urban form aspects, while perceptual tools move the attention to people experience.

Barbara Piga further investigates the usefulness of the multi-sensory environmental approach for urban design. She highlights the possibilities of dynamic and interactive tools for renovating the design approaches and for fostering a stronger and more efficient human-centered perspective. Accordingly, she proposes a theoretical framework for structuring the environmental design practice from design-thinking to evaluation and communication.

Marco Boffi and **Nicola Rainisio** delineate a holistic environmental psychological perspective for studying people's reactions to experiential simulation. They suggest guidelines for developing a mixed method for assessing inhabitants' feedbacks to future urban scenarios; this is based on a mixed approach derived from different traditional fields in the psychology domain.

The three chapters together give back an historical overview of geometrical and experiential simulation for design, while suggesting novel approaches and methods for reinforcing a human-centered multi-sensory perspective in today's urban design.

The second part explores the topics of *digital modelling and visibility studies*. Digital model of real contexts or design projects, is the prerequisite for developing different kinds of analyses and simulations. In fact, even if a 3-D model is basically a mock-up representing the geometrical characteristics of an environment, through simulation it is possible to derive experiential data out of it. The intrinsic correlation between the shape and layout of urban elements and the corresponding people's perception can in fact be unveiled in a quantitative way.

Eugenio Morello addresses the issue of human comfort and environmental quality of places starting from the visual perspective. In particular, he introduces the visibility analysis as a technique for anticipating clues about the psycho-physiological experience of places. The quantification of geometry-based visual aspects of urban spaces can have a direct applicability to design and environmental assessment of places.

Thomas Leduc, Francis Miguet and **Vincent Tourre** propose a novel technical method, based on the "open space convex partition solution", in order to study the visibility (isovist) of a person moving through a specific environment. The analytical possibilities of tools influence the possible applications, but even design results. Knowing how a tool calculates the simulation outcomes is crucial in order to correctly interpret results.

Åsmund Izaki and **Christian Derix** present part of the work developed by the design research group Superspace at Woods Bagot for analytical purposes, design and review of architectural projects. In particular, they present a human-centric approach based on a generative computing methodology that integrates visual and spatial analysis. A selection of case studies related to experience, wayfinding, collaboration and impact explain the usefulness of the method for the design process in the professional practice.

In the next section, three contributions address the potentiality of the *physical models in the professional practice*, with different perspectives. In particular, the contributions cover three crucial aspects: the relationship to the materiality of scale models as a design-thinking support, the influence of digital fabrication in the design process, and the role that mock-ups can have for envisioning immaterial design outcomes. The first two are related to model making, while the last one refers to the usage of models for simulation purposes.

Andrea Rossetto explores the potentialities of physical modeling as a knowledge-medium tool focusing on the link between the model and the reality that it represents. The author interprets the model as an instrument through which the forms belonging to the place can be expressed. He argues that the model making process is a method that supports site analysis and design conception: through the experience of modeling the architectural form arises.

Alessandro Capati shows how it is easy and effective to produce an architectural model thanks to a sharing approach based on manufacturing technologies. Architectural physical models can, in fact, become a direct output of digital 3-D model. This relationship between virtual and physical objects can amplify the possibilities of construction as well. Indeed, nowadays this modality of modeling is influencing the way architects design, but it is also innovating construction procedures and technologies. At the same time, this process is contributing to rediscover the crucial role of physical models in the design process.

Giulio Podestà presents the use of physical models in the simulation process for design, with a specific reference to daylighting simulation. The evaluation of the natural lighting environment can support the design process; in fact, the designer can compare the performances of alternative solutions and validate their efficacy in terms of building orientation, masses, type of envelope, and so on. In daylighting simulation, physical models are ideal tools because they are highly reliable, due to the fact that they do not need the intermediation of numeric simulation.

The following section presents the investigations on three different analytical possibilities of digital *mapping and simulation*. Topographic and cartographic representations have been long used to map objects and areas by quantities, using metric and geometric parameters, so responding to a need of describing buildings, cities, landscapes in an objective way. Nowadays it is possible to reconsider this traditional use and so finding new outputs, i.e. using cartographic bases to go beyond and try to widen the approach in analyzing reality including information coming from the senses.

Andrea Giordano argues how different kinds of information can be fruitfully linked to 3-D models in order to support the understanding of cultural sites. The author presents a case-study application of a multimedia platform that represents shapes, conditions and appearances of historic monuments in Venice, Padua and Carpi (Italy). The research presented explores a novel way for the fruition of cartographic and cultural information that take advantage of recent ICT developments. 3-D models become a tool of analysis for cultural heritage.

Valerio Signorelli argues that ICT improvements have led to new forms of representation able to extent the description of qualitative, temporal and emotional peculiarities of the urban environment, often neglected and difficult to treat with the traditional media. In his chapter, the author analyzes limits and potentialities of the sound-maps, conceived as solutions developed for representing the qualitative aspects of the sonic environment within the urban planning discipline.

Anetta Kepczynska-Walczak and **Bartosz Walczak** focus on digital technologies that allow to dynamically simulate different scenarios of urban and architectural designs and to test them in a virtual environment. This can support consensus building and, finally, can drive to choose the optimal solution. The authors highlight that computer techniques have become a very powerful tool for designers, not only for modelling 3-D forms but, furthermore, as an analytical tool: the environment, which requires intervention, does not even exist, or is at the early stage of planning, could be modelled, simulated and presented to enable public discussion and support decision-making.

The last section of the book focuses on *frontier tools*. In recent years, solutions for envisioning design projects in an experiential way through Virtual or Augmented Reality increased significantly. Nevertheless, so far these solutions are mainly devoted to describe indoor spaces, and are generally adopted at the end of the design process as communication media. Of course, the possibilities brought by these types of simulation could be fully exploited if used from the very beginning of the design process. Moreover, today the user interaction with the virtual environment is mainly related to navigation and a small range of some basic actions, but this is probably a temporary condition that will be overcame by the technological development, hopefully in a multi-sensory way. The last chapters present three applications of Augmented Reality for design: the first one is mainly related to its usage for the visualization of the final design project onsite, the second one is primarily connected to the sharing of ideas and solutions among the different actors, while the last one principally addresses the use of AR for the conceptual design phase.

Chiara Calabrese and **Luciano Baresi** present a tablet-based solution for outdoor Augmented Reality that enables to visualize urban design projects on-site. The accurate and stable localization of the virtual model in place is a crucial element of reliability, but it is quite difficult to achieve it in open spaces, since these generally present a high rate of visual complexity. To overcome this problem, the authors propose an integrated solution based on GPS and beacons. The application can be used to visualize design projects, or its alternatives, on the site of construction for an experiential appraisal.

Laura Cibien argues how interactive and collaborative interactive planning tables, i.e. augmented physical models, can inform and improve the dialogue and the sharing of ideas during the different phases of the design process, while supporting the envisioning and deep comprehension of project outcomes. A theoretical framework is presented together with a chronological overview of interactive tables. This outline enables to grasp the trend and to envision the possibilities that future ICT developments will bring into the professional and educational practice.

Myriam Servières, **Gwendoline L'Her** and **Daniel Siret** investigate how mobile devices are changing the modality in which architects interpret, analyses and design the urban space. In fact, these tools are not only modifying the way inhabitants interact with the environment, but are innovating methods and procedures of the professional design approach as well. In fact, mobile tools are leading to an augmented urban experience, and following this trend it is possible to imagine possible future scenarios of people and environment interaction. The authors present the results of research works and workshops on this topic.

The book contributes to portray the state of the art and the possible perspectives of research and professional practice based on the relationship between tools and urban design processes and outcomes. In particular, the advancements in the ICT domain are widening the designer toolkit and consequently the design possibilities, while enabling a more conscious experiential approach to the envisioning of places.

At the same time, it is clear that it is essential to take in serious consideration some crucial issues that this renovated panorama is generating, such as the urgent need to upgrade and reinforce an ethical, critical and deontological approach to simulation within the design process, from conception to decision-making and public participation, and from education to professional practice.

Part I
Conceptual and Experiential Approaches

Chapter 2
Mapping Urban Environment by Geometry(es) and Perception(s)

Rossella Salerno

Abstract Different ways of representing urban environment or city correspond to diverse ideas in considering them. On this respect, the studies tradition based on history and urban morphology use mostly the geometric survey at architectural and urban scale to interpret and describe the city or its parts. On the other hand, the approach based on experience, like the townscape of Gordon Cullen, prefers sketches, drawings, perspectives, watercolors. So analytical techniques respond to design approaches and different cultural interpretation and almost three are the emerging key concepts in facing analysis of urban places: further, the urban morphology and environment approaches, another one shows its relevance: the idea of ambiance wherein is crucial subjectivity and sensory perceptions. To fulfill a description not only based on quantitative parameters but also on qualitative requirements, it needs reconsidering the "map" and taking into account what is now emerging from new digital technologies.

Keywords Urban morphology · Townscape · Ambiance

Urban Morphology and Geometric Survey

The way architects and urban planners describe the urban environment owes much to the ideas and theories that support and direct the description. Talking about "urban environment" (and not of a city as a whole or parts of it) reveals there are very different approaches to the urban question. The cultural genealogy of city design, in which form is the most important feature, begins with the works of Marcel Poëte (1908–1910), in particular with the investigations that tried to outline the persistent form of Paris from the city's corpus of topographic material (Poëte 1931).

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The analysis of historical cities performed in studies in this key (which is very common practice in Italy) considers urban morphology as a qualifying element that is evidence of the memory and identity of the city itself through form. Aldo Rossi places type and morphology analyses performed by a number of Italian architects (including Maretto, Caniggia, Muratori and Cavallari Murat) side by side with regional and urban geography. In his book *The Architecture of the City* (1966), Aldo Rossi investigates the long-lasting relationship between construction settlements and urban areas. In his book, Rossi says "The hypothesis of the city as a man-made object, as a work of architecture or engineering that grows over time; this is one of the most substantial hypotheses from which to work" (Rossi 1966).

This deeply-rooted formal approach, in which history and geography intersect, makes the city appear as a large, architectural man-made object. The most suitable tools to describe this "man-made object" are the ones that are best able to capture its forms, at various scales, based on the identification of the geometry of objects and on their metric measurement, on the restitution of scale. With the legacy of a long tradition upheld by architects since the Renaissance, the set of techniques and methods for surveying cities and architecture turns out to be the most suitable and congruent tool for the graphic representation of the urban context. This tool system allows us to record urban facts between "geometry and history".

In the preface to the proceedings of a conference held in Perugia at the end of the 80s, Roberto De Rubertis outlined an interesting review of the role of surveying as a critical interface between history and science. "A survey is required to feed continuity of thought through the material support of graphic images, the simulacra of the importance of history, in which the current observation of the artefact is in harmony with what it has been over time, from the time it was born and through every phase of its use," wrote de Rubertis. "It is also required to contribute to the study of the building, to support the analyses and comparisons needed to develop every initiative of thought, study, restoration, consolidation and research that regard its physical structure and cultural values" (De Rubertis 1991).

Regardless of whether it is an individual building or urban fabric, of whether it is a study for conservation or design on "built environment", metric and geometrical surveys (including at times the survey of materials) are the preliminary and essential phase that certifies the status quo.

In the same work De Rubertis observed that in Anglo-Saxon culture there is an analytical practice, the site plan, that gathers the entire set of environmental data and orography knowledge needed to start a design project. (…) A site plan is a kind of environmental survey to which any annotation concerning an area, object or artefact is added before starting an action on it in order to make that action possible. It is strongly oriented to the way the elaborated products are to be used. The author of a site plan must know the plan's aims, how to apply them and, most importantly, he/she must be able to guide the graphic representation he/she is preparing to the needs of the intervention that must be carried out (De Rubertis 1991).

We will go back to this difference in analytical techniques, which satisfies different project approaches and cultural sensitivities. Other clarifications are currently needed to better focus on the potential and the critical issues of the "survey" tool.

To begin with, some observations need to be made on the graphic techniques. A survey is a scientific document, so it must always be possible to trace the object and there must be no ambiguous information. (…) "Generally only the outline is traced: of the objects to be represented only the edge is highlighted. This technique is justified by perception laws that identify the edges as the most significant part of items, easily understood and easy to remember. Although in direct vision the outline, even if it is the richest part in terms of perception, is always accompanied by internal shading, which is suppressed in surveys. The area between the edges of an object is implied and its presence is transmitted through a conventional language code, which is tacitly accepted in the cultural exchange established by the executor and the user of the image. (…) The omission of signs implies more conventions than their expression—omissions are considered to be implicitly understood by users" (De Rubertis 1991).

Like all techniques, this is not neutral. Its graphic language is given by workers in the industry and specialists and the space left by "omissions" cannot always be filled without the necessary cultural codes. The scientific language of measurements and geometry that supports the code of orthographic projections conveys the complexity of the urban stage certifying its history. However, it does not include colours, habits, traditions, the presence of life and people, visual and tactile elements, the perception derived from movement—in other words, it omits the description of the environment.

Sensory Perception in Environmental Analysis

In the Anglo-Saxon context, the graphic techniques introduced in the field by Gordon Cullen in the Sixties are very different because the analytical and design assumptions and aims are different. To begin with, the subject of investigation is in the root of the word,—scape, i.e. a visual component. The expression used by Cullen is "townscape" and there are other parameters that contribute to defining the urban context, i.e. "the curve of a wall, trees breaking up monotony, an unexpected contrast, a change in level, the closure of a line of sight, foreshortened rows of buildings, different materials for paving are details relevant for the perception of the urban scene, because they give the sensation of harmony and the pleasure of living."

"His drawings were always originals and used varying techniques," writes Carlos Montes. "Delicate, clear-lined watercolours (see pic.), pencil or ink jottings, sometimes fleshed out with touches of colour or patches stuck on, collages, photomontages, schematics and urban ideograms (see pic.), or apparently casual and

Fig. 2.1 Gordon Cullen, *Townscape*, The Architectural Press, 1961

carefree sketches. (…) Many drawings include pedestrians, because the principal objective was to defend urban design suited to individuals on foot" (Montes Serrano 2015) (Figs. 2.1, 2.2 and 2.3).

Additionally, Gordon Cullen uses serial visions that allow viewers to perceive contrasting elements in a path, e.g. the juxtaposition of a yard and a road, or the change from light to dark etc. The dramatic element of contrasts is what makes a city alive, just as places seem relevant because of the emotions they can stir in an individual. Here the fabric of the city is made up of colour, texture, scale, style, character, personality and uniqueness and its description can be called "mapping". The essential elements and aims of "mapping" remind us of the site plan mentioned above.

"We discovered three gateways—that of motion, that of position and that of content," writes Gordon Cullen. "By the exercise of vision it became apparent that motion was not one simple, measurable progression useful in planning, it was in fact two things, the Existing and the Revealed view. We discovered that the human being is constantly aware of his position in the environment, that he feels the need for a sense of place and that this sense of identity is coupled with the awareness of elsewhere" (Cullen 1961).

Fig. 2.2 Gordon Cullen, *Townscape*, The Architectural Press, 1961

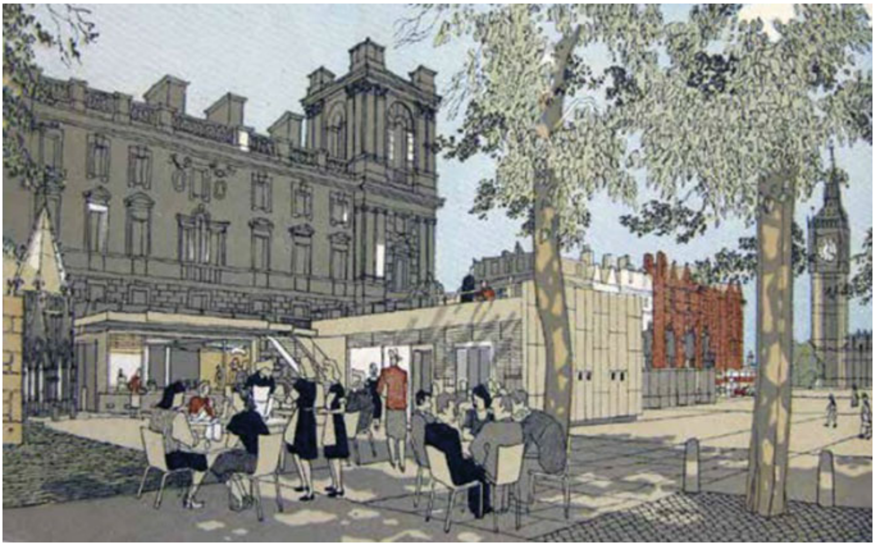

Fig. 2.3 Gordon Cullen, *Townscape*, The Architectural Press, 1961

The perception dimension is definitely part of the analytical categories that regard cities—together with vision in movement, it is what allows us to reveal the most authentic element of the environment.

"Stressing the experiences of the city instead of using building and architectural typologies Cullen contributed elements to what I would call a strategy of understanding and mapping the urban fabric inside out," states Marling (2008).

But it is still the architect who experiences the sites, whereas in the field work carried out by Kevin Lynch it will be local inhabitants who record on a map what they see, the sounds they hear and the odours they smell, so that what emerges from the map is a shared city image (to use a modern expression), which is no longer top-down but bottom-up. It is not the description of the invariant elements of form and its monuments, which have maintained the city's identity over time—it is the image produced by groups of citizens who share its uses, times and pathways.

The categories used by Kevin Lynch to carry out interviews are very well-known—path, edge, district, node and landmark—and their versatility derives from the fact they can be adapted to every kind of context (historic cities, modernistic cities or generic cities, as a part of an urban architectural mapping). We are standing before empirical categories which have had a great success in mapping architectural values in urban environments (Fig. 2.4).

"In such a whole, paths would expose and prepare for the districts, and link together the various nodes," says Lynch. "The nodes would joint and mark the paths, while the edges would bound off the districts and the landmark would indicate their cores. It is the total orchestration of these units which would knit together a dense and vivid image, and sustain it over areas of metropolitan scale" (Lynch 1960).

The graphic alphabet used by Lynch clearly marks the differences with the graphic codes of architectural and urban surveys. Lynch's drawings are the means to convey symbols based on the day-to-day experience of the people who live in cities. At the most, with the set of prevalent images, they identify relations, proximity between urban objects and their use, continuities in the urban fabric found in the paths, relation or perception contiguities. Visual perception thus appears integrated with topological relations, by the "geometries of a location" or "analysis situs",

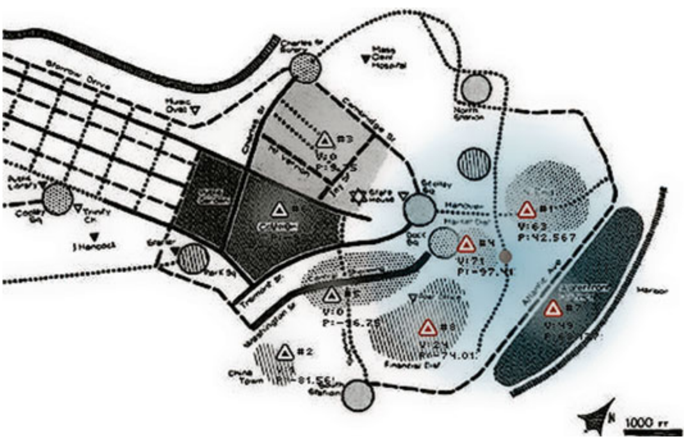

Fig. 2.4 Kevin Lynch, The image of Boston on the map, 1960

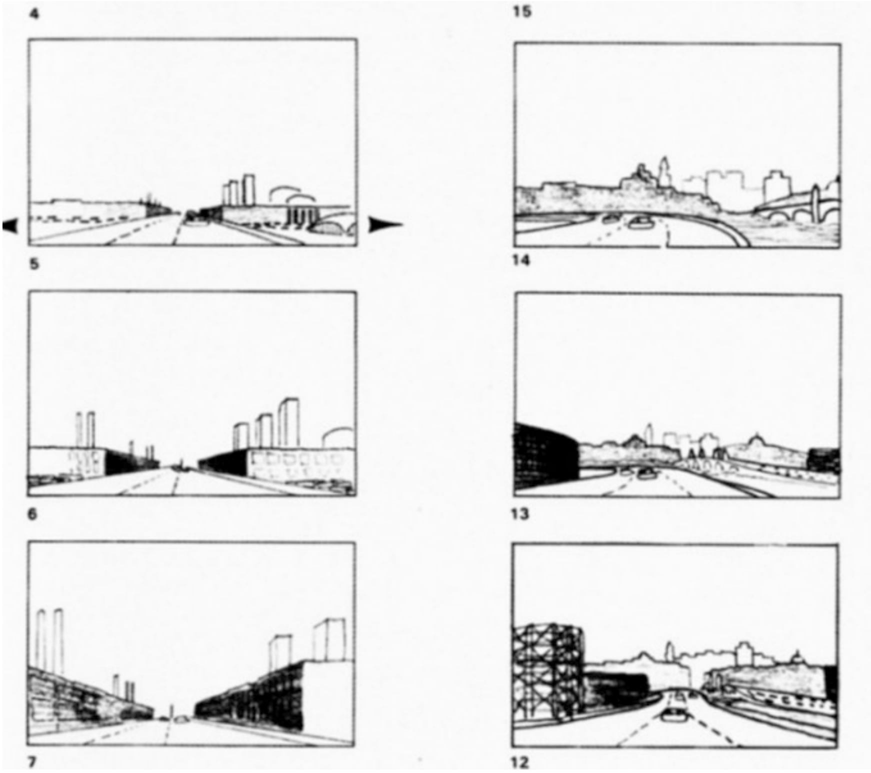

Fig. 2.5 Appleyard, Lynch, Meyer, *The view from the road*, 1964

which is the name given to topological geometry when it was first formulated (Salerno 2012, 2014).

In his book "The Image of the City" Kevin Lynch applies in the field analytical techniques connected to the perception of inhabitants along an urban pathway. However, it is "The View from the Road" (a book written by Appleyard et al. in 1964) that assumes that perception in motion is not just a crucial parameter in road planning—it is crucial for designing the surroundings of the road itself. Vision in motion relates to the form of the bordering space, the space of the relations between the subject and the urban landscape (Fig. 2.5).

Dynamic Perception and Simulation

Walking or driving along a road are ways of finding a position in space and, at the same time, an experience of recognising locations, using margins, sequences, grafting elements, differences in height. The dynamic perception of locations is connected to the human and personal dimension and the story of the spaces crossed, to the system of objects and physical relations, to the functions and uses connected to individual and collective memories(Pavia 2015).

In this genealogy of different approaches to understanding urban facts (which has the experience of people and citizens at its heart) a decisive contribution is made by Peter Bosselmann, who is from the same cultural environment of the authors of "The View from the Road". In one of his better-known books, *Representation of Places* (1998), Peter Bosselmann takes on the challenging question of how designers can communicate the changes they envision in order that "the rest of us" adequately understand how those changes will affect our lives. A crucial question is communications related to urban transformation projects aimed at lay people who live in the city which is to be transformed. Urban simulation and visualisation techniques are designed in urban simulation laboratories in Milan, New York City, and Tokyo, modelled after the Berkeley laboratory, where Bosselmann teaches.

The static perception of an urban *maquette* or the simulation of dynamic fruition through the use of micro-cameras or digital visualisation brings the interpretation codes of the projects to the levels of experience of ordinary people, who can assess the proportions and volume ratios of the buildings that could have a direct influence on people's quality of life. These are not just considerations of a purely aesthetic nature—they are very real parameters of the proposed urban solutions, e.g. with regard to the effects that the ratio of building height over road width determines in relation to sun orientation, direct sunlight, illumination, energy savings etc.

In this brief analysis of city description techniques, in relation to the design approach they are an expression of, we cannot but mention the activity of Jan Gehl (Gehl 2010), whose methodology has at its centre the life of people, as clearly stated in the home page of the study's web site "Methodology. The study of people's well-being lays the foundation for the formation of our strategic planning and design work: First Life—then Space—then Buildings. Work process. Gehl Architects have developed a work process that ensures the highest standards for city

Fig. 2.6 Jan Gehl, *Life Space Building*, 2010

development. The study of people's well-being lays the foundation for the formation of our strategic planning and design work. In our work, we utilize the empirical survey and mapping methods that Professor Jan Gehl has developed, which explore the way urban areas are used. These empirical and analytical methods inform our work throughout the process" (Fig. 2.6).

Conclusion

The pathway outlined so far briefly compares divergent approaches to urban design as well as varied analysis and representation techniques. The points of view differ in terms of geographical areas, with a Latin area that privileges history and morphology notions and an Anglo-Saxon area that by tradition values experiential data. These considerations should probably come with a critical review of the rationalist paradigm that was a reference point for architectural and urban studies during most of the last century.

Together with rationalism and its aesthetics, what has currently chiefly become a kind of epistemological obstacle to overcome is very probably the predominance of parameters presumed to be objective and quantitative, which in that culture have interpreted the life of people in the light of a concept of function, daily rhythms as standards to be satisfied, local and regional differences in the light of international style aesthetic solutions.

Going back to the more specific topic of the chapter, next to the notions of urban fabric (which historians and morphologists love), next to the concept of environment that is open to the way people live in relation to the urban context but that preserves quantitative aspects, is a third notion. This notion is ambiance, which allows to convey the subjective dimension in the relation between man and the city (Augoyard 2011).

This multifunctional expression, the intersection of urban and social studies, does not have a direct translation into other languages. It combines environment and atmosphere together, as the researchers of the French Crenau and Cerma Laboratories that study this subject write: "The notion of environment can be compared with that of ambiance, in so far as it belongs to the same semantic field. Much as the landscape, habitat or ambiance, environment belongs to the same conceptual family as ambiance, and accordingly opens up a perspective that is close to yet distinct from ambiance. This line of research explores the gap between the two terms, their complementary qualities and the dynamic they share. More exactly the articulation between ambiance and environment highlights and calls into question the "objectifiable" side of an ambiance by way of its physical and material properties and characteristics" (http://www.crenau.archi.fr).

In this meaning, time and space categories inherited from rationalism (and that are descriptive operators of urban space) require new interpretation keys. The immediate consequence of this is a new reconsideration of the "map" medium and an immediate interface with what the field of new digital technologies has to offer.

Today the challenge is to expand the quantitative information obtained from cartography through the integration of parameters that can provide qualitative and sensorial aspects as well. If this is the challenge, it is a matter of implementing analysis criteria that proceed "through" urban contexts (and not from "above"), relating spaces and experience and shifting the picture from "objective view" to "subjective vision". When moving in this direction, in addition to seeing and perceiving, it will be useful to listen to the beaten urban tracks, working on the continuity of the timeline, which can be similar to the continuity of a soundtrack or cinema film (Fig. 2.7).

Fig. 2.7 Design and renders by Aiden Carruthers, Irene Fama, Galia Shokry for the street re-design proposal "Sensory Gardens" developed by students at the university course Architectural and Urban Simulation (2013–2014) Professors: Barbara Piga, Rossella Salerno, Tutors: Laura Cibien—Anna Legnani at the Politecnico di Milan

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http://www.crenau.archi.fr

http://gehlarchitects.com/approach

Chapter 3
Experiential Simulation for Urban Design: From Design Thinking to Final Presentation

Barbara E.A. Piga

Abstract The chapter presents the research outcomes developed by the author on the topic of environmental urban design and simulation, carried out at the *Urban Simulation Laboratory* '*Fausto Curti*' at *Polytechnic of Milan*, *Department of Architecture and Urban Studies*. In particular, the author focuses the attention on the experiential approach: she proposes an urban design method that make use of multi-sensory simulation and that addresses the human-environment relationship. The author firstly traces the origins of the research laboratories dealing with environmental urban design and simulation; given this research context, she then presents an overview of the central characteristics of reliable experiential simulation. Following, she proposes a design method based on recursive key phases and a mixed used of different kinds of representations. In the conclusion she synthetically sums up the relevant issues addressed in the text.

Keywords Environmental design · Experiential simulation · Urban design

Introduction

Architecture is one of the few design disciplines that do not typically deal with one to one scale prototypes, or at least until now. In fact, new technologies are widening the possibilities of representation, especially with immersive simulation, and the popularization of such tools are enabling architectural offices to change the way they design and present their projects to clients. Today, this change is mainly affecting the end of the design process, that is the final presentation of solutions; in the future, the real impact on the design practice will probably happen when these methods and tools will be applied from the very beginning, i.e. from the conception of design. This is a revolution that will probably have a great influence on the

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profession, and on Higher Education in Architecture and Planning. Moreover, these are chances that will hopefully naturally lead to significantly re-focus the attention on the human/environment relationship, that is *environmental urban design* (Piga and Morello 2015), rather than the architectural artifact per se.

This chapter will present the theoretical approach developed by the author at the *Laboratorio di Simulazione 'Fausto Curti' [Urban Simulation Laboratory 'Fausto Curti']* (*labsimurb*)[1] at *Polytechnic of Milan* (POLIMI), *Department of Architecture and Urban Studies* (*DAStU*). The proposed methodology aims at guiding a fruitful use of experiential simulation in design towards the paradigm shift driven by emerging technologies and tools, and it has been applied by the author to profession, research and educational practice (see for instance: Piga 2011; Piga et al. 2011).

Designing the Multi-sensory Experience: The Origins

It is important to go back to the sixties, in order to backtrack the origins of the proposed approach to experiential simulation and urban design. This is, in fact, the result of a long process that involve great schools and professionals that laid the initial basis, and to whom we are all in debt.

In 1964 Donald Appleyard, Kevin Lynch and John R. Myer in the well-known *The View from the Road*, addressed the issue of visual landscape and its dynamic perception by users, in terms of aesthetics of highways and the role of design. The monograph was the result of a funded project that aimed at developing an appropriate method for designing the experience in motion. In fact, they defined a structured abstract notation method, influenced by the work of Philip Thiel, for describing the sequential view from the road; in contrast with motion videos and physical models, this approach should enable a procedure for synthetizing the "essence of the experience into a small space… [for a] rapid communication and comparison of sequence alternatives" (p. 21). However, as the authors noted, abstract notations are never intuitively obvious and immediate; this approach, in fact, provided a conceptual understanding rather than an experiential one (Appleyard 1977; Bosselmann and Gilson 1993). For this reason, in parallel, they started to develop and test some solutions for simulating the view from an experiential (non-abstract but photo-realistic and subjective) point of view, using panoramic images and videos: this was the starting point of the *Environmental Simulation Laboratory* (*ESL*) at the *Berkeley University of California*. In its long experience, the research laboratory, equipped with physical modeling and film-making facilities, deals with environmental urban design, that is focused on the

[1] *Labsimurb* is a research laboratory of *Politecnico di Milano [Polytechnic of Milan]*, *Dipartimento di Architettura e Studi Urbani [Department of Architecture and Urban Studies]—DAStU*. *Labsimurb* is coordinated by *Eugenio Morello* and *Barbara E.A. Piga*; in particular, she leads the research on experiential urban design and simulation, while he leads the research on sustainable urban design and simulation. Official web site: www.labsimurb.polimi.it.

human/environment relationship (Appleyard et al. 1973). Unfortunately, in the sixties making a video from a physical model was much more complicated than today, and this procedure was affordable for specific cases only. In the meanwhile, citizens, especially in USA, started to require a major role in the decision-making process; hence, more intuitive representations of designed solutions, that could facilitate the understanding of transformations outcomes, were needed. According to this emergent and urgent demand, in 1968 the *United States Congress* proclaimed the *Environmental Protection Act*, which promoted an understandable use of visualizations for envisioning and sharing urban and landscape transformations (Bosselmann and Gilson 1993). From that moment on, other laboratories around the world adopted the same approach and sometimes the same tools.

In Europe, during the seventies, Helmer Stenros decided to follow the same path for the nascent architectural school in Tampere, Finland. To do this, he referred to the case of a group of environmental psychologist at the *Lund University of Technology* that were using facilities similar to the ones at Berkeley. After a long process, the Finnish environmental simulator was finally finished in 1980. That period was a rich one for European simulation laboratories, and their international collaboration lead to the foundation, thanks in particular to the collaboration between the Tampere laboratory and Bob Martens from the *Vienna University of Technology*, of the *European Architectural Endoscopy Association* (*EAEA*); this process led to the first conference on the experiential simulation topics, held in 1993 in Tampere (Stenros 1993). The *EAEA* is still working today, and it organizes a biannual conference that enable to keep alive the network between simulation laboratories and the researchers committed to the issue of environmental design, heritage, psychology and of course simulation.[2] In 2009 the EAEA members agreed to change the name of the association into *European Architectural Envisioning Association* (*EAEA*), since the technological development was not linked anymore to endoscopic solutions for motion simulation. Moreover, in recent years, the association decided to widen the topic for markedly include a multi-sensory simulation approach beyond the visual one, an approach that is reinforced thanks to the collaboration with the *International Ambiances Network*,[3] which has a multi-sensory and interdisciplinary approach to the ambiance topic. Along the years, the EAEA association increased the audience and it is now a worldwide network.

[2]The *Laboratorio di Simulazione Urbana* '*Fausto Curti*' entered the association in 2009, and it held the 11th international conference in Milan in 2013 (www.eaea.polimi.it). We met some of the colleagues that are contributing to this book during the EAEA conferences.

[3]Official web site: www.ambiances.net—Ambiances Journal: http://ambiances.revues.org/.

Experiential Simulation for Environmental Urban Design

A robust approach to multi-sensory design and simulation, focused on the human/environment relationship, implies an important shift in the representation of urban transformation projects; this, of course, has also a great influence on design development and outcomes. Simulation is one of the possible solutions for dealing with environmental urban design. In particular, *experiential simulation*, that is a media able to stimulate people responses to a simulated environment (in vitro) comparable to the one they would have experienced in a real context (in vivo) (Piga and Morello 2015), or, using Donald Appleyard (1977) words, able to "reproduce a concrete representation of what a place will be like when experienced", aims at enabling professional and laypeople to virtually experience the future (designed) urban condition. Contrariwise, traditional forms of representation such as plan and sections that has been always widely used by professionals, pose the attention on the organization of the environment from a geometrical point of view; thus, these can be classified as *conceptual simulation*, since they "attempt to reproduce abstractions of underlying systems or structures" (Appleyard 1977, p. 44; see also McKechnie 1977). In fact, as Yi-Fu Tuan (1977, p. 6) asserts "experience can be direct and intimate, or it can be indirect and conceptual, mediated by symbols".

A typical lack of urban design representation is that it does not usually deal with 1:1 scale model as other design disciplines do, such as industrial design; of course, this is due to the big dimension of the urban elements. Nowadays, the rapid development of 3-D modelling, rendering software and recently low-cost immersive headset for visualization, enables to use real scale prototypes that were traditionally not employed in architecture. It is not hard to believe that this realistic and perceptual representational approach will be increasingly and widely adopted. Unfortunately, until today a diffused critical approach in urban design to this kind of simulation is lacking, and in fact it is quite often employed in a misleading way from the experiential perspective. In fact, too often subjective views of design projects seem perceptually convincing but are instead biased, since they fail in reproducing the way people would really experience the environment. Waller et al. (1998) distinguished and named two elements that contribute to define the reliability of experiential simulation: *environment fidelity*, that is the realism of the depicted environment, and *interface fidelity*, specifically the trustworthiness of the naturalistic interaction between the user and the simulation. These contribute to define the *response equivalence* or *ecological validity*, that is "the extent to which findings utilizing the simulation laboratory are generalizable to the real environment represented in the model" (McKechnie 1977, p. 183). A simulation can be unreliable in many ways; an example of a typical distortions brought by low environmental fidelity are renders that depict a design project with unrealistic materials, such as textures, greeneries or even urban atmospheres, whereas for the low interface fidelity it possible to recall views that represent the entire design project from a specific location (point of view), from where, in the real context, it would not be possible to visualize the whole setting in a glance and it would be rather necessary to look around to get the entire picture. In the first case, the problem is related to the accuracy of the representation, whereas in the second one to the sense of scale, and thus to the real magnitude of change, using Peter Bosselmann words. Of course, these kinds of distortions invalidate the representation reliability, and can lead to produce different forms of inconveniences, such as misleading simulations, unconvincing or mistrusted simulations, poorly understood or confusing simulations (Sheppard 1989. See also: Appleyard 1977; Bosselmann 1998; Piga and Morello 2015). Such problems can occur in different phases of the design process; in fact, these do not affect the final stage only, when professionals present the solutions to decision-makers, clients or citizens, but also during the conception phase, when architects or planners produce these type of media for supporting design-thinking. Indeed, when a professional produce a simulation, based on geometrical data s/he inputs, s/he generally trusts the simulation outcomes and might not realize that the realism often relies on the photographic appearance only, whereas the perceptual experience is not correctly delivered. This is a relevant issue that is too often underestimated, and that can lead to relevant errors of evaluation at different levels and stages of the process. As a matter of fact, if experiential simulation is biased, it is quite hard to take 'informed decisions' (Bosselmann and Gilson 1993). This does not mean that these visualizations are useless, rather, this stresses the fact that is crucial to know which are the media/tool limits for not being misled (Carmona et al. 2010). Nevertheless, it is important to remember that, even if the visual simulation is accurately prepared, the lacking of the other sensory dimensions generates a distortion that is important to take into account.

Reliable realistic virtual models displayed using tools that allow a naturalistic interaction enable to experientially test future urban settings; in the past, this possibility was devoted to the architects' imagination only. An immersive and interactive fruition of a virtual environment drastically increases the sense of presence (Loomis et al. 1999), and consequently the understanding of the design outcomes from a personal perspective. This chance introduced by technology is of course relevant for architects and planners, but also for all the actors involved in the transformation process, from designers to decision makers and final users (Foo et al. 2015). Moreover, it can have a great value for students that are supposed to acquire the abilities of envisioning the complex and cumulative outcomes of their design projects. Nevertheless, it is always important to remember that this form of representation is not a substitute of others; in fact, different typologies and forms of representation are not alternative but rather complementary, and their systematic and conscious usage can support a comprehensive understanding for a fruitful approach to environmental design (Appleyard 1977).

Unfortunately, today the visual domain is the only one that is easy to accurately reproduce in an experiential simulation depicting a future urban environment. In fact, even if it possible to synthetize and simulate sound, for instance, this dimension is far from being easily manageable as the visual one, especially in terms of accuracy and thus reliability; indeed, most of the design project simulations display the visual outcomes only. This lack is even more evident if we refer to other senses, such as touch or smell; for this reason, the sensory spheres are hardly included and foreseen by experiential simulation or other forms or representation, and this might lead to disremember their importance during the design phase (Pallasmaa 1996). An important sensory sphere that, instead, is often represented in immersive simulation together with the visual sense is the kinesthetic one, and this is crucial for providing a media able to give back the sense of motion along with the sense of presence (Danahy 2001; Lathrop and Kaiser 2002; Lange 2005).

The use of experiential simulation, based on the kinesthetic and multi-sensory human experiences, forces the designer to think in dynamic terms, or in other words in time and space. Of course, this way of thinking is not new to the design domain, but it is hardly displayed in conventional drawings. I argue that depicting and simulating these evolving dimensions is crucial to continuously consider these aspects along the design process, and to better govern the complexity given by the ever-changing interaction among the urban elements, including people. Simulation can play an essential and pivotal role in supporting the spatial and experiential understanding of the cumulative implications of urban transformations in an evolutionary, dynamic and interactive way (Piga and Morello 2015). In fact, the changes generated by the design project can be of different kinds: the physical transformation can be considered a *direct impact*, while the social and personal wellbeing conditions it induces can be contemplate as *indirect impact*; these determine the project *intrinsic* or *extrinsic performances*, that are dynamic in several ways, i.e. *short-term* and *long-term scenarios*. For instance, in the long-term view it is possible to study different effects, such as the permanent change induced in the urban and the social contest by the design solution, or the durability of materials under different wheatear conditions along the years. In the short-term scenario, it is instead possible to consider, for instance, the functioning of the urban transformation in different hours, days or seasons, but also the different sensory perspective (sight or other sensory spheres) according to the user location in space and her/his travelling route (Bosselmann 1998). To manage these complex dimensions in a systematic way, and with a comprehensive and interdisciplinary approach that considers the urban structure in time together with the experience of people in motion, the support of representation is needed. I argue that conventional representation along with experiential simulation is a fruitful way for dealing with the urban complexity during the design phase.

Learning from Peter Bosselmann: The Environmental Approach in Theory and Practice

The inhabitants/environment relationship, that is the bases of any environmental approach, is the core focus of the *Laboratorio di Simulazione Urbana* '*Fausto Curti*' in research, professional practice and education. The *labsimurb* methodology had a great imprinting from the founders Fausto Curti and Peter Bosselmann (Bosselmann 2008a; Curti et al. 2008), so it is not surprising that some of the key issues presented are straightly related to these great professionals. Of course, what guides the entire process is a tension to define design solutions that contribute to people well-being, that is an immaterial and intangible goal reached as an indirect impact of the design project, i.e. environmental outcome (Piga and Morello 2015). Thus, we believe that the relation and mutual influence of inhabitants and urban setting should be the central matter of all design phases, from conception to evaluation, decision and even presentation. If the experiential approach innervates the entire design process, simulation can support the environmental understanding, and operate as a support to creation and validation. Nevertheless, the combination of different modalities of representation and simulation can contribute to portray the complexity of reality. Even if each case should be analyzed singularly, according to the specific context and needs, in order to infer the proper depiction mode along the process, it is possible to affirm that a combination of conceptual and perceptual simulation (McKechnie 1977) facilitate to keep into account the unbreakable relationship between physical structure and people experience.

Different tools can enable to reproduce and study the urban condition from a *quantitative* or *qualitative* point of view,[4] singularly or in a systematic way. The *quantitative approach* generally offers a solid base for comparison that starts from objective data. The *qualitative approach*, instead, even when it relies on scientific procedures, is hardly generalizable such as the mathematical quantifications based on geometrical measurements, and needs a socio, cultural and temporal contextualization to be correctly interpreted. Of course, if the qualitative approach is developed together with the quantitative one, these can reinforce one another, since they look at the same issue from different perspective and they get to different, but interrelated, types of results. So, for instance, we can easily declare in front of an audience that a path is 1 km long, and it would be difficult that someone disagree if the measurement is correctly taken, but when we associate a qualitative description to the path, for instance is too long or too short, is beautiful or awful, then discussions generally arise. Often these considerations rely on technical drawings that require a high ability of interpretation for correctly envisioning the designed urban setting, or—even worst—they are accompanied with biased simulations that depict a distort representation of the design solution.

Experiential simulation cannot entirely solve the problem, but it can at least provide a valid support for discussion and evaluation. In fact, it represents a sharable base that can virtually put the people in the context, aligning the discussants on the same reliable prefiguration of the designed project. Of course, this does not mean that the public will perceive and evaluate things in the same manner, since to the same urban condition can correspond several qualitative evaluations (Thiel 1997); it would only guarantee that the base of evaluation is consistent for everyone. Nevertheless, experiential simulation that guarantee *response equivalence* can be used to anticipate and study people feedbacks to the designed environments. To do that, it is necessary to rely on assessment methods belonging to the

[4]Some of the tools that can be used in this direction are described in the following chapters.

environmental psychology domain (see Chap. 3). If the inhabitants involved in the process are representative of the target users of the area when developed, this procedure is able to portray an overview of the trends of the subjective evaluations of respondents. Hence, experiential simulation of design projects together with psychological assessments can anticipate and unveil some features of the human/environment interaction in terms of comfort and wellbeing; this procedure can thus be considered a valid scientific support for design, since it can inform architects and planners about the correspondence between the project desiderata and it presumable outcomes, and for public/private negotiation (Curti 2006; Curti et al. 2008), since it enables to determine the project social return on investment.

Starting from Peter Bosselmann (1998, 2008b) work, I propose to highlight the constitutive methodological key-actions of environmental design and simulation as follow: *to observe* & *to interpret*, *to measure* & *to compare*, *to model* & *simulate*, *to strategize*, *to design*, *to communicate*; I consider the process of *evaluation* & *decision-making* transversal to all the categories. Even if the design process is not linear and is rather a recursive process of trial and errors or generate-and-test procedures (Rowe 1987), it is profitable to present these key-actions, that occur along the design phases, in a sequential way for describing the approach, as shown in the matrix below (Table 3.1). Traditionally and for simplicity, it is common to address design phases, such as analysis and design, as separated; for the sake of schematization, I will keep this distinction for the proposed matrix. In any case, it is relevant to stress that in practice this is not the case, since it is quite hard to separate observation and interpretation of reality or its representations from design conception, in fact they are activators and references of design thinking. In fact, these moments are so strongly connected that they become a unity, i.e. the design process.

Observation and interpretation are continuous activities that we carry out during the design development, a process of continuous monitoring and evaluation that guide the action. According to the progression of the project, we can represent our impressions in several ways. Often, technical drawings are not effective for studying and expressing our personal impression of a place, while imaginative or artistic representation can better fit the communicative goal (Fig. 3.1). Therefore, the qualitative phase of *observation and interpretation* can be strengthened by some *measurements and comparisons*. The comparative approach works as a contrast method, and in so doing it enables to focus on the change. For instance, it can be useful to underline the transformation from the current condition to the future one, where it is possible to illustrate or demonstrate some characteristic of the design solution in juxtaposition with the current situation; likewise, it can support the evaluation between different alternatives of design schemes. Moreover, a comparison of the study area with other alike cases can bring out some unforeseen aspects; this can support a deeper understanding of the context, or can highlight the potentialities and weaknesses of the design solutions. In other words, it can support the process of learning from comparable experiences. By comparing measurement (quantity) and experiential outcomes (quality), it is possible to better govern the goodness of design. Different forms of simulation can boost the process, enabling to

Table 3.1 Schematization of the proposed method for an environmental urban design approach.

(recursive) DESIGN PHASES					(recursive) KEY-ACTIONS	
to ANALYZE	to PLAN	to DESIGN	to ASSESS	to COMMUNICATE		
					to observe & to interpret	EVALUATION & DECISION-MAKING (internally and externally)
					to measure & to compare	
					to model & to simulate (designing from)	
					to strategize (design guidelines)	
					to design (project solutions and alternatives)	
					to communicate (internally and externally)	

The synthetic matrix relates recursive design phases and key-actions. From darker to lighter *blue* and *white*, the cells highlight from the stronger to the slighter relationship between the elements. Evaluation and decision making are transversal to all the phases and guide their development (*credits* the author)

relate quantitative and qualitative aspects, e.g. combining isovist analysis (see the following Chap. 5 and Chap. 6) to panoramic images of the same point of view. In all these cases, to deliver an efficient comparative study, it is important to provide an equivalent and homogeneous treatment of data, layout and media. In other words, for a proper comparison only the content, i.e. the environment, should change, while scale, appearance or style, represented data, size of the area and of the media, should remain equal for all the patterns under study (Bosselmann 1998, 2008b) (Fig. 3.2).

Modelling responds to two main goals, one related to the urban context representation and the other to experiential simulation. In fact, modelling—either physically or digitally—allows the designer, or the researcher, to bring the city into the office or the laboratory. Manipulating the environment is an essential procedure that enables to get greater confidence and understanding of urban dimensions and morphologies; at the same time, this is also crucial in order to produce the basis for

Fig. 3.1 Photograph of via Celoria in Milan (*left*) and interpretation of the author's first impression (*center* and *right*). The images were elaborated during the Master of Science course of *Architectural and Urban Simulation* university course, Prof. R. Salerno and B. Piga, at Politecnico di Milano (academic year 2013–2014). Images by Prap Chaiwattana (courtesy of the author)

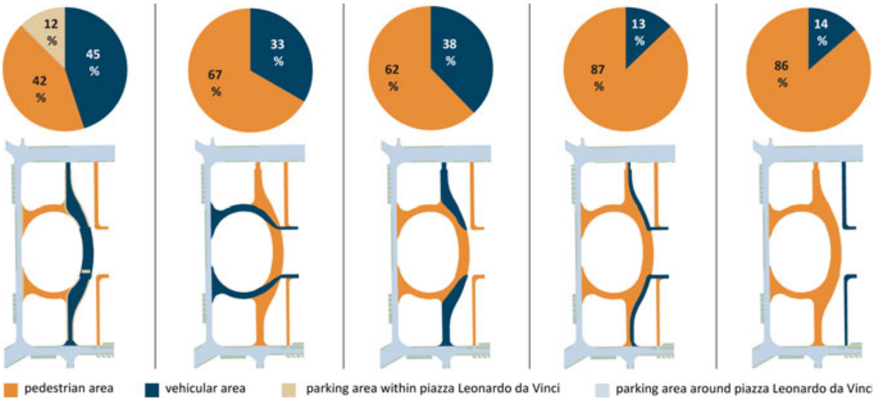

Fig. 3.2 Comparative study of possible solutions for the renovation of piazza Leonardo da Vinci in Milan (Italy). The study was developed by *Laboratorio di Simulazione Urbana* '*Fausto Curti*' within the *Città Studi Campus Sostenibile* inter-university project (*credits* labsimurb)

developing different kinds of *simulation*, including the experiential one. Through *modelling and simulating*, the designer can reinforce the phase of observation and interpretation of the current condition, while supporting the definition of *design strategies*, for instance, by relating target points and angle of views. In fact, it is possible to roughly define and test the allowable limits of a new urban structure shapes, by analyzing the possible impact of the design project in relation to subjective views from significant urban locations, or, conversely, it is possible to define the design composition according to relevant urban views (Fig. 3.3). Of course, many software can support and accelerate this process through automatic

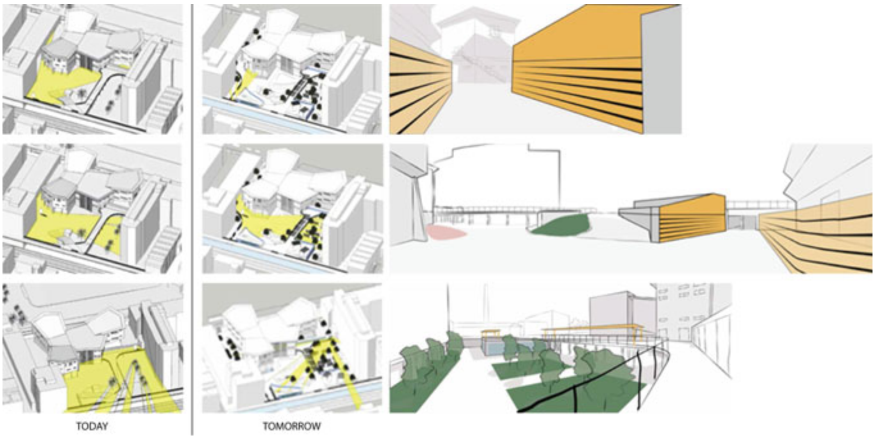

Fig. 3.3 Comparative study of visibility (isovist) of the Trifoglio open area at the Polytechnic of Milan: on the left side the visibility analysis of the current condition, on the center side the testing of the design project occlusions and the generated visibility, on the right side a sketch of the design solution. The work was developed during the Master of Science course of *Architectural and Urban Simulation* university course, proff. R. Salerno and B. Piga, at Politecnico di Milano (academic year 2014–2015). Simulation by Alexander Öhgren, Diego Largo, Julia Frisk, Laura Garcia-Frontini, Valentina Petri (courtesy of the authors)

computation, but the evaluation of the cumulative environmental outcomes and the continuous refinement of solutions is certainly the designer mission.

The previous steps contribute to identify and disclose strengths, weaknesses, opportunities, and threats of the urban context, and thus to move a step forward towards the design project development. These are in fact relevant references for delineating *guidelines and strategies*, which in turn are supposed to guide the urban design or the architectural project development. In fact, these establish the vision, the mission and the frame of reference to be detailed in the following steps. Of course, a multi-scalar approach is crucial to verify and validate the performances of the hypothesis at lower or wider scales, and at the same time a process of back and forth along the proposed key phases and actions is crucial to keep a systematic, consistent and thus informed process.

Guidelines and strategies together with a process of modelling and simulating should support the *design* framing and development through a constant process of trials and errors by mean of comparative evaluation of the project ideas and alternatives. In fact, the physical or geometrical dimensions together with perceptual or experiential outcomes facilitate to underling weaknesses and potentialities of the design project, stimulating new solutions towards the accomplishment of the strategic vision, and thus supporting the decision-making process. This procedure is of course a recursive process that uses analytical methods for evaluating solutions and potentially re-directing the project development. Moreover, as described before, if experiential simulation is associated to psychological assessment with target users, it can better support the design development and decision-making by anticipating inhabitants' responses to the designed setting. This procedure would thus inform the process about the possible gap between expected results (desiderata) and outcomes.

With some final refinements, the same representations and simulations used along the design development can be used for *communicating* to an external audience. Of course, according to the communication target and the information needs by the actors involved, it is possible to select which are the relevant media to present. The combination of technical drawings, that directly portray quantitative dimensions and implicitly contain the qualitative ones, together with media that allow to anticipate and assess the experiential outcomes, can support well-informed discussions and the decision making process. Moreover, if the presentation phase includes experiential simulations and contemplates different steps, according to the different stages of the designed solution, these can be planned as moments for collecting people feedbacks through professional psychological assessment methods, beyond having an informative goal only.

Evaluation and decision making is the decisive factor that crosses, innervates and directs all the key phases and actions described above. In fact, in each moment the architect or planner has the crucial duty of evaluation, that involves interpreting, estimating and valuing, a process that continuously drive actions. This process of continuous assessment, whether internal or with external actors, should lead to fine tuning the design project by re-defining strategies or detailed solutions. Even if the final decision is of course a public administration responsibility, a designed process based on a shared vision—and thus shared results—validated not only in compliance with technical standards but also endorsed by the final users' feedbacks, can faster the decision making process and reduce the risks of failure. Last but not least, the experiential anticipation of urban transformation can favor the people place attachment, increasing and fostering the potential wellbeing generated by the design project (see Chap. 3).

Final Remarks

In short, a systematic and conscious approach to *conceptual and experiential simulation* can be a valid support for urban design, from conception to evaluation, negotiation, and communication. In fact, *qualitative and quantitative* analysis can indeed aid the entire process, since they enable to look at things from different perspectives, portraying a comprehensive picture of the urban transformation cumulative outcomes. In fact, representation acts as a support for design thinking and as a demonstrator of the design solution validity. Hence, a combination of different depiction and analytical methods is able to sustain the study, design and managing of complex systems, such as the city, but it is crucial to keep in mind that tools and techniques have intrinsic limits; in fact, they allow to highlight some issues while hiding others. In addition, these supporting tools cannot in any case substitute the difficult task of evaluation, that remains the duty of the professionals involved in the process. I strongly believe that in a period where emerging tools are influencing and changing the way we design, a more conscious approach to simulation, starting from higher education, is necessary.

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Chapter 4
To Be There, or not to Be. Designing Subjective Urban Experiences

Marco Boffi and Nicola Rainisio

Abstract This chapter proposes innovative paths of interaction between design sciences and psychology, highlighting man-environment transaction models that could be integrated into design practices through the aid of urban simulation techniques. In particular, it is argued that designers mainly base their activity on implicit models coming from the behaviorist and cognitive psychological tradition, criticized as inadequate to richly depict people experience in environment, as they neglect its complexity, immersivity and eminently social nature. A psychological approach based on the central role of subjective experience is advanced, focusing on optimal experiences and their heuristic potential for design sciences. Some useful tools for an anticipated assessment of spatial design projects through urban simulation are presented. It is also underlined the relevance of urban simulation for the general public, as it is often involved in processes of urban renewal that are strictly connected with the social debate in the contemporary city. The need for an interdisciplinary approach is stressed, proposing to conceive the simulations as urban cultural artifacts able to promote social engagement and community well-being.

Keywords Psychology · Subjective experience · Social context

Introduction: A Psychological Contribution for a Multidisciplinary Approach to Urban Design

The general purpose of this chapter is to contribute to the development of an interdisciplinary approach to urban design. This need is well delineated by Romice et al. (2016), who suggest to reframe the concept of city as an element that is

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constitutionally defined both by its spatial features and the social processes occurring in it. These two dimensions should then be conceived as reciprocally influencing each other, with no hierarchical subordination of one to the other. Even though some disciplinary integrations have occurred, looking at the correlation between space and social dynamics or at the contribution given by powerful mathematical models, the role of social sciences remains restricted mainly to research and only occasionally included in the actual design process. This condition is well observed both in the research field, where terminology obstacles prevent scholars from reaching effective disciplinary exchange, and in practice, where consequently just a superficial awareness of the topic is spread. An example is represented by the concept of well-being, described mainly in terms of comfort by designers (e.g. temperature, light, sound) and conceived by psychologists as a multidimensional notion that can be at least separated in its hedonic and eudemonic components (e.g. satisfaction and self-realization) (Ryan and Deci 2001); such reciprocal difficulties in the use of lexicon certainly does not favor the spread of an informed vision among practitioners.

More specifically, the first goal of this chapter is to delineate the role that simulation can have for urban design, as reinforcement of the connection between physical and psychosocial aspects. Indeed, in our perspective the experiential simulation of environments is the activity where the natural encounter between social scientists and designers can most fruitfully take place. Urban design, if interested in projecting spaces enhancing human quality of life, is expected to devote more attention to the inhabitants' scale (Romice et al. ibid.), which implies an increased sensitivity to human experience. In this transition we see the main connection with psychology, especially referring to studies exploring the components of well-being. In fact in the last years different branches of psychology faced a renewed interest for the positive features promoting optimal development of individuals and communities (Seligman and Csikszentmihalyi 2000); even if it cannot be defined as a scientific paradigm shift, considering the important dissimilarities observed in the theoretical and methodological approaches, it certainly gave more prominence to the study of subjective experience and its relation with other dimensions, including environmental and social aspects.

The second goal of the overview of psychological theories, presented in the following paragraphs, is to increase the awareness of designers about the implicit use they make of psychological concepts. As the core competence of architects is to design spaces for people, they develop strong skills in analyzing and reproducing the environmental elements necessary to realize the physical transformation. Yet, since the human component cannot be neglected in the process, they rely on implicit assumptions about human functioning that only occasionally are formalized, and which appear diluted in design theories, even when they represent actual models describing a human-environment relationship (Hanson 2000).

In the second part of the chapter we discuss the common scenario occurring when the psychosocial aspects are taken for granted without an explicit reflection on the psychological model. In fact, within the wide spectrum of the discipline, design sciences mainly derive the psychological approach to the perception of space and its qualities from a cognitive and rational perspective. For this reason, they assume that the individual can be described as a processor of information received from the outer world, who analyzes its components and formulates a judgement based on utilitarian goals and aesthetic elements, which are supposed to be universal and culturally invariant; even more, in some cases the human being is conceived as automatically driven to perform a behavior by external stimuli that function as activators. Namely, in such perspective, the needs for understanding, orientation and territorial defense steer individual preferences.

In the third part of the chapter we show how this view neglects three elements equally present in the psychological literature. First, everyday life can be interpreted not as a context to be analyzed separately, but rather as a subjective experience, in which there is no separation between momentary cognition and bodily presence in the socio-physical environment where it is generated. Second, such experience is characterized by being a unity (gestalt, atmosphere) which cannot be described referring to specific or isolated aspects, but rather depending on their temporary relations. Third, the wholeness of the experience includes the social relations and the public discourse, rather than resulting from a purely individual perception of space. From this point of view, urban simulation processes, designed to collect impressions and suggestions by citizens, should take into account the complexity and inseparability of the relationship among person, society and environment. This implies to analyze the user experience focusing on theories like sense of presence (Ijsselsteijn and Riva 2003) and flow of consciousness (Csikszentmihalyi 1975/2000), which are related to the quality of the simulation and the features of the environment. This approach also leads to devote more attention to systemic features of spatial experience.

In the fourth part of the chapter we finally explore those aspects regarding social interactions, considering how they affect the individual and collective relation with the urban environment. The level of investigation in this case is no more exclusively focused on individuals, but on communities as a whole. We argue that theories developed in this domain should be taken into account not only to assess specific aspects of a simulation, but also to manage the whole process that includes the simulation itself. The main aim is to emphasize the value of this process as a way to engage people in taking care of their spaces and communities, that is a meaningful qualitative improvement of civic participation. Then it is not only a technical issue regarding those directly involved in urban simulation, but also the wider spectrum of public and private social actors who benefit from it.

Human/Environment Interaction: The Behaviorist/Cognitive Perspectives in Psychology

Man-environment transactions are a privileged subject for both the design sciences and the psychological ones. It can be said that these disciplines are two sides of a same coin, as they look at a unique phenomenon, the person in environment, from two different perspectives. Since the late 50s the two research traditions have been progressively contaminating each other, creating hybrid disciplines such as architectural and environmental psychology. This process entailed a gradual transition, from psychology to design and urban simulation, of the mainstream frameworks that were used to model the relationship between man and environment. In this regard, two reviews (Altman 1973; Altman and Rogoff 1987) underline the existence of four general models across the psychological literature on environment: (i) mechanistic, (ii) behaviorist, (iii) cognitivist, (iv) systemic (ecological/transactional). In a parallel way both disciplines have aligned in interpreting such frameworks, postulating holistic approaches but conducting their researches as if environment and man, and their wholeness, could be disassembled in a huge number of atomistic variables that influence or are influenced by other elements, to be observed separately. In other words, the mainstream approaches claim to be inspired by ecological models, rejecting the linear causality in favor of a multifactorial interpretation able to take into account the dynamic complexity of the real contexts. Nevertheless, in practice they tend to use as daily research tools measures of discrete and separate physical or psychological variables, denying the holism assumed as the theoretical foundation for their research. For example, simplified indicators are often used both to measure complex psychological states (e.g. blood pressure as representative of a stressful experience) and to epitomize environmental qualities (e.g. light intensity, number of trees).

Such a way of thinking is criticized by Bonnes and Secchiaroli (1992) as they state that this field shows a divergence between its theoretical intent, oriented in a psychosocial sense, and research practice, basically oriented rather in a molecular way. Taking as reference Altman's taxonomy (1973) described above, we can say that there has been a tendency to evoke systemic models on the theoretical level, except then applying mechanistic models in practice, whether they were behaviorist or cognitivist. These two facets of dominant models show fundamental analogies and some significant differences. The behaviorist approach is supported by a fairly stable form of environmental determinism, assuming the existence of variables that affect the individual from the outside and invariably produce the same physiological, behavioral, or perceptual/evaluative reactions, in a context-driven framework called stimulus-response (S-R). This can be considered the oldest form of models describing the human-environment relationship in psychology, in which a mechanistic linear causality model is applied to human behavior. In the cognitivist approach, a perspective that remains individualistic and mechanistic but introduces a circular information-processing system, external stimuli are supposed to be analyzed through schemes and cognitive maps. The analysis then produces a behavioral output consistent with the cognitive categories and the personal history of the subject. So this is a schema-driven vision, focused on the study of the human information processing, namely the human capacity to cope with an external environmental stimulus or set of stimuli (Stimulus-Organism-Response, S-O-R framework). In this vision, human beings provide a rational analysis of the perceived environment, relying on utilitarian goals and/or on a limited number of environmental features with an "universalistic taste".

It seems possible to hypothesize that, in addition to an objective need for simplification, there are two concomitant causes for the central role gained by these models in design sciences. Firstly, it could depend on the traditional structure of the scientific method, which is based on the manipulation of the independent variables measuring its effect on human behavior, and is thus defined around discrete, atomistic variables, separated one from the others. Secondly, it is noteworthy that the historical period when the integration between the two disciplines started was also marked by the affirmation of cognitivism as the mainstream paradigm in psychology. Probably, design and urban simulation have been then mainly influenced by cognitive psychology rather than from other theoretical trends. The pervasiveness of these orientations contributed to make them "immanent", as they are automatically adopted without a conscious reflection on implied weaknesses. Far from being neutral, the chosen human-environment interaction model influences any further development, severely impacting on the practical aspects of research. From the definition of a reference model derives in fact the operationalization process, i.e. the translation of abstract concepts such as behavior, environment, well-being in concrete variables and indicators to be measured and analyzed. That immanence emerged to the detriment of other less known theories which could show a wider heuristic power in building innovative models about the man-environment transactions. In the next section, they will be explored as responses to the main critiques addressed to behaviorist and cognitive models, and their use as new research tools in urban simulation will be suggested.

Human/Environment Interaction: Towards a Holistic Perspective

With respect to the popular visions described above, three significant criticisms may be advanced (for a more comprehensive discussion, see Rainisio et al. 2014). First of all, the normal condition of everyday life is not a rational analysis of the context, but a continuous experience, in which is impossible to separate subjective cognition and bodily presence from the socio-physical context by which they occur. As noticed by Ittelson (1973): "*One cannot be a subject of an environment, one can only be a participant. The very distinction between self and object breaks down: the environment surrounds, enfolds, engulfs, and no thing and no one can be isolated and identified as standing outside of, and apart from, it*" (pp. 12–13). Secondly, such a continuous experience is subjectively perceived as a whole (a *gestalt*, and regarding the urban space, an a*mbiance*) not reducible to particular/isolated stimuli/spatial objects, but rather dependent on their momentary relations. Furthermore, this gestaltic experience is a result of the social and public discourse too, hence more than the outcome of a purely individual perception of space.

A qualitative urban simulation process, designed to collect impressions and suggestions from the citizens, then should take into consideration some contributions from psychological theories that have not been adequately considered so far in this field, as they are based on a different conceptualization of the human-environment relationship, founded on the unifying concept of *experience*. This research paradigm characterizes in fact part of psychological research since its origins, focusing its attention on subjective experience seen as a totality and on the inseparable nature of the person-environment dyad, thus rejecting every type of mechanistic reductionism. We could define such an approach as phenomenological, and select among its most recent contributions two concepts that might be a useful support for the design process: *presence* and *flow of consciousness*.

The concept of *presence* was defined by Lombard and Ditton (1997) as a "*perceptual illusion of non-mediation*", which is a basic condition to allow a subject to interact realistically with an environment through the mediation of a virtual reality support. It was born within the studies on the user experience with telecommunications and videogames, which consider immersive experience in virtual scenarios one of its central research topics. A causal correlation between a high level of perceived immersivity in a virtual environment and its perceived realism has been proven in this research area, and a high perceived value of immersivity is then considered conducive to the involvement in the game and to the pleasure of the game itself. As summarized by Ijsselsteijn and Riva (2003, p. 3), presence is neither a reaction neither a response, but a gestaltic experience grounded in the phenomenological *here and now, and* "*there is consensus that the experience of presence is a complex, multidimensional perception, formed through an interplay of raw (multi-) sensory data and various cognitive processes*". Although being not feasible to completely eliminate the *mediation bias*, namely the distortion forcedly introduced by the mere presence of any kind of medium, it is in any case useful when using a virtual environment to measure the "*presence*" variable, in order to understand how this is related to some features of the medium and to what extent it is instead connected with the environmental assessment eventually requested to the users.

Moreover, in a broader vision that goes beyond the media field, the presence (called *inner presence*) is a system of continuous monitoring of individual activity operating in two ways: "*first, presence 'locates' the Self in an external physical and/or cultural space: the Self is 'present' in a space if he/she can act in it. Second, presence provides feedback to the Self about the status of its activity: the Self perceives the variations in presence and tunes its activity accordingly*" (Riva et al. 2011, p. 3). This means that presence is connected with human well-being, because a greater sense of presence corresponds to a feeling of optimal functioning of the person in a given environment, whereas the opposite perception (a lower sense of presence) is conducive to a breakdown and a behavioral re-orientation.

The possibility of measuring this optimal experience in its entirety is given by another construct that have received wide consideration in psychology, called *optimal experience* or *flow* (Csikszentmihalyi 1975/2000). Flow is described as a condition of engagement and enjoyment lived by people while performing challenging tasks. When the task is performed well and naturally, the individual experiences a feeling of involvement that merges concentration with action, resulting in a smooth execution "flowing" spontaneously. It is considered an *optimal experience*, because *in such complex state cognitive, affective and* *motivational processes interact in an ordered way eliciting a positive sensation and hence becoming intrinsically rewarding*. The flow of consciousness can be experienced only when individuals perceive the environmental challenge as highly demanding and at the same time feel they can cope with it. Since the first studies Csikszentmihalyi have described different components to be included in the definition (Csikszentmihalyi and Csikszentmihalyi 1988): challenge-skill balance (subjective perception of competence in the situation); action-awareness merging (actions are done spontaneously without effort also when including complex tasks); clear goals (to identify specific route of action); unambiguous feedback (regular monitoring of how well one is going); concentration on the task at hand (ignoring thoughts and environmental inputs not related with the performance itself); sense of control (it transmits a feeling of mastery and self-confidence); loss of self-consciousness (oneness with the environment that leaves no space for others' evaluation); transformation of time (it seems to speed up or to slow down); autotelic experience (the reward is the positive feeling itself, that is the ultimate aim of the activity: it is intrinsically motivated). The flow experience cannot be consciously controlled: it is not possible for individuals to make it voluntarily arise at any given time. Researchers though identified individual (Csikszentmihalyi 1997; Csikszentmihalyi et al. 1993) and socio-cultural characteristics (Delle Fave et al. 2011) that can affect the insurgence of flow, increasing its frequency, the quality of the experience and the activities from which it originates. Empirical studies have focused largely on positive effects that flow has on performance in a variety of domains such as education (Shernoff and Csikszentmihalyi 2009), work (Wright et al. 2007) or sport (Jackson and Csikszentmihalyi 1999). This dynamic is considered the driving force generating the phenomenon defined as *psychological selection* (Csikszentmihalyi and Massimini 1985), the process that accounts how choosing on a daily basis the activities source of flow we build the cultural environment and our personal *life theme* (Csikszentmihalyi and Beattie 1979; Inghilleri 1999). It is in fact assumed that flow is an active incubator of socio-cultural dynamics through the ongoing selection of simple and complex artifacts (e.g. objects, concepts, places) and their dissemination across the life contexts.

In summary, it is possible to suggest a new interdisciplinary holistic approach for guiding urban design and simulation towards the delivery of a comprehensive strong methodology grounded on the human/environment relationship. This framework emphasizes the existence of an *entity*, namely the *person-in-environment*, that does not receive stimulations from another separate entity, but that is instead an inseparable part of the whole; thus, it is not affected by single stimuli but is rather involved in an ongoing and totalizing experience of *being in place*. In this sense the *person-in-environment* is not passive, but rather actively builds the conditions to improve its individual and social wellness. As presence and flow have been found to be connected to optimal cognitive functioning, positive emotions and well-being in general, they can become operational indicators of a wider experience of space, describing more accurately the spatial-socio-cultural dynamics of everyday life; hence, the proposed approach does not fragment the *person-in-environment* entity in a myriad of single stimuli disconnected between one another.

Moreover, we are not proposing to rely on a purely abstract framework, since in both cases several measuring tools have been developed over time able to ensure an adequate operationalization of the two concepts, making them suitable and fruitful for applied research too. With regard to the presence, we can indicate as useful tools two questionnaires validated in the international literature: the UCL Presence Questionnaire (Slater et al. 1994) and the Independent Television Company Sense of Presence Inventory (ITC-SOPI; Lessiter, et al. 2001). Also flow could be measured using several quantitative instruments, including the Experience Sampling Method (ESM, Csikszentmihalyi and Larson 1987), the Flow Questionnaire (Csikszentmihalyi and Csikszentmihalyi 1988) and the Flow State Scale (Jackson and Marsh 1996), just to mention the most widespread. These tools may be supportive for architects and planners decision making in some crucial phases of their work. Through the support of the environmental simulation, a quick assessment could be conducted during any step of the design process to find out whether places/buildings currently under design are able to elicit a flow experience in a chosen audience, or which intensity in the sense of presence can be generated by a given virtual environment. The collected values can be correlated then with different design versions, to understand which design elements can be varied to generate optimal experiences in people. Moreover, these tools can be used by the public authority to define richer design guidelines, or to choose between different projects in an open competition. As discussed in the following section, these tools would also appear relevant for the broader social context, given the importance of environmental simulations as objects of social interaction and debate on a local scale.

Human/Environment Interaction: The Perspective of Community

The theoretical and methodological contributions summarized so far investigate the relationship between people and environment exclusively or principally at the individual level. However, taking into account the contribution that can be offered by the psychological field to urban design, we cannot neglect the branches more focused on social dynamics and on their influence on such relationship. In our attempt to depict a broader framework for the kind of interventions developed by urban designers, we are stressing the consequences that their work has on people living in the environment, who can be conceived both as individuals and as communities. Referring to this specific aspect, we are assuming that communities cannot be simply described as a collection of individuals, but instead represent a level of investigation that requires particular constructs and tools in order to be portrayed (Kitayama et al. 1997; Zimmerman 1990). This means that, as for the transition from a merely cognitive and perceptive level to a more experiential one, a theoretical shift should be considered in order to tackle group interactions. To do this, it is important to identify the proper conceptual background and consistent methodologies.

As we have already discussed previously, flow is a construct that opens the way to the description of social and cultural experience, building a direct connection between the intrapsychic world of the individual and the physical and social environment in which s/he lives (Boffi et al. 2016). Then, if we consider urban environments, where transformations are planned and take place, as complex systems of socio-cultural artifacts which are the precipitate of symbolic and affective meanings, we cannot ignore the people who give origin to those meanings.

Moving a step further in that direction, we consider in this paragraph some of the concepts developed by social psychology that can fruitfully integrate the perspective of designers. Our goal is to sketch out the kind of contents that we consider generally underrepresented in urban design processes. In particular, we are mainly interested in clarifying two levels of disciplinary contribution. On the one hand, some constructs can be directly included when assessing the features of places most probably related to psychosocial aspects. On the other hand, the wider psychological approach to group dynamics, especially when regarding the interaction between citizens and institutions, can be considered as the general framework to manage the whole process of participatory design.

The first level, likewise contents presented in previous paragraphs, is mainly focused on psychological notions useful to interpret the physical and social environment. In fact there are some specific constructs developed in the field of social psychology that could be included in the process of evaluation, both of existing conditions and simulations of planned changes; such constructs would allow to inform designers about social consequences of their projects, helping them in anticipating some features of their projects not directly inferable through their own technical skills.

Sense of community is recognized in the literature as one of the most fruitful constructs describing factors promoting positive communities (see Talò et al. 2014 for a review). It was first defined by Sarason (1974), and then described by McMillan and Chavis (1986) as formed by four distinct elements. *Membership* regards the sense of belonging to and identification with a given group, which implies the exclusion of those who are considered out of the boundaries; this element is connected with emotional safety, the sharing of a symbolic system and a sense of personal investment. *Influence* includes the bidirectional relationship involving the individual and the community, hence describing the perception of both the opportunity a member has to exert an impact on the others and the role that the group plays in affecting individual decisions. *Integration and fulfillment of needs* describes the positive effects that being a member of a community produces on individuals, satisfying needs that would not be answered otherwise. *Shared emotional connection* covers the relevance of positive interactions reinforced through important events and opportunities, which results in stronger social bonds. Such construct, although over the years has been modified with reference to specific populations and measured with an array of instruments, is widely recognized as a positive factor influencing individuals and communities, playing a role in promoting well-being (Francis et al. 2012). Among the measures used to assess it, the most widespread in the literature is the Sense of Community Index (SCI; Perkins et al. 1990), applied to different populations under examination. Notwithstanding the difficulties of translating these theoretical concepts and their assessment directly into operational recommendation, findings suggest to increase sense of community by facilitating interaction among neighbors and their long term stability in the area (Farrell et al. 2004), or by offering public open spaces and shops in residential areas (Francis et al. ibid.). Interestingly the construct is positively associated with other measures, like sense of safety (Zani et al. 2001) and place attachment (Long and Perkins 2003). The latter is particularly profitable for the purposes of the present chapter.

Place attachment is a set of place-based bonds existing between individuals and the environments important for them. It can be conceived as a multidimensional construct, including three main dimensions (Scannell and Gifford 2010). *Person*, describing the actor of the attachment that can be both individual and collective; even if these aspects can overlap, it is useful to emphasize distinct features referring for example to personal memories and shared historical events, respectively. *Psychological process* concerns the dynamics taking place in the formation and maintenance of place attachment, which are mainly organized around three kind of components: affective, cognitive and behavioral. *Place* represents the object of attachment, that is inherently physical and social; the first aspect is studied at different geographic scales (e.g. room, house, neighborhood, city) or in various typologies of environments (e.g. built, natural), whereas the second is explored by a bulk of literature describing the connections with other psychosocial constructs. Among these, it is relevant to consider its association with well-being (Brown et al. 2003) and the general positive aspects it implies, that can affect also the behavioral dimension encouraging people to maintain closeness to meaningful places (Giuliani 2003). According to Fullilove (1996) familiarity with an environment is an essential cognitive component of place attachment: in our perspective if experiential simulation of a place enhances the knowledge and the organization of its components, it can serve as an indirect instrument to increase place attachment. In a broader perspective, Manzo and Perkins (2006) suggest that acquiring information about place attachment of different groups in a community can help in developing more successful strategies of land use, resulting in higher consensus of the population. A questionnaire developed by Hidalgo and Hernandez (2001) explores the construct including social and physical dimensions at three different levels (house, neighborhood and city).

The findings illustrated so far, like those deriving from social sciences in general, require caution in generalizing the relations among variables and even more in applying them on the field. As claimed by scholars, even if it is possible to depict some general trends, assessments regarding particular populations (e.g. adults, adolescents, immigrants, wealthy people) or specific places (e.g. metropolitan areas, small towns, green spaces) can significantly vary the results (Long and Perkins 2003; Zani et al. 2001). The phenomenon is even more pronounced when combining these factors among them. For this reason, relying on literature when designing a specific urban area can offer some general insights, to be complemented with in situ evaluations in order to better tackle the overwhelming complexity of the real context. The role of experiential simulations in building this specific added value is discussed in the following part of the paragraph.

The second level of contribution of social psychology is represented by a shift from theoretical and methodological knowledge to the application of such knowledge to the management of the process. So far we have considered the kind of information that can help designers in directly assessing the advancements of their work. But in an interdisciplinary perspective the whole process of designing an urban transformation, simulating it, and communicating it to citizens in order to obtain a feedback cannot be handled by designers alone. We imagine such a process as a cooperation among different competencies, for a series of good reasons. In fact, proposing the citizens a simulation of future changes of the spaces where they live, work, spend their free time and in sum build their lives cannot be considered a neutral action: in doing so one not only collects information and feedback from them, but also actively changes the social field by creating expectations, stimulating the formation of new groups (e.g. those directly interested by the project, those resisting to the transformation), inserting a new topic in the public debate. Underestimating such aspects would lead to a great misconception of the social consequences of this activity, which indeed is not simply a collection of information from passive individuals but instead a call to engagement to active citizens. This topic may appear less important for designers at first sight, as it is not directly informing them on the qualities of their projects. Yet, the effectiveness in governing the entire procedure of involvement is key to make simulation be perceived as an informing tool for decision making, and not as an appealing toy for institutions or private actors to cheat citizens. This aspect is particularly crucial, considering the decrease of trust in institutions that is observed in many countries, including the United States (Dalton 2005) and the European Union (Braun 2012). As shown in literature, the lack of trust can be considered either a general obstacle to the development of active citizenship (Uslaner and Brown 2005), or a catalyzer for it but promoting forms of participation alternative to the institutional ones activated by those seeking an interaction with citizens (Citrin and Luks 2001; Dalton 2002). Then it is fundamental to conceive experiential simulation as part of a deliberative process aimed at involving citizens, and not as a technical tool to inform designers only. As such, it is required to face two different paths that can lead to participation (Stürmer and Simon 2004): the first is linked to social identity, therefore more sensitive to the identification with the group; the second is instead based on personal identity, hence referred to the cost/benefit ratio regarding the effort of participating to the process and the actual results deriving from it. The first path is traditionally followed by those who self-identify as activists (Klar and Kasser 2009), namely people with a high sense of responsibility toward the community as principle driving their choices, who live it not as an imposition: "activism is not merely something which the respondents do, nor even just a part of them. It is them. During their long, accumulated years of engagement, they have come to define themselves through their activism" (Andrews 1991, p. 164). These people are extremely sensitive to the political, ethical and social imperatives that call for a development of participatory practices (Burton 2003). Obviously this general identification is not sufficient to activate and maintain in the course of time the participation of citizens, whereas more meaningful group identification (e.g. inhabitants of a given area in a neighborhood, local associations, parents of kids attending a specific school) can foster the will to directly engage. The second path regards those who are more interested in the concrete outcomes resulting from the process. In this case people are more interested in evaluating the quality of participation, namely the effort required in terms of time and competences to handle the issue at stake, and the benefits deriving from the whole procedure, in order to decide whether to be directly involved and persevere in it. Scholars in the social field include among such benefits not only economic improvements or better services, but also relational rewards like the perception of having more responsive institutions (Finkel 1987) or individual gain in terms of subjective well-being (Stutzer and Frey 2006).

The very nature of experiential simulations we are taking into account, that are applied to real urban environment, defines the boundaries of the consultative arenas they can be included in, that in the first place would be mainly focused on pragmatic issues regarding the qualities of the project. Moreover, considering the amount of effort, in terms of time and economic resources, necessary to build a reliable experiential simulation with current technology, it is plausible to imagine their use in one or few recursive phases with predetermined duration, since the implementation of the changes resulting from the information obtained by citizens would not be sustainable if repeated too many times. Finally, the resources and the technical skills required to develop the simulations suggest that they would be included in processes managed by influential stakeholders, who then would activate ad hoc deliberative settings which would be perceived as controlled and non-spontaneous. In consultations sharing these kind of characteristics, that is (i) focused on single pragmatic issues, (ii) most likely concentrated in a short period and (iii) formally led by public or private institutions, it is more plausible that social identity remains less significant, shaping a situation in which participants are more prone to consider themselves as single individuals (Mannarini et al. 2010). This is not a problem per se, but implies that setting-related variables, like the evaluation of efforts and benefits or the emotional aspect of the experience, acquire even more importance. The weight of these variables is intensified by the fact that in this kind of consultation it is more frequent to observe intermittent attendance at the meetings and pragmatically oriented approaches. To put this in different terms, the kind of participatory processes where experiential simulations can be most effectively included are those where the quality of the tools and procedures is overall crucial to facilitate the inclusion.

We are sketching out the guidelines of a method integrating design phases and decision making process, which is hinged on experiential simulations as pivotal decision support system (Bosselmann 1998; Piga and Morello 2015). The ultimate goal is to provide architects, public institutions and private stakeholders with the most adequate information necessary to manage urban transformation. In order to maximize the possibility to acquire those information, social actors in charge of designing inclusive practices should create positive participatory settings

(Boffi et al. 2014), which can be defined by accessibility (amount of time required and information given to participants), sustainability (relational and emotional experience), transparency (aims of the consultation) and effectiveness (actual consequences of the opinions collected) (Mannarini et al. 2010). Some of the required properties can be directly tackled through experiential simulations. For example, they can facilitate the transmission of information regarding a given space, especially with a population without technical skills in envisioning it; this would also result in time savings. Sustainability is reinforced by the degree of playfulness introduced by the technological tool supporting the simulation, which is a valid help to build a general positive emotion—clearly such effect should be given adequate consideration when using the assessment of the simulated environment to forecast the assessment of the real environment. Finally, it is useful to enhance transparency, making more evident the elements and their related attributes potentially modifiable in the project. As we already highlighted, the use of simulations must be consistent with the whole process which take place before, during and after simulations themselves. The expectations elicited during the initial communication, addressing participants as "beneficiaries", "clients", "users" or "citizens" (Cornwall 2003), define a specific framework that must be in harmony with the activities designed. In a similar way, the complete lack of impact in the real space of the suggestions gathered during the process can severely ruin the reliability both of the proponent and of the methodology.

Conclusions

Our attempt has been to delineate the logic that should drive the creation of a shared ground for urban design. In such perspective designers and planners are seen as professional figures at the intersection of a flow of information, coming from different disciplines. The main point we have tried to stress is that they are not supposed to become experts of other fields, but instead (i) be aware of the competencies available to complement their skills and (ii) recognize the consequences of a theoretical or methodological choice made at any stage of the design process. From a broader perspective we are imagining a cultural shift in the professional domain of architecture and planning which redefines its borders. On the one hand, it requires to expand the area of information collection when designing, giving actively more space to other professionals or to non-professional figures, considering in the first place citizens and users of the spaces. On the other hand, such professional variation implies to loosen these borders, favoring an informed use of other expertise even if not directly involved in the design process. The ultimate goal is not to substitute designers, but to reinforce their capability to transform ideas and principles into spatial features by providing them feedbacks about the development of their work.

From the psychological point of view such feedbacks are mainly focused on subjective experiences. Given the nature of psychosocial variables, it is key to remember that the choice to refer to a specific construct to conduct data gathering and assessment is not a neutral action, as it influences the subsequent representation of the topic under investigation. Indeed, psychological constructs are not directly observable, but rather hypothetical explanatory concepts, often composed by related sub-concepts, which can be measured by means of different tools. Among the most used are focus groups, interviews, questionnaires or validated scales, which can depict the construct itself in a wide range of shades. Unlike physical variables, which remain stable across various tools even if the accuracy of measurement can increase, psychological variables are affected by the epistemology of the tool. In other terms, measuring the length of a building using a professional tape measure or a laser meter can increase the precision of the assessment, but does not change the numerical synthesis of the information obtained and the nature of the length itself. Appraising the capability of a building to favor the sense of community with an interview or with a scale not only can offer qualitative versus quantitative data, but changes the type of phenomenon described, as choosing one tool or the other has deep theoretical implications.

Effectively developing the disciplinary integration described beforehand has important consequences not only in the field of research, but also on education and practice. It implies the recognition that the role of designers is to create the preconditions for flourishing communities, not to prescribe their behaviors, and that a complex interaction among external variables play a crucial role in determining social dynamics in relation with environment. The over professionalization of urban place-making isolated designers from the beneficiaries of their work, and covered any decision with an aura of technicality (Romice et al. 2016), erasing the space for consultation whose recreation is ultimately the main political goal to be addressed.

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Part II
Digital Modelling and Visibility Studies

Chapter 5
Visibility Analysis for Open Spaces in Urban Areas: Coupling Environmental Quality and Human Comfort Assessment

Eugenio Morello

Abstract The spatial configuration of places affects the environmental quality, the human comfort and the practices of space usage. Both domains of urban morphology and perceptual analysis investigate the relationship existing between open spaces and built-up areas from different perspectives. The quantification of visible areas—what scholars call the visibility analysis—represents the first quantitative exploration that can be performed just by referring to the 3-D model of a physical space. In fact, extracting the geometrical features and indicators of visible areas allows to derive some first considerations about the potential experience in terms of human comfort and prediction of usage of that space. This study introduces available visibility analysis tools and measures in design and critically discusses the limitations of a purely quantitative approach. In fact, I argue that integrating the quantitative visibility analysis to the qualitative perceptual analysis of the visible elements (through photography and 3-D modeling) can represent a crucial step towards a more realistic and reliable visual analysis of space.

Keywords Visibility analysis · Human comfort · Urban simulation

The Quantification of Visual Perception: Recent Boost from Scientific Research and Technological Innovation

The evaluation of Urban Environmental Quality (UEQ) and human comfort and well-being of people in the public realm derives from multiple features that define a place. I start with the assumption that the overall evaluation of a place is determined by many factors. For instance, we cannot ignore social and cultural aspects that inform the perception of places through the imagery and prejudice that the perceiver

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brings into the scene every time s/he enters a place; s/he also carries contextual personal physical and mental conditions, and recent or accumulated experiences of visited places, including the reaction to recurrent paths or explorations of the unknown; and many more features affect the understanding and evaluation of places. Inside this giant and hardly controllable physical and mental experience, the visual perception of spaces plays an important role.

This paper discusses the reasons and the technical possibilities we have today for measuring visual perception, starting from the principle that this quantification alone can contribute to better understanding of places and support design. Two main recent arguments have recently revived research and applications of visual studies in architecture and urban design, and are the anchor points for legitimating a renovated interest in the quantification of visual information. Firstly, the advancements of neuroscience research in the last decade have opened new insights about the mechanisms of sensing, perception and cognition in relation to the activation of different areas of the brain, hence giving a more solid ground to perception studies within the domains of environmental psychology and design. Secondly, the technological development of ICT and in particular of visual devices (e.g. Head-mounted-displays) enables today an impressive engagement and empathy to virtual and augmented reality immersive and interactive scenarios, hence advocating for new research in architectural visualization.

Unconsciously and instinctively we measure space. For survival reasons we have to understand where from a potential enemy can attack us, or where we have more chances to reach protection or find useful resources. All these mental processes activate different areas of the brain. Recent neurological theories argue that the visual perception and the consequent motility reaction are highly connected (Gallese and Lakoff 2005). So called mirror neurons are involved in this process and are responsible for the activation of a simulation of movement inducted by visual perception (Gallese and Lakoff 2005). For instance, the perception of a specific item, a tool for example, activates the thought of using it. Similarly, the perception of a space, makes us immediately think about the possibility of entering, crossing or avoiding it. In other words, this is what Donald Appleyard calls the affordances that a place offers us (Appleyard 1977). Hence, the very first form of simulation occurs in our brain, and is always a dynamic experience.

We are still at the very beginning of this cross-fertilization between neuroscience, environmental psychology, architecture and urban studies as reported by Harry Francis Mallgrave in his recent book ‘Architecture and Embodiment’ (Mallgrave 2013). Most of the time, the attention to the visual qualities of space is part of the designer’s education toolkit, as a cultural background of the discipline, which derives from centuries of design theories and mental imagery collected through the history and heritage of architecture and town planning.

If we are becoming more and more aware of the mental processes occurring in our brain during the act of perception, we can then reverse the same processes and use the expected mental mechanisms to inform design and partly predict the perceptual reaction of people to places. In other words, to our sensitivity to design and place making and to our individual and cultural design references, we can juxtapose more scientific tools for anticipating and testing perceptual features of spaces. Of course, this ambitious operation has to take into account all the limitations listed above and be aware of the fact that visual perception is only one aspect beside cultural, societal and individual factors affecting our perception. Nevertheless, entering deeper into the mental processes of cognition is responsibility of the architectural and urban simulation discipline, which cannot rely on the evaluation of photo-realistic images alone.

Moreover, innovation in visualization tools opens up new questions within the disciplines of architectural representation and simulation. It is evident that the availability of novel visualization devices and the rapid increment of computation power requires more and more sophisticated input information. In fact, immersive and dynamic scenarios only work with very detailed and heavy digital representation. Hence, we are getting closer and closer to iper-realistic images to give back future conditions of places; this fact allows for more sophisticated implementations of visualizations (that include motion and sensory aspects, beside more attention to details) and—far more interesting for supporting the thesis of this paper—enables to carry out responsive analysis of people reaction to immersive environments, what we call here visual simulation. In the future, we aim at studying and comparing the reaction to images (which is a subjective and qualitative operation) to quantifiable features of the same simulated environments. This same comparative study can be carried out in a physical setting, i.e. through the recording of the experience in a real environment, but simulation is useful for design purposes if we aim at anticipating the psycho-physiological reaction to an envisioned future condition of space.

Modelling and Measuring Visual Perception for Urban Simulation: The Concept of Isovist

Visibility analysis translates geometrical features of spaces visible from a vantage point into measurable quantities. The basic original unit that initiated the mainstream of visibility studies goes back to M.L. Benedikt's seminal work "To take hold of space: isovists and isovist fields" (1979), when he diffused the concept of isovist to the arena of spatial analysis and architectural research. Isovist is defined as the field of view, available from a specific point of view. The isovist represents a horizontal slice through this field of view taken at eye height and parallel to the ground plane. In its simplest geometrical translation, the isovist is a closed 2-D polygon. Assumptions and limitations for this basic modelling of visual perception into quantifiable metrics are many. Firstly, the isovist does not take into account stereoscopic vision, but is based on a one-eye seeing process. Secondly, the isovist is a 360° panoramic scanning of space from the vantage point, as opposed to a ca. 180° of the human vision field (see Fig. 5.1); in fact, with isovist analysis we refer to direct perception of space (looking around). In a certain sense, the assumption of the panoramic view enables to get rid of the directionality of vision and synthesizes

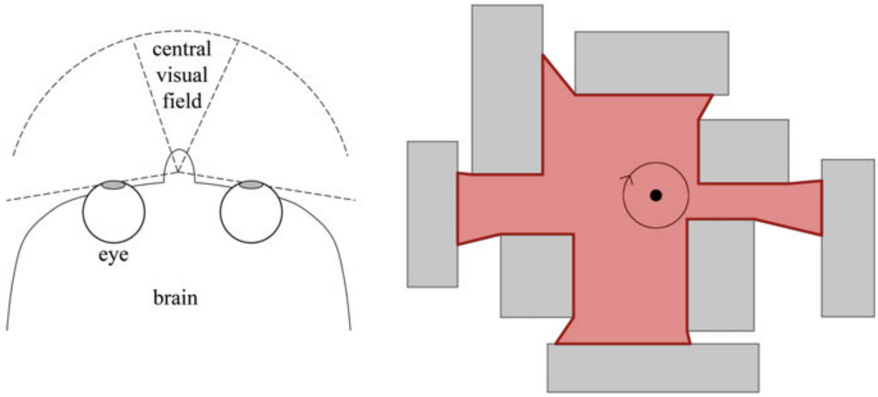

Fig. 5.1 On the *left*, the stereoscopic human view covers about 180° of vision; on the *right*, the 360° offered by the 2-D isovist representation (the *dark gray* closed polygon) is used for visibility analysis (*credits* The author)

all the possible views from that vantage point. Consciously, we are aware about what is located around us, even if we do not grasp all images of the surrounding features at the same time. In other words, the isovist contains a sort of spatial memory acquired during the process of experiencing places.

Isovists can be generated using simple algorithms based on the calculation of lines-of-sight. Lines-of-sight are calculated passing through the vantage point and with circular rotation covering 360°. From the viewpoint, a series of arrays are generated and stop when they find an obstacle, i.e. a solid edge. Once we have determined the polygon of the isovist, numerous indicators can be computed based on its geometry. These indicators represent the translators of the isovists to meaningful applications in architectural and urban design. A list of isovists' features is reported in Table 5.1.

Isovists represent a starting point for the visibility analysis. If we want to add complexity, we have to take into account the dynamicity related to the perceptual experience and the three-dimensionality of space. Hence, we have to introduce the concepts of isovist fields (Benedikt 1979) and 3-D isovists (Morello and Ratti 2009) (see Fig. 5.2 for instance).

Representing a sequence of isovists can already tell something about the potential experience of places. While walking, people can move from a narrow street with well-defined built frontages (also called urban canyon) to a big open space like a park (see Fig. 5.3). This motional view makes the invisible character of openness of space readable.

Isovist fields (Benedikt 1979) are defined as the representation of an isovist feature over a discretized space. In other words, the intensity value of an isovist (for example, the area of the isovist) is computed and reported in all points in space. In so doing, the spatial mapping—and in certain sense, the dynamicity—of the gradients of the isovist features are revealed and are represented through an abstract top view image (see Fig. 5.4).

Table 5.1 Principal isovist features (*credits* by the author, from Morello and Ratti 2009)

Fundamental properties		Elongation properties		Radial variances	
Area of isovist (A)	(m^2)	Compactness	(−)	Entropy	(−)
Perimeter of isovist (P)	(m)	Convexity—cluster index	(−)	Radial standard deviation	(−)
Solid perimeter (Ps)	(m)	Concavity	(−)	Radial variance	(−)
Solid perimeter to perimeter ratio	(−)	Ratio of eigenvalues	(−)	Radial skew	(−)
Occluding perimeter	(m)			Skewness	(−)
Maximal radial distance	(m)				
Minimal radial distance	(m)				
Average radial distance	(m)				

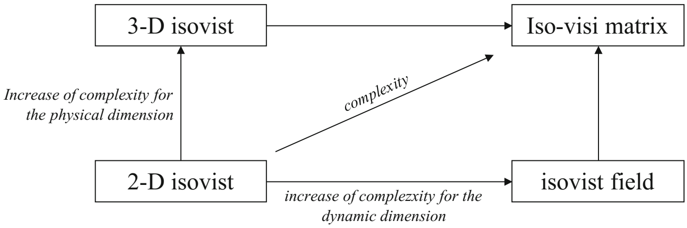

Fig. 5.2 2-D relationships between isovists, isovist fields, 3-D isovists and iso-visibility matrixes (*credits* The author)

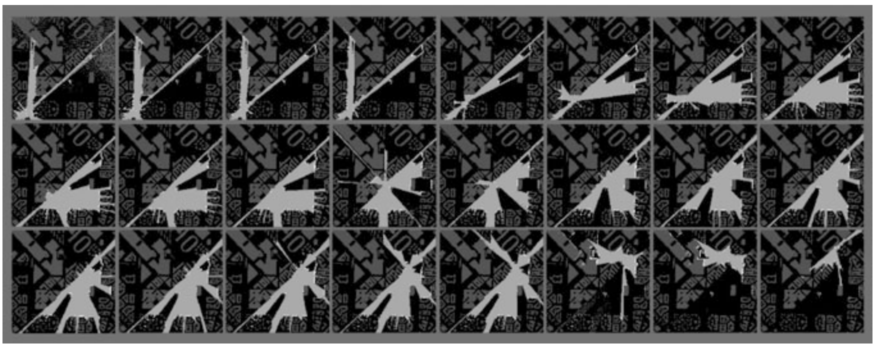

Fig. 5.3 The sequence of isovist configurations (in *gray*) gives back the dynamic change of the visible space along a path, a fundamental feature for visual knowledge (*credits* The author, from Morello and Ratti 2009)

The issue of three-dimensional space is a crucial aspect if we want visibility analysis to get closer to visual perception. Moving from a two-dimensional cut of space to the three-dimensional space, requires abandoning the representation of the

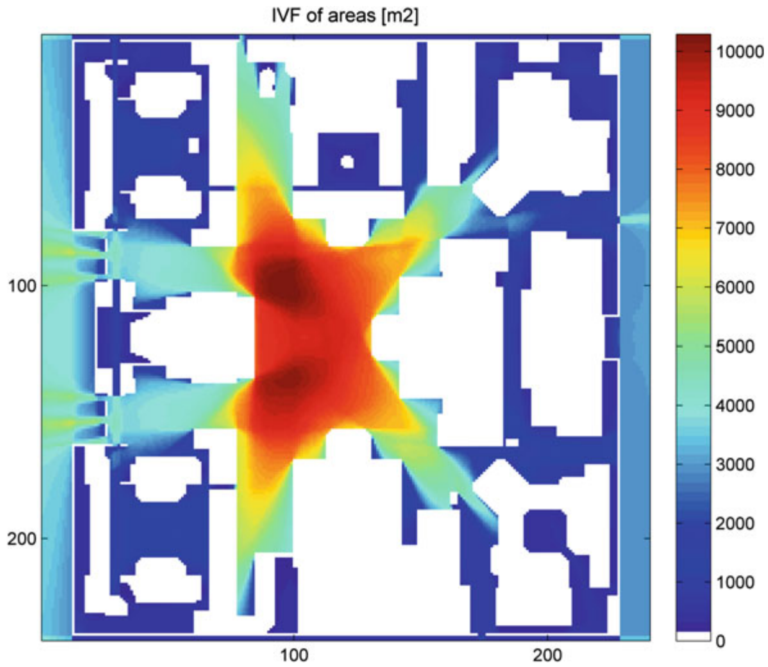

Fig. 5.4 Isovist field representation. The figure shows the trend of the variable "area of the isovist" (m^2) over all points of the open spaces in an urban area, where buildings are represented in white (*credits* Magri 2013)

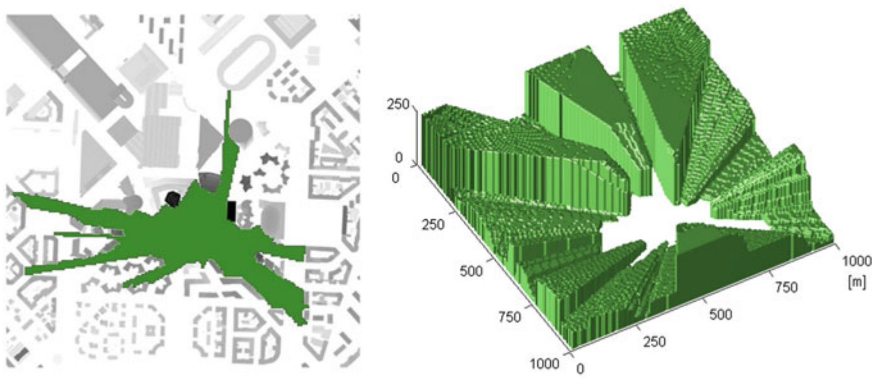

Fig. 5.5 On the *left*, the top view of the digital urban model of the first masterplan of the CityLife redevelopment project in Milan, Italy. On the *right*, the representation of the 3-D isovist computed at the ground from the central open space surrounded by the towers. The shadow cones generated by the towers represent the space excluded from that specific vantage point (*credits* The author)

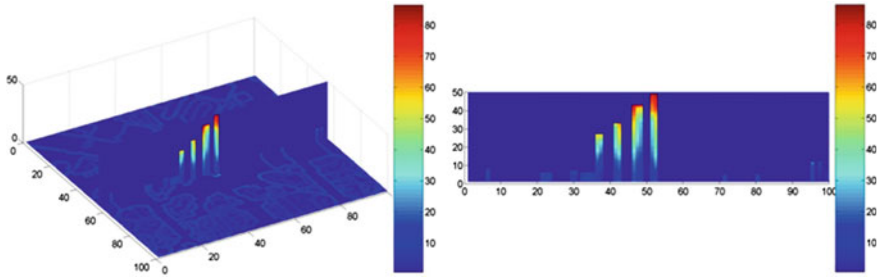

Fig. 5.6 In a 3-D space, the rate of visibility of building facades from all the surrounding open spaces is computed as a percentage value. The most visible surfaces are on the top of the towers, here displayed as a vertical section through the voxel space (*credits* The author, from Morello and Ratti 2009)

isovist as a flat closed polygon. Tracing lines-of-sights in space will generate an envelope of visible surfaces, which separates volumes that are visible from those that are cut from the view. This new shape is called 3-D isovist (see Fig. 5.5) and enables to calculate obstructed volumes and visible surfaces.

Finally, the isovist field approach can be computed over the voxel (i.e. the 3-D pixel) space, generating the 'iso-visibility matrix' (Morello and Ratti 2009). Specifically, intensity values computed on 3-D isovists can be stored on a 3-D grid of voxels. In Fig. 5.6 the values of visibility of each voxel in space are weighted on the considered viewpoints in the open space, i.e. the vantage points on street level.

Visibility Analysis Applications in Urban Design

The interest for designers is related to the potential of using this simplified analysis to suggest expected psychological and physical reactions by people that experience that space. In short, taking into account geometry features of space alone can tell something about expected behavior, comfort and perceived environmental quality of places. For instance, the openness and sense of enclosure, the rhythm of a street landscape along a regular urban canyon or in a scattered built environment, can be quantified through a number of parameters that refer to the shape of the visual field of the observer.

The link between visibility analysis and experiential evaluation of spaces—and in a wider sense to architectural and urban design—has not been fully explored both in research and practice. In fact, on the market we only find few available—and definitely not highly diffused—evaluation and design tools that incorporate visibility analysis in the professional practice. The most popular tools exist at the regional scale for landscape applications. For instance, view-shed analysis tools developed within Geographic Information Systems (GIS) environments are mostly used to assess panoramic viewpoints along touristic routes, or the visual impact of

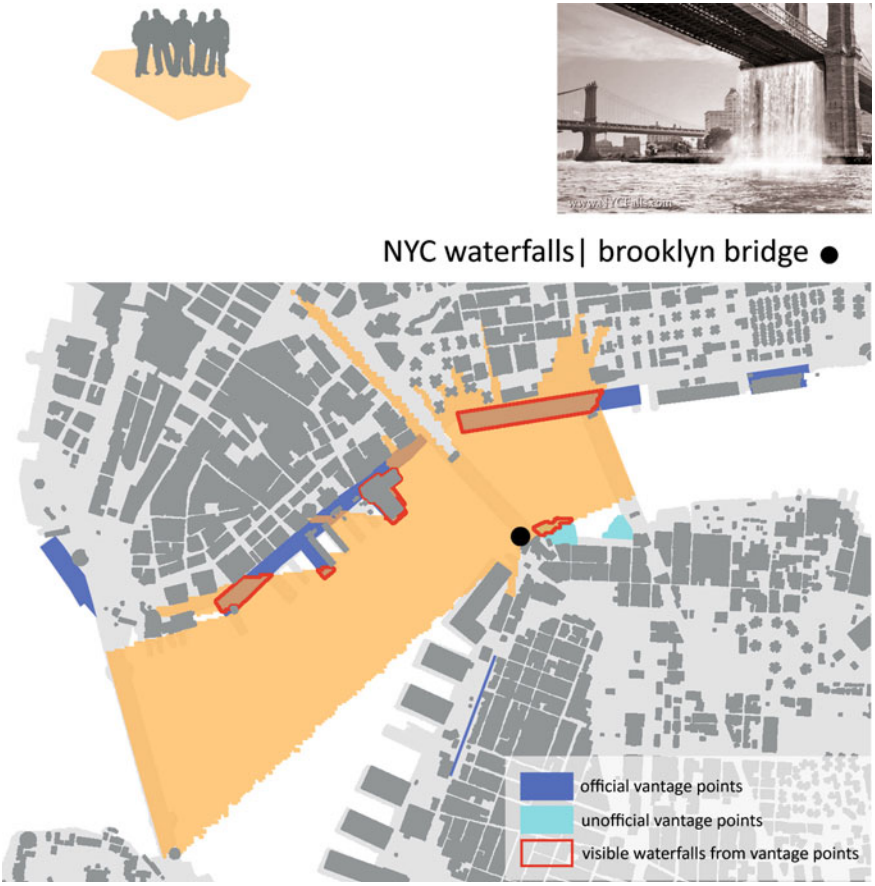

Fig. 5.7 "Where from can I watch the NYC waterfalls?" The computation of simple 2-D isovists was enough to assess the vantage points on the waterfront of The New York City Waterfalls project by Olafur Eliasson in 2008. The City of New York wanted to grasp the number of people visiting the installations diffused over several locations. By catching people at these vantage points it was possible to concentrate advertisement and initiatives (*credits* Study and image by the author, Senseable City Lab, MIT)

objects on landscapes (see Fig. 5.7). Typical examples of application are the environmental assessment of wind turbines and other human-made infrastructure insisting on open areas. These applications derive from compulsory requirements within well-established environmental impact assessment or strategic environmental assessment procedures regulated by norms. Nevertheless, the evaluation of visual impact represents only a small portion of the potential use of the visibility analysis, which, instead, could be efficaciously used for design purposes and especially during the conceptual phase. In other words, the application of visibility analysis for composing and testing design could accompany the creative conception of spaces, thus supporting the sensitivity of the designer with quantitative measures.

In particular, urban design applications for open spaces are the center of attention of this contribution. The above presented measures related to isovists geometrical properties can be used for different purposes. Herewith, I identify two main categories of applicability in design, namely human well-being studies and commercial purposes.

Firstly, in designing open spaces, isovists' measures can predict expected human comfort and psycho-physiological well-being conditions. For instance, the sense of openness, enclosure, continuity and regularity, or fragmentation and disorder of the boundaries of a space (Fig. 5.8) can be given back at a specific location (simple static isovist), along a path (sequence of isovists) or over a large area (isovist field). For sure, the psychological implications of space over large open areas (I refer to streets, parks and urban squares) are less immediate compared to the emotions a closed and narrower interior can generate to the user. We all experienced the impact of architecture on our feelings: A religious temple, a grandiose monument or a tiny cabin can generate attention to our senses because of the proximity to our body and the immersive atmosphere we perceive. Nevertheless, the same happens at a wider scale when we walk through an open space: we can be impressed by the repetitiveness of a peripheral landscape made of copy-and-paste towers, or a terrific monumental path designed to go along with specific procession rules; we can get surprised by the sudden change of the visual landscape when we enter a large square arriving from narrow medieval alleys.

Another aspect related to well-being is the measurement of social distances in space, especially in the urban public realm. In particular, the discipline of *proxemics* refers to "the interrelated observations and theories of man's use of space as a specialized elaboration of culture" (Hall 1966, p. 1). Assessing measures of radial

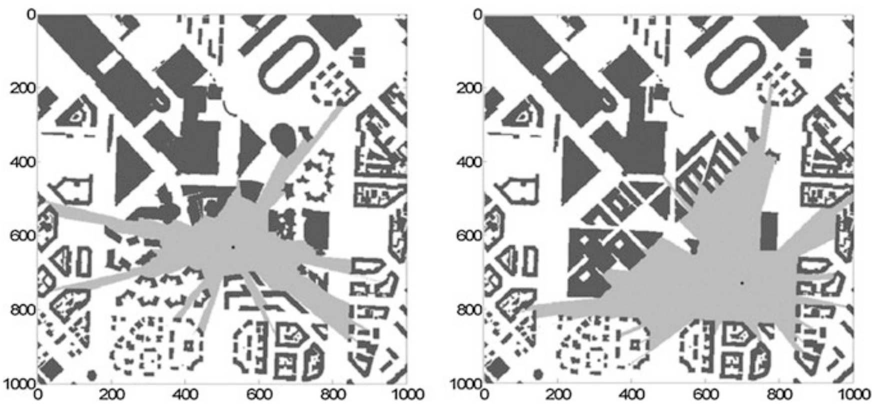

Fig. 5.8 Two design proposals for The Milan Trade Fair redevelopment masterplan: Isovists can help in comparing environmental features of alternative open spaces (*credits* The author, from Morello and Ratti 2009)

Fig. 5.9 The desolation of contemporary large urban squares. Piazza Portello, Milan, Italy. The sizing of the space was not defined on the basis of social distances' principles, but rather on the idea of the monumental plaza for big events (*credits* The author)

distances from vantage points can support the sizing of open spaces. Often people complain about the dimensions of public squares that are perceived as too big, too empty and, consequently, alienating and unfriendly to social interaction (see Fig. 5.9).

On the other side, economic-based applications for visibility analysis respond to the simplest question for commercial purposes, i.e. how much is a specific space visible from the surroundings? How far can it be seen? How far can I look into the landscape from my window? Measuring the extension of panoramic views for real estate investment, establishing the most visible window on a street landscape, the best blind wall in an urban-scape to locate an advertisement or a landmark, are sound examples for marketing and communication in the geo-location business. Moreover, we can increase complexity and take into account the dynamic of perception. For instance, our perception of places changes depending on the speed with which the user approaches that space: retail landscapes can vary from pedestrian commercial streets, to urban car-dependent urban areas and large motorway landscapes where the communication of brands becomes a large scale challenge (see Fig. 5.10).

Fig. 5.10 The communication of shop signs changes according to the speed of the observer. The effort of retailers in catching the attention of people has to take into account the size of the sign, the colors and other effects. From top *left* clockwise: a medieval street in Austria where slow mobility allows to focus on the details of high-quality handmade signs, to a dense Asian retail street where signs enhance colors and size in order to be perceived by cars driving through, to an extreme attempt of whole architectural design (the Kilometro Rosso Technological Park by Jean Nouvel along the A4 motorway near Bergamo, Italy), whereby the building itself becomes the advertisement for the distracted car driver on the motorway (*credits* The author)

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Chapter 6
Motion Perspectives Integration in the Qualification of the Urban Spaces: Towards a 2D- and a 3D-Enrichment of the S-Partition Method

Thomas Leduc, Francis Miguet and Vincent Tourre

Abstract The spatio-cognitive properties of urban surroundings must be taken into account in the design of urban spaces. However, there are few methods and software tools to assess the visual properties and the spatial identity of places, and most of them are based on two-dimensional visibility analysis only and on a static analysis of surroundings. Our proposal aims to provide turnkey solutions that could increase the implementation of urban planning policies concerned with sensitive impacts of urban fabric renewal. The method presented in this chapter enhances the urban space partition proposed by Peponis et al. (Environment and Planning B: Planning and Design 24(5):761–781, 1997) in order to qualify all pedestrian paths in the studied area taking into account the importance of changes in visual surroundings and the vertical landmarks. In our use case, the results of our method applied on two paths are compared with a 3D isovists analysis in order to clearly show the key-points in the path. A software solution has been developed as a plugin of the well-known SketchUp computer-aided architectural design (CAAD) tool to be tested by students in the context of project teaching in School of Architecture.

Keywords Convex partition · Vertical landmark · 3D isovist

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Introduction

The design of urban spaces is a complex activity involving cognitive tasks related to numerous parameters. The projection into a spatial configuration to analyze the perception of surroundings and their influence onto the behavior of inhabitants is a difficult cognitive activity. It is possible to produce realistic urban environments in order to experiment them through numerical simulations (as virtual reality), but generating these realistic environments is a time consuming task with a significant cost. Another approach consists in analyzing the urban space with metrics and indicators, producing maps describing the qualities of spaces.

As these spaces are experimented, in the every-day life, while moving through them, it is necessary in introduce the people movements into the metrics. As we assume to focus on the pedestrian movement in this work, we have to qualify all the possible paths a pedestrian could walk along to go from one location to another. Therefore, we propose a method to map the visual perception of urban morphology in order to analyze any of the potential paths into a predefined urban area. This perception of urban morphology is measured with tools based on visual appreciation. This method is synthetic, transposable and systemic in order to be applied on all urban areas. The mapping of the pedestrian visual perception is intended to identify and analyze the ambience potential which belongs to all the pathways, allowing the method to be independent of any given path beforehand.

Various methods to analyze open spaces or indoor spaces have already been developed in the state of the art. This includes, among others, the axial lines and axial maps of the space syntax from Hillier and Hanson (1984), the isovist fields developed by Benedikt (1979), Batty (2001), Lonergan and Hedley (2016), sky views and spherical analysis developed in particular by Teller (2003), the visibility graphs of Turner et al. (2001), and the convex partitioning of spaces such as the one proposed by Hillier and Hanson (1984), Hillier (1996), Peponis et al. (1997).

The latter method (Peponis et al. 1997) proposes a partition of indoor spaces based on building shape, each facade is prolonged by a line until it finds another building blocking it: the s-line. Therefore, according to (ibid.), "*Each time such an observer crosses an s-line, an entire surface either appears into the visual field or disappears outside it. For any two different s-spaces, there is at least one wall surface which is entirely visible from one but not from the other*". Based on the principle that "*surfaces and parts of surfaces may appear or disappear without crossing an s-line*" (ibid.), the same authors propose also another space partition linking "*extendible diagonals*" (ibid.): the e-line. In this approach, the urban space is partitioned into a set of partition (s-partition or e-partition). "*The e-partition represents a layout in terms of constituent convex spaces that are stable with respect to visual information*" (Peponis and Bellal 2010).

This is an efficient approach that can be computed easily but the analysis of the partitions is difficult, especially into old city centers, due to the combinatorial dimension (and its explosive growth!) of demarcation lines and convex spaces. The main interest of these partition-based methods is their intrinsic characteristic and their attempts to capture the structure of the involved architectural space through a dedicated discretization. Thus, they only rely on pure geometrical aspects of the urban fabric surroundings. The annoying counterpart of this intrinsic property is that these partition-based methods of urban spaces do not take into account the true visual perception of a moving pedestrian.

To overcome this drawback and to delineate iteratively the surroundings of a moving pedestrian (using the visual-based perceptive approach), another effective possibility consists in assessing the isovists field proposed by Benedikt (1979). Whereas an isovist is the polygonal set of horizontal points in space that are visible from a given vantage point (up to the closest opaque facades surrounding the view point), the isovists field consists in some sort of scalar field which gives the ability to map the numerical (visual) properties in each vantage point. As noticed by Peponis et al. (1997), "*One implication of this is that isovist analysis, although easily applicable if we have reason to select some particular viewing points, cannot readily be automated or proceduralized to deal with an entire plan. It is always necessary to devise ways for sampling the set of points from which we will draw the isovist.*" Moreover, contrary to the convex partition approach, the parameters extracted from isovists do not clearly show the visual events that affects the visual perception. Therefore, the arising question can be set as: How to compute partitions in outdoor urban spaces showing homogeneous areas with the same visual elements, and how to highlight the importance of the visual events?

In order to map the ambience potential of urban open spaces, two different alternatives can be considered. The continuous approach, commonly referred as the field-oriented open space analysis, consists in the spatial representation of any visual property [such as the surface of the corresponding isovist, or its perimeter as proposed by Benedikt (1979)] in each sampling position. Although precise and efficient, this field-oriented method does not exhibit easily the transitions between portions of space in terms of visual events. Indeed, in this conception of space, the void in between buildings is viewed as some continuous substrate (such as a "magnetic field") with fuzzy boundaries, and where sometimes some sub-portions of space overlap.

Conversely, in the discrete approach (such as the convex partitioning already mentioned), space is potentially dividable into identifiable partitions, defined a priori by clear and stable spatial limits. This approach provides the advantage to organize open space as a tessellation of discrete entities, which we can handle directly.

Our proposal is to extend the discrete approach [and more precisely the s-partition method proposed by Peponis et al. (1997)] so as to enhance it to handle urban open spaces in a more efficient way. This twofold adaptation consists in an integration of 3D saliences, and in a weighting of visual transitions clues according to the distances to corresponding generators.

Outdoor Convex Partitions

Our hypothesis is the following: by enhancing the convex partition method of Peponis et al. (1997) with a valuation of s-lines and the adding of vertical landmarks, we can produce areas with homogeneous visual elements, and we can quantify the importance of the transition between two s-partitions. We compute these partitions relying on an analytic approach based exclusively on the geometric shape of the buildings. The s-line shows a changing configuration of boundaries within the visual field, a visual event which is a discrete change in visual surroundings (ibid.): the appearance or disappearance of a façade in the field of view of the moving pedestrian produces the s-line. By weighting the s-lines and adding the v-lines (vertical lines), we can assess the difference between two isovists in two different partitions.

In space convex partitioning approach, the s-partition method splits the urban space by prolonging the facades footprints until encountering another facade that stop the cut. The space is then partitioned into several areas that share the same facades (visual obstacles) in their field of view. Crossing an s-line by moving from one s-partition to another (contiguous), means having one facade added or removed from the field of view. This move thus involves a visual event by the appearance or disappearance of the facade. But the difference between two s-partitions are sometimes very slight because the visual event is quite unimportant, the facade producing the crossed s-line could be very far and/or very small. Therefore, the full set of s-partition exhibits all the visual events without any contrast. Moreover, the standard s-partition method is computed in 2D space, and does not take into account the height of buildings. Therefore, some visual events caused by vertical landmarks or high buildings are not represented. Computing several 3D isovists on one s-partition clearly shows that these isovists could have a very different shape.

Our approach proposes two enhancements of the s-partition method: (1) we weight the s-line according to the distance to the corresponding facade (i.e. the facade that generates the given s-line), (2) we introduce the v-lines in the partition to take into account vertical landmarks. The benefits of these improvements are to qualify any given pathway and to quantify the importance of the changes of the visual events.

Implementation

The implementation of the outdoor convex partition method is achieved by weighting the s-line of the convex partition method and by introducing v-line. This section details the full process: (i) data preprocessing; (ii) building footprint generalization; (iii) S-line generation; (iv) V-line generation; (v) partitioning; (vi) S-line and v-line weighting; (vii) path definition and analysis.

Data Preprocessing

The spatial datasets we use are the ones provided by the IGN, the national French institute in charge of the management and updating of geodesic and leveling networks, aerial photographs, and geospatial data. The aforementioned datasets are part of the Large Scale Reference database (RGE®), a standardized and precise description of the French territory and the country's land use, and more precisely of its BD TOPO® 3D component, a 3D vector models of significant spatial features such as footprints of individual buildings, transport network, forest cover, etc. The needed pre-processing operations has been made using the Geospatial Data Abstraction Library GDAL/OGR (GDAL 2016). Specifically, the merging of the geospatial data and the clipping of the input data sources to some specified bounding box.

Generalize the Building Footprints

As mentioned before, the aim is here to reduce as much as possible the complexity inherent to any real input dataset. Reducing this complexity while preserving topology means to minimize the number of useless nodes in buildings' exterior rings. This preprocessing consists in several operations such as the removing of the useless inner courtyards, the building footprints generalization using the Douglas Peucker simplifier and a double buffer technique, the removing of the quasi-collinear nodes, etc.

S-Line Generation

The s-line are generated using the standard convex partitioning method developed by Peponis et al. (1997). Each facade is prolonged by a line which divides the space into two partitions: one partition sees the facade while the other not (Fig. 6.1, left).

V-Line Generation

The same idea is used to generate the v-lines, the difference is that the generator is punctual and located on vertical landmark. The v-line can be seen as the border of the conic projection of the building on the ground, its center being the generator point (Fig. 6.1, right). Four punctual generators at various heights are chosen on the vertical landmark (the Bretagne tower in the use-case presented hereafter), in order to generate four sets of v-lines delineating the portions of ground spaces in which

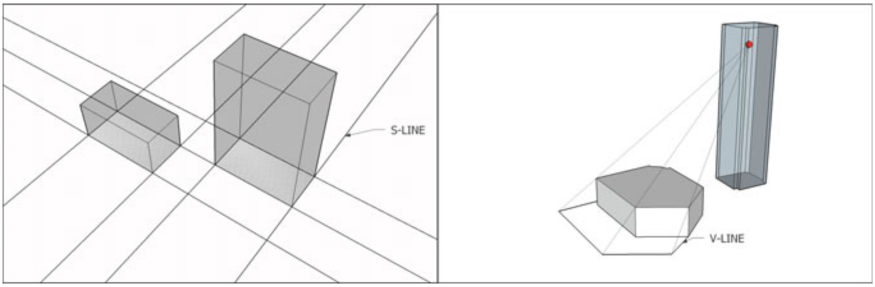

Fig. 6.1 s-lines (*left*) and v-lines (*right*) design drawings. Two different manners to subdivide the ground space in between the buildings

these generators are visible or not. As these punctual generators may be arbitrarily positioned at gradual distances from the top of the vertical landmark, these several v-lines may show either the progressive, either the sudden apparition of the landmark in the field of view of the moving pedestrian.

Partitioning

The s-lines and v-lines are used to define the space partition. In each of the numerous items of this space partition, the visual properties are largely the same (both in terms of vertical saliences' visibility and in terms of breach or continuation of the visibility of surrounding facades).

S-Line and V-Line Scoring

In order to distinguish the numerous items that result from this space partition, we have decided to score the contours according to their relative transition effect in terms of visual appreciation. Therefore, for each s-partition, the segments of s-line contours are weighted according to the distance to the generating facade. In the same token, the various v-lines contours are weighted according to the aforementioned punctual generators (lower is the elevation, greater is the visual impact).

Path Definition and Analysis

To demonstrate the viability of the method (an attempt to qualify a priori the urban fabric), several paths crossing a variety of urban viewscapes are defined. By systematic evaluation of the score of each crossed s- or v-line, a diagram is produced which renders the successive visual appreciations (emergence, vanishing) all along the path.

Use Case

The chosen use case consists in a flat central district, mixing of quite homogeneous urban fabric with organic morphology, with some scattered and massive saliences. The use case area is 213,000 m^2 wide containing 351 buildings footprints in 2D and represented by 4717 nodes. A process in 5 steps allows to simplify the initial BD TOPO® data and then resulting in 62 footprints with 516 nodes in our use case. The Fig. 6.2 shows a subset of 87,000 m^2 containing 36 footprints and 296 nodes: (i) simplification of the detailed footprint of Saint-Nicolas Church in order to reduce the number of generated s-lines (see Fig. 6.2); (ii) aggregation of the connected buildings in order to remove the common lines; (iii) use of a dilatation-erosion process to smooth the building footprints; (iv) removing of the courtyards to keep only the public spaces; (v) removing of the quasi-linear nodes and Douglas-Peucker generalization.

Starting from this 87,000 m^2 subset 408 s-line are generated (Fig. 6.3, left). In order to enhance the legibility of resulting s-partitions, we choose a thematic cartographic representation with proportional symbols: the width of the s-lines is inversely to the distance from the generator. As shown in Fig. 6.3, right, from 0 to 5 m, the s-line is thick, from 5 to 26 m, the s-line is medium, farther than 26 m, the s-line is thin. This partition corresponds respectively to a strong, average and low influence in the field of view.

Concerning the vertical landmarks, we only consider in this use case the Bretagne tower[1]: A 37-storeyed building of height 144 m located about 200 m north of the region of interest. The co-visibility areas presented in Fig. 6.4 show four distinct thresholds: the v-line from the lightest grey to black shows the areas in which a point located at 12, 22, 32, 42 m respectively from the top and on the central axis of the Bretagne tower can be seen.

The Fig. 6.5 shows two distinct pedestrian paths that help us to assess the enhancement of the convex partitions method that we developed. These paths start from Commerce square located south in the region of interest and end up at the Bon Pasteur square. The first path: A, 320 m long, bypass the Royale square on its west side and exhibits some obvious visual events in the field of view: outlet the Port au vin street on Fosse street (Fig. 6.5, point A3), visibility of the Bretagne tower on the second half of Contrescarpe street (Fig. 6.5, points A5 and A6). The second path:

[1]The tool developed within SketchUp allows to take into account other vertical landmarks as the bell tower of Saint-Nicolas church.

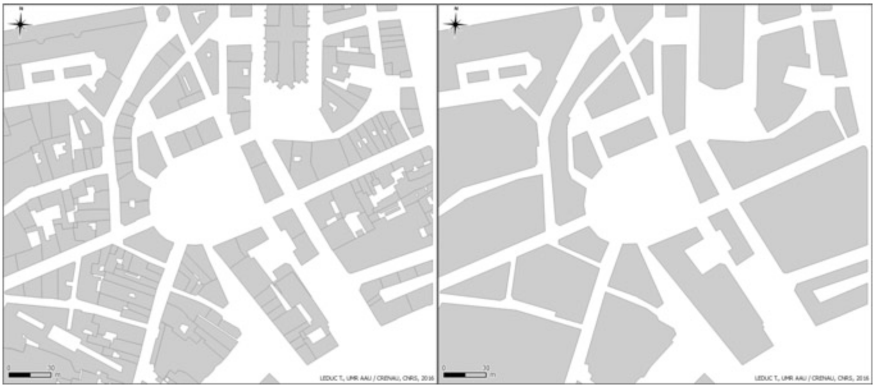

Fig. 6.2 The buildings' layer simplification process. The objective is to reduce the set of opaque edges able to generate visual cuts

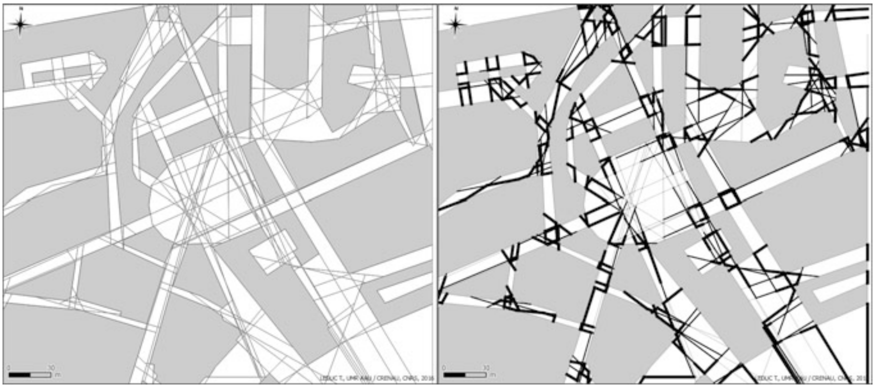

Fig. 6.3 The s-lines' layer weighting process. The objective is to enhance s-lines' readability

B, 280 m long, crosses the Royale square from SW to NE (Fig. 6.5, points B1 to B4), goes straight into the Arche sèche street and turns into Échelle street (Fig. 6.5, point B6) before taking the stairs to Bon Pasteur square (Fig. 6.5, point B7).

The Fig. 6.6 confirms with a fisheye picture, a fast 3D rendering in the 3D mockup, and the 3D isovist simulation the emergence of the Bretagne tower as a vertical landscape at point B5 in Fig. 6.5.

The color plate presented in Fig. 6.7 summarizes the visual appreciations (the effects of the various visual properties) all along the path A. As one can notice at first glance, the second half of the Contrescarpe Street offers to the pedestrian a direct visual access to at least three of the punctual generators previously mentioned (the closest to the top of Bretagne tower). Regarding the s-lines' transitions, the kind of "frequency diagram" represented in this figure is less easy to encompass.

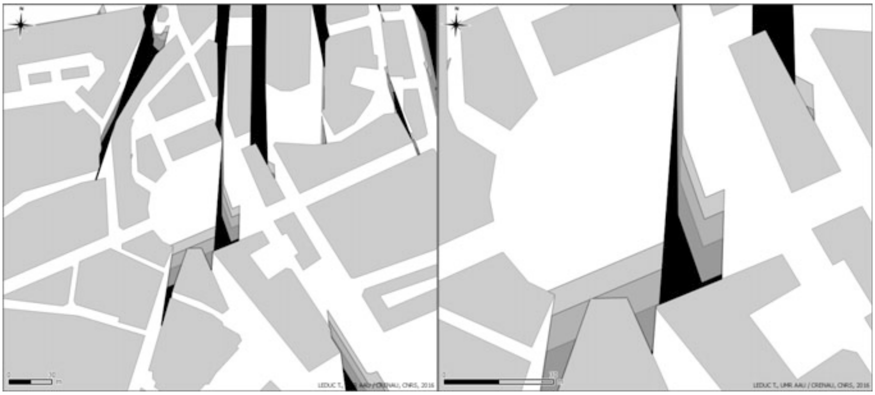

Fig. 6.4 The four set of v-lines with a zoom in on the Royale square (*right*). The *black* (resp. *dark-grey*, *grey*, and *light-grey*) polygons correspond to portions of ground space in which the punctual generator located at 42 m (resp. 32, 22, and 12 m) from *top* of the Bretagne tower is visible

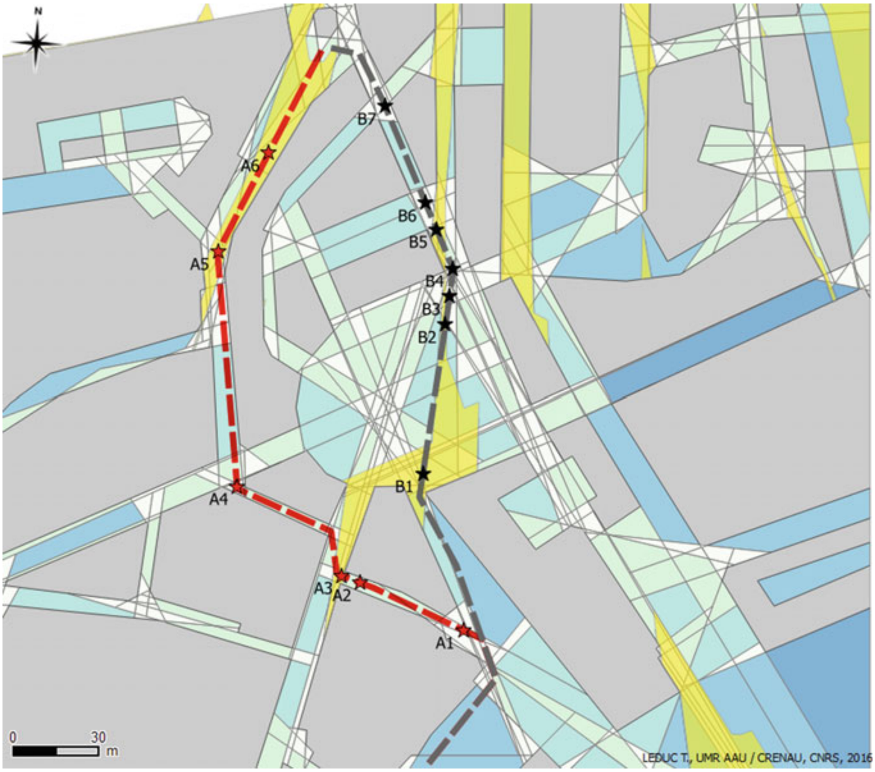

Fig. 6.5 The two studied urban paths with some emblematic positions. In the background map, s-partitions and of yellow-colored areas of co-visibility with the Bretagne tower are presented

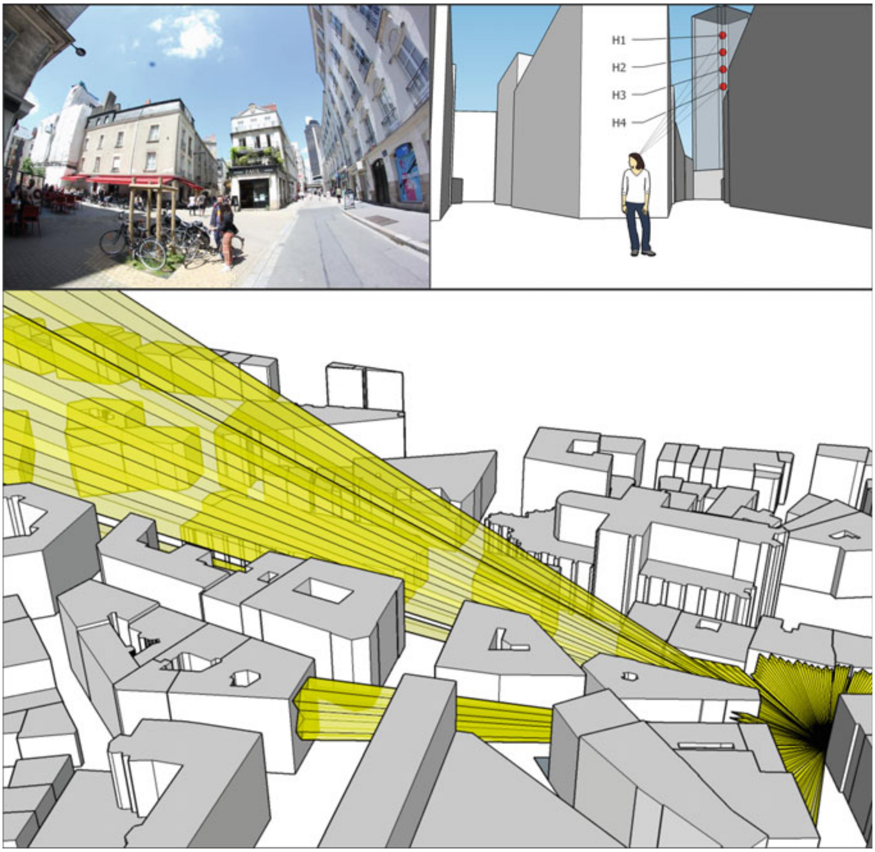

Fig. 6.6 The visual access of the Bretagne tower vertical landmark from the Arche Sèche Street (close to the point B5) is confirmed by all at once a fisheye photographic survey (*top left*), a perspective view from inside the 3D mock-up (*top right*), and a 3D isovist (*bottom*)

Nevertheless, we may observe that the transition between the points A2 and A3 (from Port au Vin Street to the Fosse Street) is clearly underlined and similar to a tunnel exit. Lastly, after the A4 position, the crossing over Crébillon Street and the entrance of Contrescarpe Street causes a strong visual event.

Regarding the color plate presented in Fig. 6.8, we obviously notice than the sub-areas linked to the v-lines are shorter but better distributed all along the path. The Bretagne tower is viewable regularly but each time for a small period. With reference to s-lines, one may note the lack of strong visual events between B1 and B3 positions (where the path B crosses the Royale square). More globally, comparing both frequency diagrams, the s-lines' transitions in path B seem less significant than in path A.

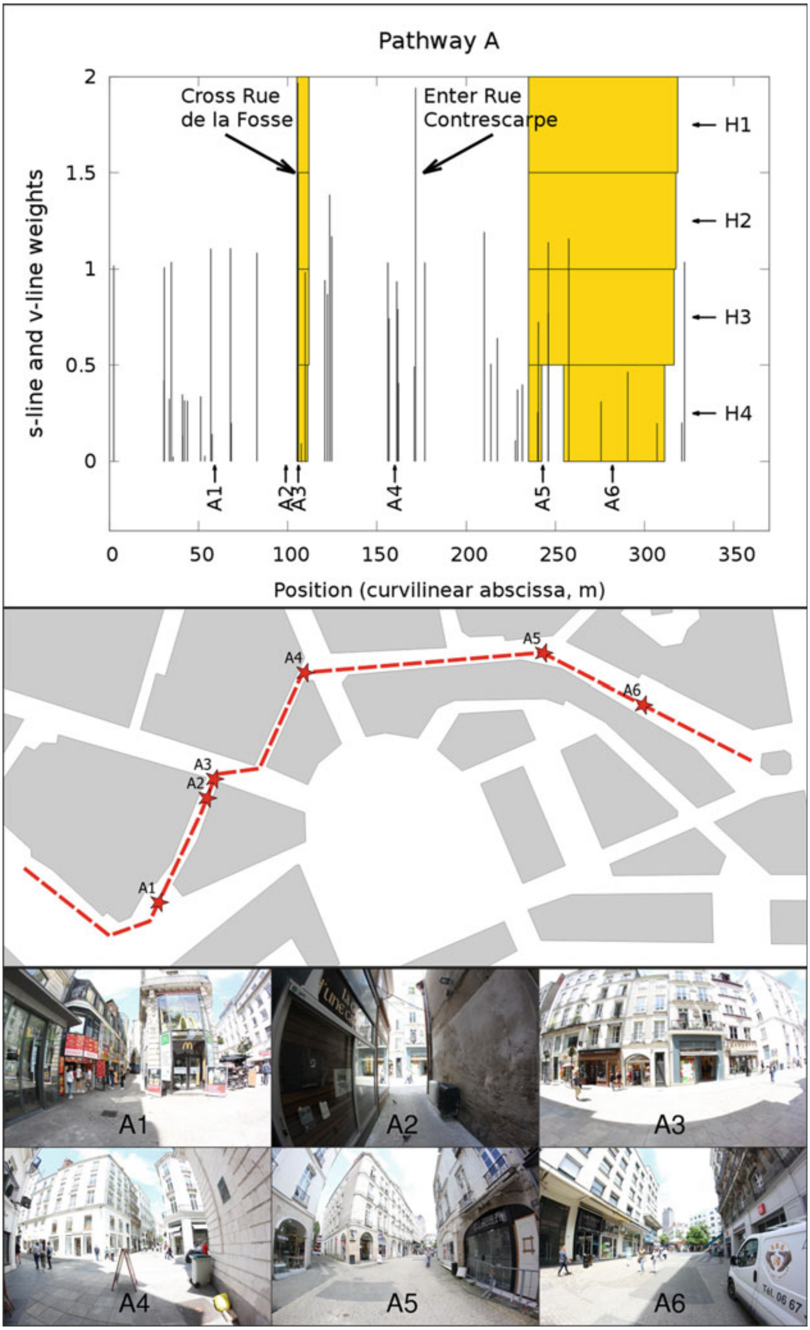

Fig. 6.7 A step-by-step description of path A in terms of visual transitions

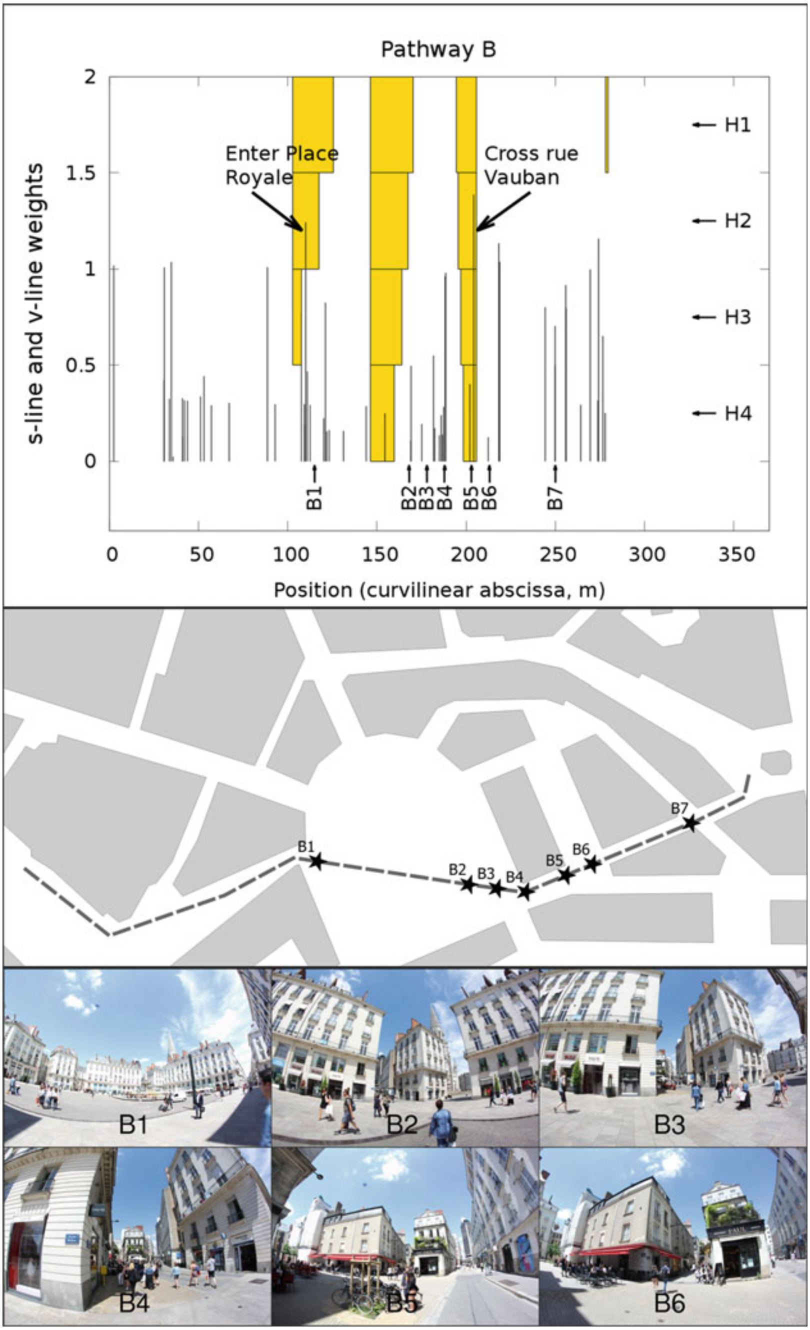

Fig. 6.8 A step-by-step description of path B in terms of visual transitions

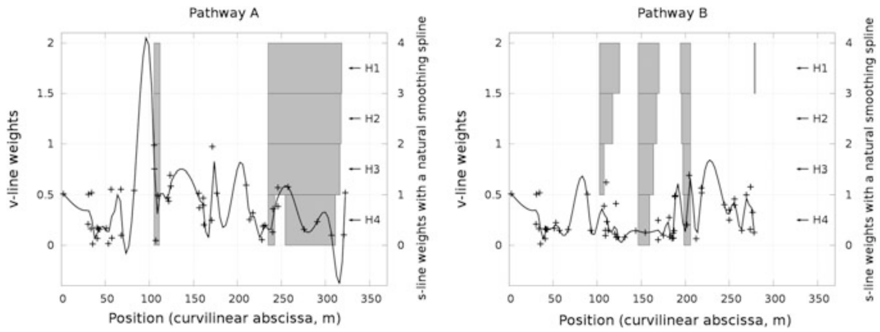

Fig. 6.9 Comparison of diagrams related to the visual properties of paths A and B

Discussion

Figure 6.9 shows an improved representation of visual events linked to s-line. From the points of the Figs. 6.7 and 6.8 we have produced a curve with a natural smoothing spline operator. This arbitrary smoothing exhibits two phenomena related to s-partitions: amplitude and frequency of visual events. The A path shows strong variations on long periods, and the path B shows small variations on short periods. Therefore, concerning the horizontal visual events (s-lines), the A path could be described as varied while the B path can be described as more constant. And concerning the vertical visual events (v-lines), the A path is clearly less fluctuating than the B path.

This method could be used to show the discontinuities or visual events in the field of view and therefore shows also where we could find some important changes in 3D isovists. This assumption is limited by our approximation of vertical events: we only take into account the central axis of the vertical landmarks while they have an unneglectable width. This approximation allows more legible maps but at the cost of the precision of the results.

Concerning the e-lines, the question that arise is how the e-line and e-partitions could be weighted in order to be combined to the weighted s-line and v-line. In other words, how we could assess the importance of the visual events represented by e-line?

Conclusion

This study is a contribution to the open space convex partition solution proposed by Peponis et al. (1997). Our main goal is to enrich their pioneering proposal in two different manners. First one has to do with some sort of s-lines' weighting. Second one integrates landscape saliencies (from verticality point of view). Both extensions aim to put the emphasis on anthropocentric aspects, and to go beyond pure geometrical partition of open spaces.

Further work concerns the application of our method to the e-partitions in order to study the relative importance of e-lines compared to s-lines and v-lines. Secondly, the v-lines generation has to be done from any vertical landmark with some perceptive quality. And lastly we have to integrate the terrain model in the computation as the variations in the terrain could bring some new kind of convex partition of the space.

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Chapter 7
Evolution of Planning with Visual Conditions

Åsmund Izaki and Christian Derix

Abstract The design research group SUPERSPACE at Woods Bagot has a 15 year history of developing design methodology based on visual conditions in academia and professional practice. This chapter will review the many pioneering developments of visibility design that provided the basis for much international academic research in the field, such as an interactive VGA for CAD at Aedas in 2004 for passive supervision design of schools, the first 3D volumetric and sequence-based visual conditions analysis for the National September 11th Memorial Museum New York in 2007 or the introduction of the fast polygon traversal algorithm for visual fields in 2013. SUPERSPACE has always integrated visual and spatial analysis into its generative computing methodology and the case studies show the relation between analytic and generative design.

Keyword Urban design · Architectural design · Representation · Simulation · Education · Professional practice · Visibility · Isovist · Generative design

Introduction

The design research group SUPERSPACE at Woods Bagot has a 15 year history of developing design methodology based on visual conditions in academia and professional practice. This chapter will review the many pioneering developments of visibility design that provided the basis for much international academic research in the field, such as an interactive VGA for CAD at Aedas in 2004 for passive supervision design of schools, the first 3D volumetric and sequence-based visual conditions analysis for the National September 11th Memorial Museum New York

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in 2007 or the introduction of the fast polygon traversal algorithm for visual fields in 2013. SUPERSPACE has always integrated visual and spatial analysis into its generative computing methodology and the case studies show the relation between analytic and generative design.

Methodology

The methodology for the study of visibility for analytical purposes is well developed in the context of spatial architectural analysis, for example in research communities related to Space Syntax, as well as in spatial cognition research about wayfinding, in other words how visual conditions affect route choice and other decision-making involved in navigating through an environment. In parallel, a strand of research in the field of computational geometry study methods for calculating geometric visibility and related problems with many applications ranging from triangulation to robotics and motion planning (O'Rourke 1987). There are peculiar overlaps between these fields as, that in spite of the fact that their motivations for studying visibility problems are divergent, they have similar fundamental problems to be investigated in common.

Matters confronting the practising architect that actively aspires to be in control of the visual qualities inherent in their designs are only sporadically addressed by the profession, with a few exceptions, and usually not taught as part of the education in a coherent and systematic way. One development that incorporates an understanding of the role of the person's movement through space and its importance for the visual experience is the concept of serial vision sketches developed by Cullen (1961), while other conventional practices of interrogating visual conditions of designs tend to be based on perspectives constructed from the point of view of a single user; nowadays more commonly by the use of 3D modelling and CAD/BIM software. There has recently been an increase in engineering approaches based on ray tracing, to optimise for example a stadium design in order to make sure all the spectators have an acceptable view of the sports ground, or analysing visibility values on facades to create heat maps highlighting which parts are more (or less) visible from the street level or other points of interest. However, it is worth to question whether visibility should be treated as a concern that can be solved or optimised in a generic model based on the same premise as the study of solar radiation.

SUPERSPACE finds itself at the intersection of the academic domains and communities mentioned above, while also confronted with the challenge of translating and applying the research in a meaningful way, being situated in an architectural practice with real-world constraints of designing buildings, interiors and urban environments. In the following section we present a selection of methodologies used by the group and that make up the digital framework for integrating visibility conditions in the analysis, design and review of architectural projects: i.e. the different forms of representing and coding forms and structures of visibility conditions. The framework is built up of the basic building blocks necessary to

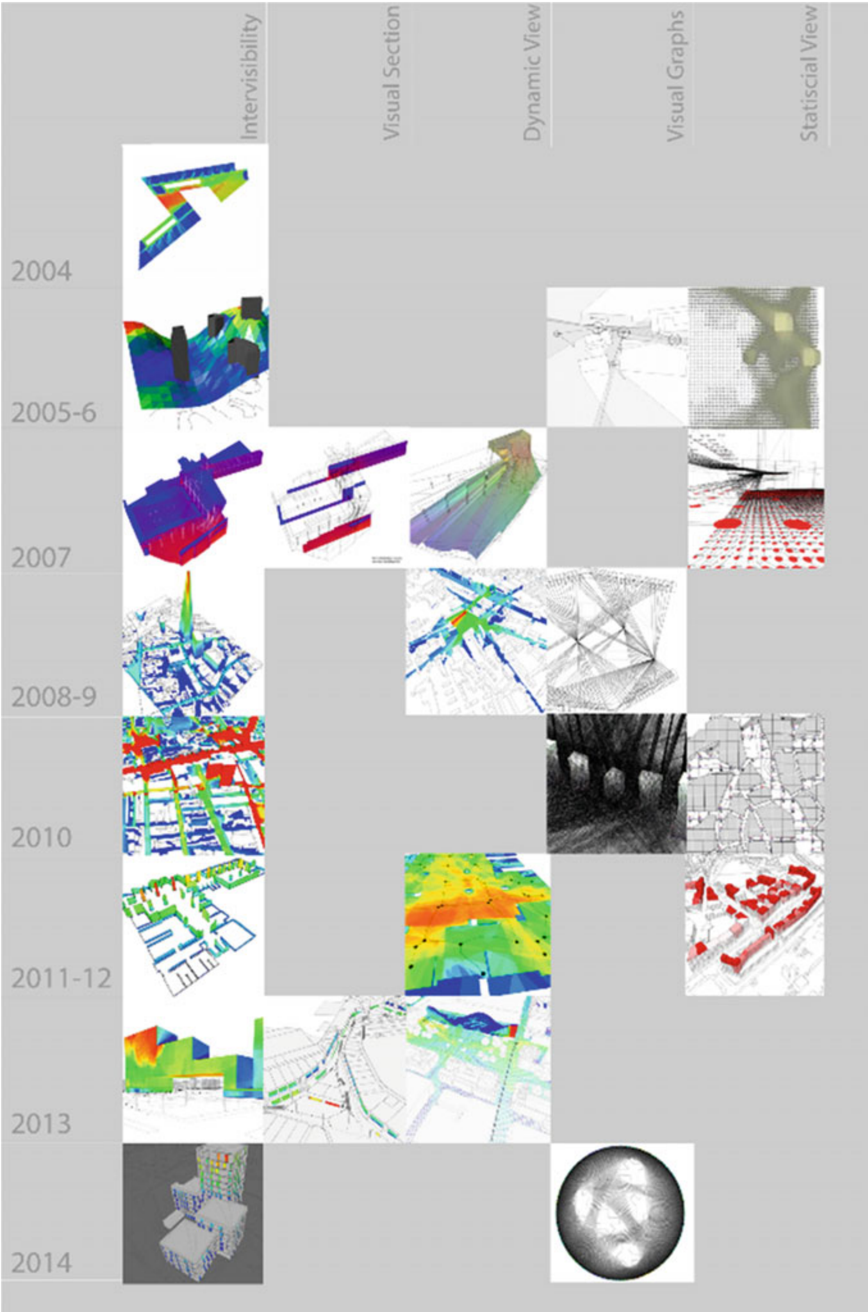

Fig. 7.1 Evolution of visibility structures developed by the SUPERSPACE group from VGA analysis to the 3D isovist and isovist fields (*credits* Derix 2015)

meaningfully represent and manipulate visual conditions, and have been developed by the group over the course of many years in an effort to include visual conditions as an integrated part of architectural and urban design activities. This has gradually evolved into a flexible toolkit which allows the group to assemble tailored applications to a specific design or concept, while some recurring analytical techniques are compiled with interfaces for more immediate use (Fig. 7.1). The result is a network of transparent bespoke simulations, rather than a single integrated tool (Derix 2012). The methods are sourced from the fields described above, where SUPERSPACE also contributes, and complemented with in-house research. The research carried out by the group can be strategic internal developments or externally funded research projects, the latter was the case for example when SUPERSPACE participated in the EU funded project *Resilient Infrastructure and Building Security* from 2010 to 2013. The methods are then continuously applied, fine-tuned and validated on projects.

Forms of Visibility

The computation of visual relations results in forms and structures that are both geometric and topological, and in many ways architectural in themselves. The premise of the work is the assumption that we can interpret geometric or topological measures of these forms to create understandings of how the space affect its perception and use, and in this way make ephemeral qualities of space into tangible operational diagrams. These forms of visibility range from visibility polygons and polyhedra (isovists) to scalar fields and visibility graphs (Fig. 7.2).

Abstract structures have supported the creation of new architectural and urban environments throughout history. There is precedence in urban planning of using topological and geometric structures to both plan and read cities, for instance the use of grids have shaped many cities from Piraeus to Manhattan, or the semilattice structure described by Alexander (1965). Computing and representing visibility as a form, based on abstract mathematical models, was introduced by Benedikt (1979) in "To take hold of space: isovists and isovist fields", where Benedikt showed how measures of the isovist could be used to quantify visual and experiential aspects of

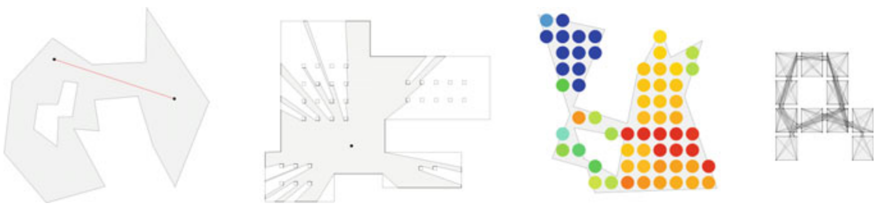

Fig. 7.2 Forms of visibility in 2D: Two intervisible points, 2D isovist, mean depth of the visual graph and visibility graph between corners typically used for finding shortest paths (*credits* Izaki and Derix 2013)

space. We show how this work can be expanded further in three-dimensional space, and in the meeting with concepts and constraints specific to each design when applying the methods on projects.

Individual Points

In some situations, a set of individual points in a plan, that are not structured in a regular form as a grid or distributed along a path, may be of particular importance to study. The points can be derived from observations of people in an existing environment, or directly from information encoded in the plan, for example when evaluating positions of people such as seating arrangements in a workplace, important decision points which could be the exit of a tube station, or the location of an important small object in the space such as an art piece in a gallery.

The 2D isovist is a representation of the visibility from a single point; it describes the visible polygon or region from a point typically in a polygon with holes representing the occluding elements in a plan or section. The original implementations of calculating isovists were based on projecting radial lines at a fixed angular interval. This approximation has some limitations such as a diminishing resolution in areas far away from the viewpoint, and it is difficult to distinguish between open and closed edges in the isovist. The "Visibility polygon traversal algorithm" (Izaki and Derix 2013) forms the backbone of many of the two-dimensional visibility structures used by the group. It provides a fast and robust method to construct two dimensional exact isovists without the resolution issues present in the radial line method. Furthermore, it distinguishes between open and closed edges which provide additional information about the visual conditions, such as how many unseen spaces can be reached from a given location, where the presence of many open edges indicates that there are more topologically different routes to take from a given position, providing a higher number of route choices to the person.

In some cases, the use of two-dimensional isovists can fail to properly represent and evaluate essential spatial features, such as the visibility between floors. Thus the traditional techniques have limited value in practice for a number of spatial

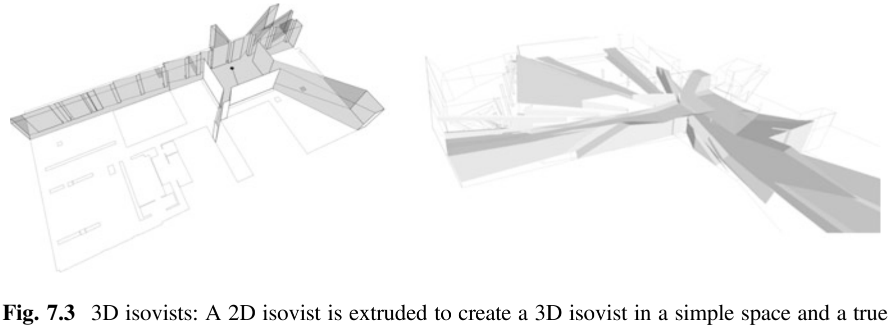

Fig. 7.3 3D isovists: A 2D isovist is extruded to create a 3D isovist in a simple space and a true 3D isovist in a complex three-dimensional space [*credits* Computational Design Research group (CDR) @ Aedas]

typologies. The same representation in 3D is then more appropriately applied: the visibility polyhedron or 3D isovist (Fig. 7.3) describes the whole visible volume seen from a location (Derix et al. 2008). Properties of the visibility polygon have equivalent measures in two and three dimensions. The 2D area becomes volume in 3D, the perimeter of the polygon is the equivalent of the surface area, and the centroid and drift stay as a point and vector.

Along a Path

The sequence of isovists and how it changes along a path representing a person's movement through the environment is a useful way to study how the sensations associated with the visible volume changes as you walk through a space. Similar to the idea of "Serial Vision" described by Cullen, this can also be studied using the type of abstract structures that we have introduced here (Fig. 7.4). By constructing a single isovists along a path at a certain rate, the changes from one point to the next can be measured to show where there are abrupt changes in any of the properties of the isovist. For example, one can study how the overall visible area or volume changes as a person is moving along a path to understand where along the path the view opens up or narrows down.

Fields

Isovist fields are used to study how the space itself creates a range of different visual conditions that exist independently of the many particular locations associated with its occupation and use. In a mathematical field any arbitrary point has a value associated with it, but for practical purposes in an algorithmic system the space is sampled using a uniform interval to approximate the continuous field. The field is typically computed in a 2D plan in order to show how local visual conditions vary through different parts of a layout, but fields can also be embedded in 3D space on

Fig. 7.4 Isovists from paths: 2D isovist along a path in an urban environment and 3D isovist along a path in the 9/11 Memorial Museum [SUPERSPACE @ Woods Bagot & Computational Design Research group (CDR) @ Aedas]

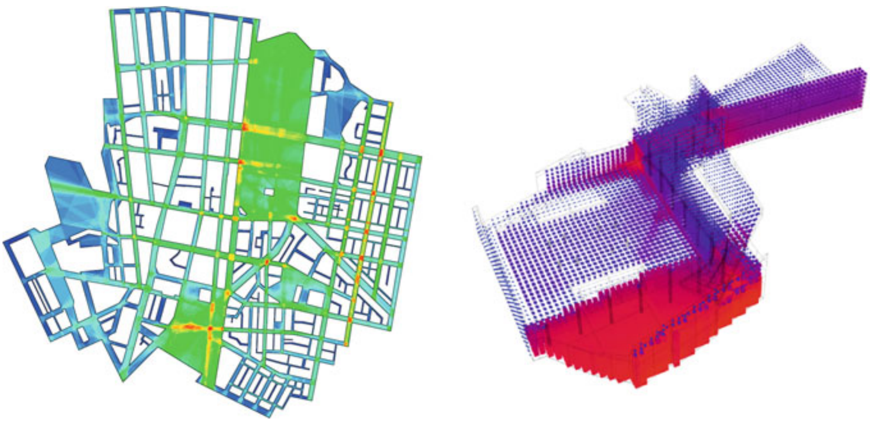

Fig. 7.5 Isovist fields: 2D isovist field of number of permeable edges and 3D isovist field of visual connectivity (SUPERSPACE @ Woods Bagot & Computational Design Research group (CDR) @ Aedas)

surfaces, or as true 3D fields where each grid point makes up a voxel. Most of the fields contain scalar values, but one exception is when one is calculating drift as a vector, and in this instance it becomes a vector field.

The fields which in themselves are nothing more than matrices of numbers can be translated into maps so a designer or analyst can interpret their meaning. Benedikt introduced the idea of making landscapes with contours mapping the intensities of the different isovist measures he proposed. Other types of maps can be constructed by representing the values using colours or by other visualisation techniques that show how the intensity of a quantity fluctuates throughout the environment (Fig. 7.5). The maps describe how the various parts of a layout or urban environment are associated with different spatial qualities, for example if one point in the space has a high visual connectivity value, a person occupying this position might use it to get an overview of the space, but they might feel more protected and comfortable to wait in an area where the drift value is high, meaning they are occupying the periphery of the visual field and can focus their attention in a limited and directed field of view, in a natural response to the properties of the human vision.

Graphs

A graph or network can be created between a set of intervisible points in an environment (Fig. 7.6). Benedikt's work on isovists, paths and fields, was later on expanded by Turner and Penn (1999) who introduced the concept of Visual Graph Analysis (VGA) (Turner et al. 2001), that shifted the focus from geometric measures towards connectivity and graphs measures. VGA has laid the basis of much of the work in the field denoted as Space Syntax together with axial line analysis.

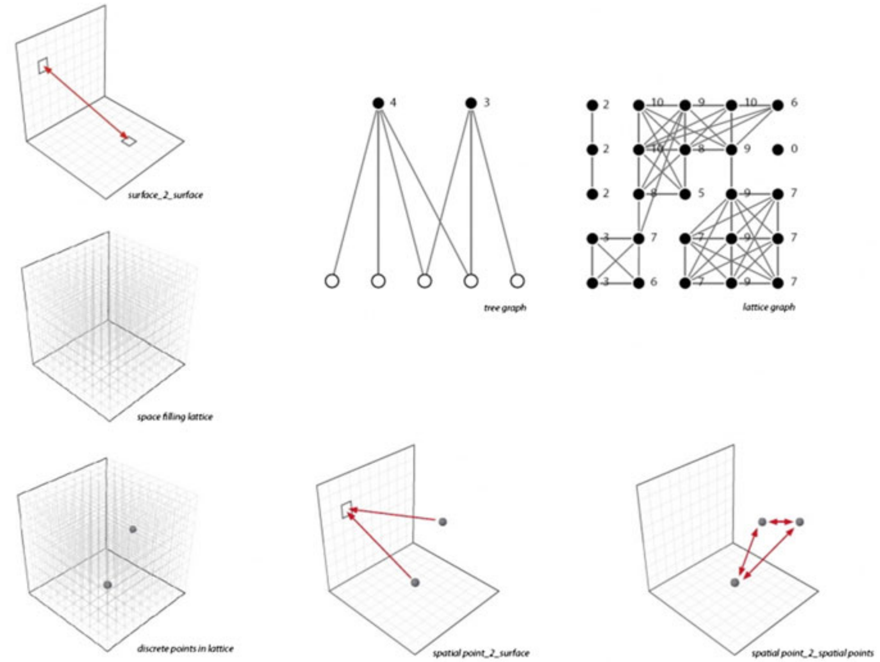

Fig. 7.6 Visibility graphs on different sets of points, between surfaces, voxels or grid points (copyright: Computational Design Research group (CDR) @ Aedas)

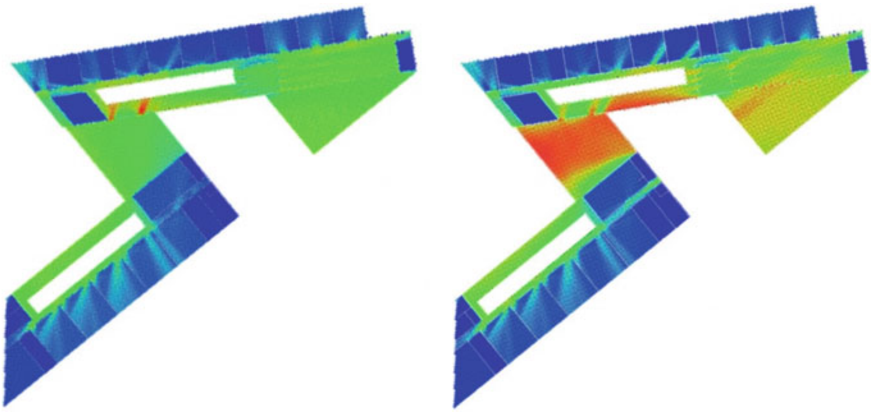

Fig. 7.7 The first live interactive VGA for AutoCAD that was programmed in VB, shown here on Darwen Academy [copyright: Computational Design Research group (CDR) @ Aedas]

While the isovist field describes how the local visual conditions vary across the space, visibility graphs describe the relationship of a point with the whole structure of intervisible points (Fig. 7.7). For example, one way to measure the centrality value of a point is to calculate how many steps (intermediate points) in the graphs must be taken on average to reach every other point; this measure is called the mean depth. When calculating graph measures on each vertex in the graph a field is created. Rather than measuring local conditions as we have seen in the isovist field, these fields created through a graph map out how each point's relationship to the whole vary across the space.

Case Studies

A set of case-studies are presented under four thematic headlines: Experience, Wayfinding, Collaboration and Impact. The general relevance of each topic in architectural design is discussed with a human-centric design principle in mind. These exemplify how the methodology is applied in order to help bring the visual conditions created by a design solution to the attention of the architect, and to suggest variations and alternative configurations that more closely adhere to the design intent. This is followed by a discussion on how to use generative design to address visibility conditions in order to generate new typologies based on creating specific user experiences rather than solving functional principles or replicating superficial stylistic expressions.

Experience

Engaging architectural experiences can arise from the scale and proportions of a spatial enclosure, and the sequence of enclosures we walk through. The architectural means of composing the possible spatial sequences for a visitor or inhabitant is limited compared to the prevalence of available tools for sculpting volumes or designing intricate surfaces and patterns. There is thus a need in the professional architectural design field for methods that support the creation of spaces that offer rich visual experiences to the user. As architects we are responsible for choreographing sequences of spatial conditions with different shapes of the visibility volume: Long, thin, centred, peripheral or tall.

Memorial Museum 9/11

The WTC Memorial Museum concept and intentions by Davies Brody Bond–Aedas matched the methodology proposed and developed for the project by the SUPERSPACE group, then Aedas R&D (Derix et al. 2008). The central concept was to not only present the exhibition inside a museum space, but that the journey through the museum should itself become the central experience that affects the user

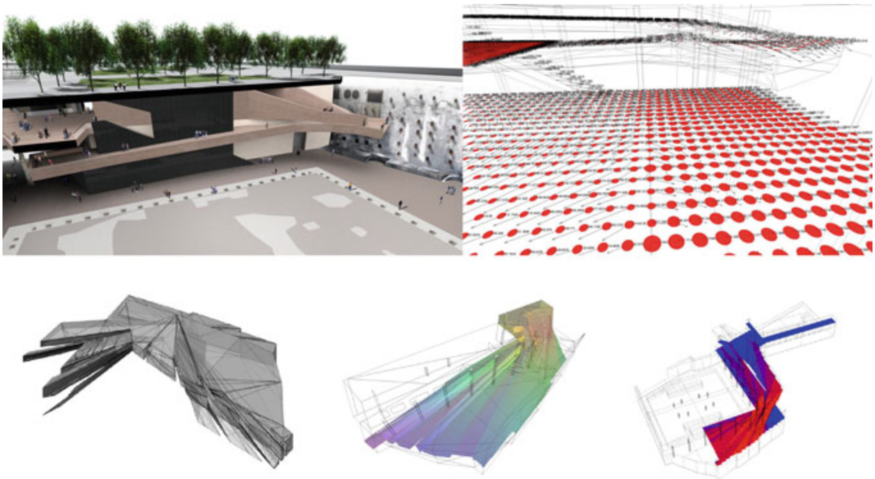

Fig. 7.8 3D visibility for 9/11 Memorial Museum [copyright: Computational Design Research group (CDR) @ Aedas]

and evokes an empathic connection to the site. In order to treat the procession as a part of the exhibition, it was necessary to provide the means to curate and direct the visitor's experience descending from ground zero down to the underground museum on a ramp. The concrete articulation of the ramp had intangible consequences that were difficult to control and understand without the construction and visualisation of the structures describing these visual conditions in 3D (Fig. 7.8).

Wayfinding

People make decisions of where to go depending on visual cues in the environment. A pedestrian is more inclined to follow the long straight street than narrow, winding streets with more turns. One condition is not better than the other, but supports different behaviours and uses. The straight street works well as a high street for commerce and a social arena, and the other supports more local activities, or accommodates the curiosity of visitors who enjoy wandering narrow alleys to discover hidden paths. By relating geometric visibility conditions to cognitive phenomena through computation one can support the design, control and verification of these characteristics. The aim is to establish wayfinding as integral consideration that is part of the spatial design, and not solved as an afterthought separated from the architectural design process, where often ambiguous spatial configurations are remedied using signage or in the best case colour coding.

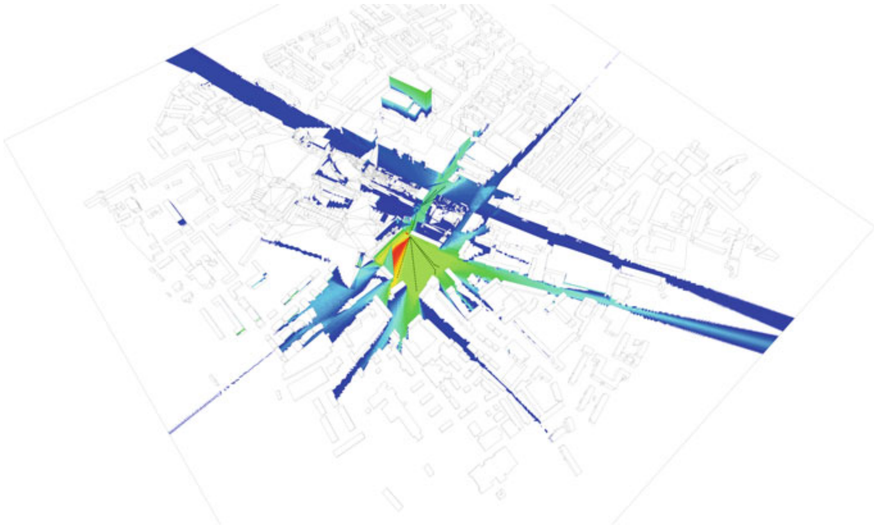

Fig. 7.9 Visual connectivity from paths approaching the entrance of Whitechapel station [copyright: Computational Design Research group (CDR) @ Aedas]

Whitechapel Crossrail

The interplay of movement and visibility was further elaborated in the urban study for Crossrail, Whitechapel Station (Izaki and Helme 2014). The number of trips at different times of the day from origins in the surrounding parts of the station was found through the collection of survey data, which informed the modelling of likely paths approaching the station. Comparative studies showed how the placement of the entrance to the station, and the number of entrances, affected the pedestrian flow leading up to the station and the visual connectivity of the entrance from these paths (Fig. 7.9). This is thus an example of an urban planning methodology applied in the design of a single building.

Collaboration

Today's workplace is adaptive to changing requirements of groups and individuals in the workplace, and the layout of the workplace can promote different types of collaborations and work cultures. Departments sitting on different floors have a strong physical separation, unless there is an atrium that creates a visual connection between the floors. A particular layout defines the visual connectivity between groups and individuals, and both the architectural form and how the organisation is placed are important tools for the business or organisation occupying the space to thrive. A particular workplace environment can increase the likelihood of spontaneous encounters between co-workers in different departments or groups which in turn can foster knowledge sharing and alignment of efforts in the practice. In other cases, it might be desirable to separate groups into autonomous units, for example in the case of certain research environments where different groups are exploring disparate approaches based on independent findings.

Workplace Simulation

A simulation was developed for a confidential Fortune 100 Tech Company workplace design (Fig. 7.10). The purpose was to help the planner determine suitable team allocations on a given plan, and to make sure the layout is flexible enough to accommodate changes in the distribution, size and requirement of different teams. The graphic interface allows the user to suggest team locations, but with an allocation algorithm that swaps team members to better match adjacency, distance and visual requirements. Clusters are formed based on both distances and visibility, and tested for conflicts between the actual layout and the team requirements gathered from interviews. The experience and intuition of the workplace

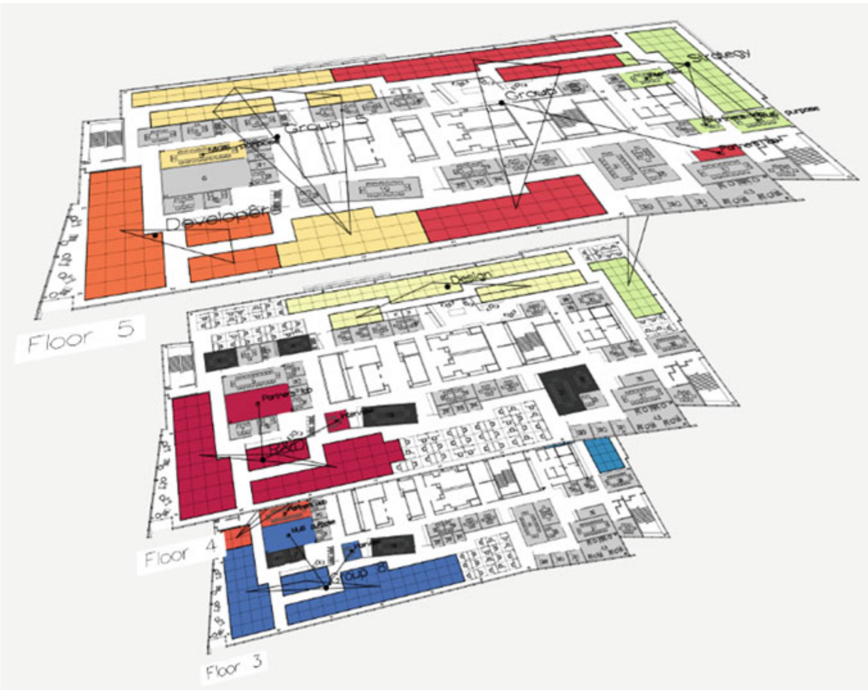

Fig. 7.10 Workplace simulation showing different teams forming clusters on a layout to be evaluated (SUPERSPACE @ Woods Bagot)

planner is combined with the rigour and speed of the algorithmic system, while ensuring that requirements that are normally difficult to verify are built into the planning process from the beginning.

Impact

The visual impact is the most direct application of visibility analysis, and is typically based on the visual connectivity of a piece of architecture or urban fabric. The visual connectivity value quantifies how visually accessible a surface, point or object is in relation to occupational positions, paths of movement or a uniform field. This has many use cases, whether the sector is urban, transport, commercial or interiors. By calculating and visualising the visual impact one can start to answer questions such as: How visible is this corner shop or shop frontage? Can this building work as a landmark defining the urban landscape? Or even for security: Are there too many small places to hide or are sensitive areas too exposed? Conversely it can be used to show how a new building alters the existing viewscape, is it interfering with an important view corridor, or would it alter the visual profile of the cityscape? To make sure a new intervention is not weakening an existing visual condition is in some cases just as important as it is to make sure a new addition is properly exposed to the inhabitant.

Retail

SUPERSPACE informed the design of a retail project with simulations and analysis to understand how the space might be used and experienced by the customer. In this project a number of 2D and 3D visibility methods were combined to understand customer behaviours in a retail environment (Fig. 7.11). Different types of shops are suited for different visual and access conditions, and the spatial information guides the retail planner in making decisions about the allocations of shops in the layout, while also highlighting potential problem areas that should be addressed during the design stage.

Generative Synthesis

Visibility conditions are suitable to be included in generative design as social and experiential parameters. In order to reach solutions that take into account a wide range of criteria, several concerns should ordinarily be considered. While in the analytical work each value is usually shown in the most transparent way possible so that emergent patterns are easily read and understood by the designer. While in the

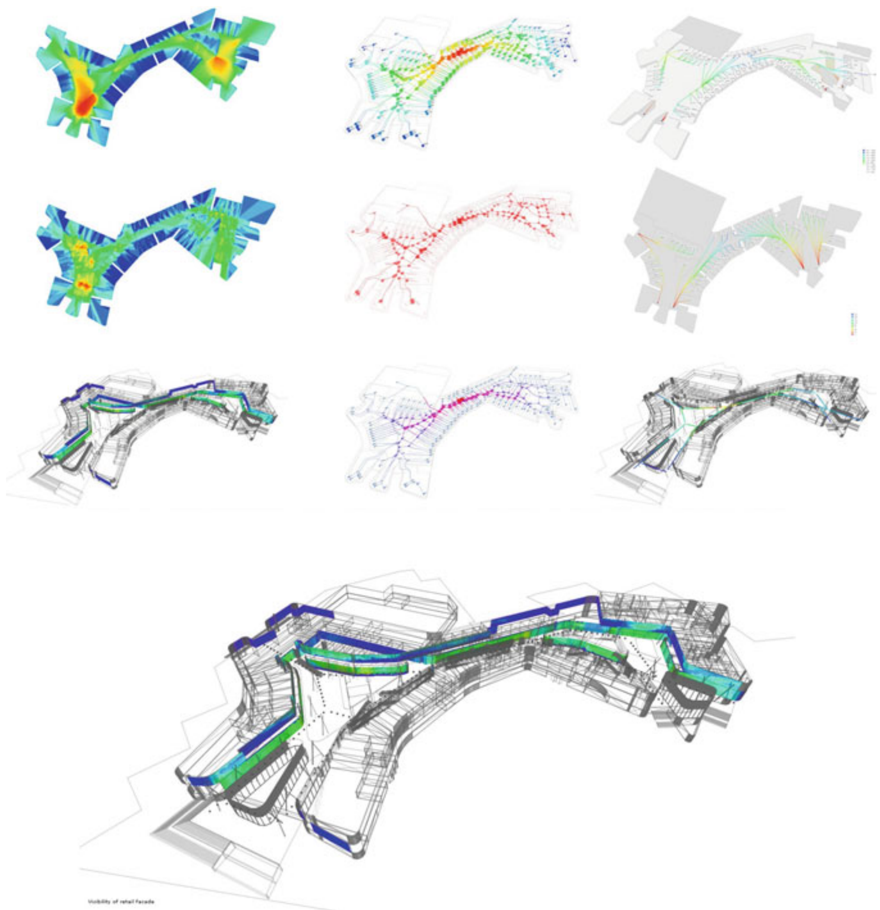

Fig. 7.11 Visibility analysis on a mall, showing visibility from the circulation to the shop frontages (copyright: Computational Design Research group (CDR) @ Aedas)

case of synthesis it is just as important that the principle behind the outcome is still legible, it is at the same time desirable to combine or treat the measures in a polyvalent manner, and to avoid direct single-objective optimisation. There are themes that are naturally revisited, but at the same time we strive towards finding different forms and expressions in each unique context and tailored to the brief rather than looking for a universal solution.

During a visiting professorship at TU Munich (Derix 2012) a methodology for integrating experiential aspects of space in generative design systems in three stages was introduced. It started with behavioural mapping from observing an existing space, spatial analysis on the same layout and developing notational systems that would become generative systems based on the behaviour-space interactions observed in the first two stages. The notational systems could be used to translate the empirical findings of occupational and spatial interdependencies into new architectural instances, and thereby becoming generative principles.

In the project “Floating Room” the students explored the concept of fuzziness related to visual relations in an environment. Whether a space is private or public, connected or disconnected is not a binary state, there is a fuzziness that gives nuance and richness to the architectural space. The layout was subdivided in a grid of interconnected cells, much like the VGA, and each cell was given a value depending on its connectivity. Together with this analytical measure the group of students developed a system to modify the layout by introducing internal partitions. The generative system was then used to design a residential block consisting of small apartment units where the subtle differentiation of private and social areas was carefully assembled (Fig. 7.12).

In “Visual Voids” another group of students in the same course explored how in the section of a building the visual condition is not symmetric in the sense that the visual relation between the observer and the observed is in some cases a directional relationship. In a mathematical sense the intervisibility between two points is perfectly symmetrical, if A is visible from B; B is also visible from A. But due to how our bodies occupy space, and how our eyes function, with a limited field of view, it is far easier to have an overview from a higher floor down the lower floor, than the other way around. Again, a notational system was developed to represent these asymmetric relations and their relationship as a configuration that became the basis of generating solutions with the desired visual conditions present (Fig. 7.13).

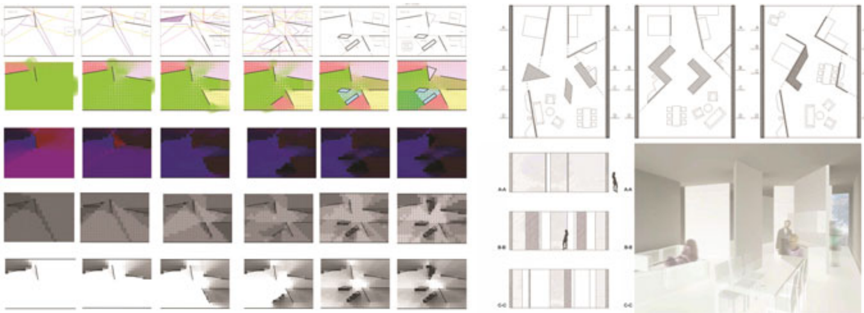

Fig. 7.12 “Floating Room” generative system and result [copyright: Christian Derix]

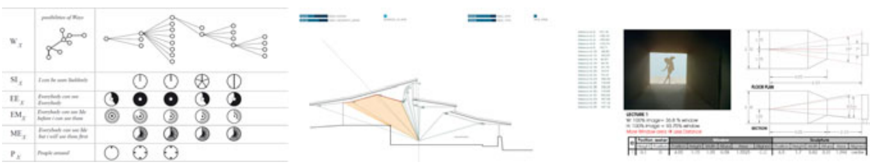

Fig. 7.13 “Visual Voids” generative system and result[copyright: Christian Derix]

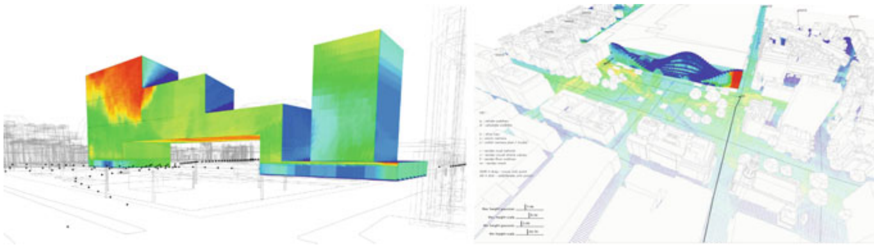

Fig. 7.14 Euston station: Orthogonal massing option with visual connectivity values and smooth massing option showing relationship to the visual conditions in the context [copyright: Computational Design Research group (CDR) @ Aedas]

In the Euston Station proposal, the massing of the station was developed by an interactive generative system. An isovist field was calculated for the surrounding streets adjacent to the footprint of the station. The values, such as the number of permeable edges in the isovist, as described above this is the number of topologically different routes, and was used to understand where the entrance should be placed to give the best overview of possible routes into the context. The massing itself responded to the field as well, and would increase where the visual connectivity was large and contract where the connectivity was small in a reciprocal relationship to its visual context (Fig. 7.14).

Conclusion

Systematic approaches to integrate the design of visual conditions in the professional work of architectural practices have been lacking, and left to the intuition and tacit knowledge of the individual architect. This chapter outlines the methodology of designing with visibility conditions in mind in a wide sense, but with a particular emphasis on constructing geometric and topological visibility structures. We have presented the differences between looking at individual points, paths through the environment, scalar and vector fields as well as different forms of visibility graphs. We have considered these structures first in two dimensions, and have shown the implications of extending the methods to 3D.

The case studies show possible paths to bridge the gap between academic research and practice. The methods have been developed, refined and applied in order to design-in visual conditions according to design intent, or respond to visual conditions in the context in which the project sits. A series of case studies illustrates a selection of topics where the methods have a practical significance, that we have labelled Experience, Wayfinding, Collaboration and Impact. Finally, we have discussed how visibility structures can be part of generative design systems.

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Part III
Physical Models in the Professional Practice

Chapter 8
The Model as Experience. Experience with Models

Andrea Rossetto

Abstract The contribution presents the author design methodology experience based on the process of handmade modeling. Starting from the definition of what a model is and which role it plays in human learning, the author explores the meaning it has for design thinking and development. Referring to the collaboration with Renato Rizzi, and according to his design approach, the model making is here conceived as a design process. In fact, transcending the pure architectural dimensions, the model demonstrates its essence of knowledge method by being the medium for molding the real environment. By means of the author's professional and research experiences presented in the text, it is possible to figure out how the theoretical approach becomes professional practice, and then reality. The entire work is permeated by a process of direct experience and continuous dialog with models, that represent the territory and the architectural artifact; modeling becomes a process of learning and discovery that naturally lead to the final design solution.

Keywords Plaster model · Model · Architecture

Introduction: The Model as a Method

First of all, it is necessary to agree on terminology. Within the discipline of architecture, in order to name the physical, material representation of a building or a territory, we refer to scale model, mock-up, maquette. But the term *model* is the one that better fits the purpose of modelling in the architectural discipline and the way it is conceived in this text. Mock-up or maquette only give back the objects physical entity, but these terms do not embrace meanings that exceed its materiality. In fact, these cannot fluctuate between the material and immaterial world, as the term *model* does: it can recall a physical model, but even a spiritual or an ethical model, and so on. In the connection between the model and the reality it represents, there is a

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Fig. 8.1 Madagascar, example of a model. A child, through playing with a model, anticipate the activity of sailing and fishing, that will ensure him the survival. (*credits* The author)

tension that is sealed in the cyclical nature of the relationship itself; in fact, as we will see later, the term *model* is here intended as method, while I refer to method as the way to reach a purpose, and the final goal is a new start.

Since childhood (Fig. 8.1), in a continuous attempt to know the world, to explain it, to experience it, to be prepared for it, the use of models is essential. The man, that is the child, experiences reality by playing, using both physical models (toys) and intangible imaginaries (the playful reproduction of an activity acts as a model). In this sense, it is possible to asserts that humans know the world only through models: is not any representation a model? The model is universally used as a learning procedure, that enables us to be prepared. In this sense the model is a method.

The Model as a Design Experience

In most cases, in education or in the professional practice, the scale models are used as a communication media. However, the more profitable use of models is during the design process, where they can lead the process instead of being a mere presentation media. At the end of my higher education career in Architecture, I had the opportunity to meet Renato Rizzi, who became my Master of Science thesis supervisor. I immediately started to collaborate with him, firstly in the professional experience, and then in education as well. A fifteen years long journey, during which I worked, on around 3/400 models, most of all made of plaster.

In 2001–2002, I worked for a year for the Grand Egyptian Museum competition (Figs. 8.2 and 8.3). I collaborated to the design process, but my hands dealt with models, contour lines, molds. I was starting to learn how to make plaster models. The project was classified third on two thousand.

This direct experience was crucial to begin to conceive models in a different perspective; this was also due to the fact that I had the chance to read Massimo Scolari (1988) essay on models, that is strictly related to my own reflections arose during the process of model making. Above all, along this process I definitively solved the embarrassment that stopped me every time I had to face a design project. What to do and why? Whatever form I would draw, it seemed to me a forced

Fig. 8.2 Three territorial models for Cairo Grand Egyptian Museum Competition. From *left*: 1:500.000, Nile delta. 1:50.000, Desert leap, 1:5.000 Project site. (*credits* Renato Rizzi)

solution. Someone might call it fear or getting stuck on a blank white page. I think it was a kind of respect, of inability to impose a sign on the territory driven by the personality of the sign itself, rather than its meaning. But what I learnt during the competition experience solved this awkwardness. I discovered that it is possible not to be the one who chooses the sign, or at least that it is possible to greatly reduce the architect's will; that is, to be a means of expression of the forms already belonging to the place. In other words, models can be a design tools, and not just a mere form of final representation.

The fundamental problem that arises is: where do the figures of the design project come from? Where can we find the origins of the forms we "create"? In our imagination? Are we truly the creators? Which relationship do these figures establish with the context they are located in?

Even if the attempt to summarize the theoretical apparatus of Renato Rizzi would be an impressive feat, and it is not the aim of this text, it is relevant to remind that Renato Rizzi developed a deep ontological disciplinary reflection. The crucial question to deal with, is how to reduce the violence expressed in architecture with self-referenced design projects by keeping in mind the great work by Emanuele Severino, considering the *Whole Eternal*, and criticizing the nihilistic madness that dare to think that it is possible to create from nothing and to destroy at our own will. The disciplinary consequence lies in the construction of a method that aims at decreasing the design arbitrariness as much as possible, and increases the sensitivity of listening and interpreting what is already encompassed and authentically belong to the place. As if the design forms have always been part of the environment.

The tools of this method are models. And the method, that already includes the project, is quite steady. The process requires the production of at least three territorial models at different scales referring to the same place before starting any design path. The development of these models implies a process of selection of the figures to represent, a choice, which is the first design decision. In so doing, slowly, the authentic figures belonging to the site begin to appear, to be seen. Then the design project attempts to get in relation with those figures. The different scales are used to disclosure the permanence of the place identity. Every model has the same

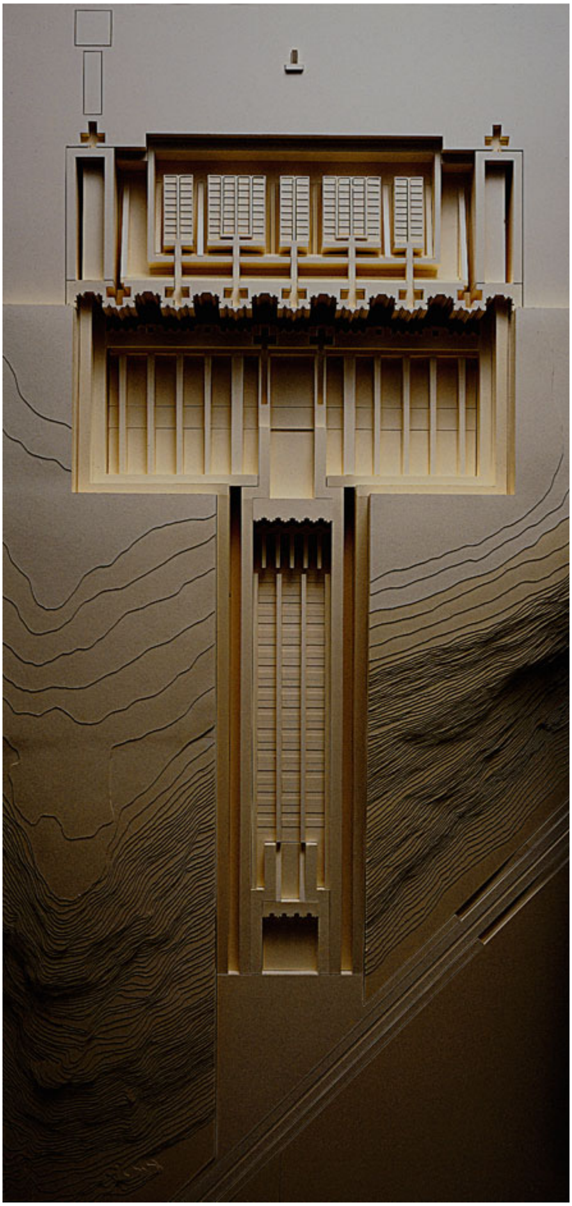

Fig. 8.3 Model for Cairo Grand Egyptian Museum Competition. Scale 1:500 (*credits* Renato Rizzi)

construction process, a common method, the beginning of a liturgy: (i) general model overview; (ii) complete redesign of the morphology and selection of figures to represent; (iii) sample of construction of a model part in order to verify the consonance between mental image and the model itself; (iv) manufacturing of the positive or negative master in cardboard; (v) realization of the mold (if the master is positive); (vi) plaster lay into the positive mold; (vii) assembly. This method is not perfectly linear. There is no automatic result. Even if there are some steps that are automatically linked one to the other, in certain moments of the process there is a leap in the dark. When the plaster model is completed, it has to be reduced once again to the bi-dimensional surface, to an image. The three-dimensional model is photographed with specific lighting conditions. The weight of the plaster goes back to the two-dimensionality of the image.

What the technical ability mastered and controlled during the complex execution of the model building operations, at a certain moment goes out of control. What was not already seen before, autonomously reveals itself for what it is, thanks to the intuition of an expert eye. The model speaks of itself. This is the first fundamental lesson, which has its counterpoint in the maniacal sequence of operations needed for construction. It is essential to take care of how your own idea is fulfilled, since once built, the architectural artifact become an autonomous entity that speaks by itself. From the model to construction, the delivery of the work is the cathartic moment of the art of building.

It is possible to identify some key-concepts of this method, as follow: (i) the model is a design tool: the model is not an instrument to represent a design scheme only; rather, the realization of a model is in itself a design operation. (ii) The model leads you step by step, scale to scale, to the design solution: the production of images, resulting from a sequence of models, is a design method itself, since it lays the foundations of the figurative apparatus onto which the design is projected. The model leads, passage after passage, throughout the filters of the various scales, to the design solution. (iii) The model is a scale representation of a certain reality, but it is also a reality in itself. Any model is an accomplished world: beyond the figurative content, that is a selection, each model adapts itself to the scale that must represent; in fact, it has to face the limits and characteristics of the construction material in relation to the physical size of the model, and this can have an impact on the size ratio. For instance, to correctly represents a setting at a certain scale, the relationship between the dimensions of the X Y axis and the Z axis can be altered, as it occurs in the hydraulic engineering representations, which are reshaped in order to make profiles readable. The scale reduction implies the adjustment of the figures. That is why each model, although made to represent a certain reality, is a reality in itself, and why in order to be productive in the design process, its study should necessarily fluctuate between what it represents and what it physically is. Each action is embodied in something physical, that becomes materialized and reaches an independent value in itself. Each *parva mundi* (Rizzi et al. 2014) is a concrete step towards the design project. (iv) The model is not intended as a representation of a design proposal, but it is a medium for reaching the design solution; since it provides the images that leads you to the final configuration, the model influences and intervenes in the design process itself: in this sense, it contributes to the design phase, both in the liturgical procession of images that constitutes the logical-figurative sequence leading to the final project, and in its physical being. That is, each type of model, either in wood, cardboard, wax, plaster, during construction behaves according to the physical laws of the building materials. Wood cannot ignore the effect produced by its veins. Cardboard models are produced by flat surfaces composition, or by overlapping layers. The various plans assembly implies the problem of corners. Wax, possibly, works with material subtraction and reassembly of parts. Plaster converges in a single block during the casting process and it does not admit not extruded shapes. Hence, choosing the model type and its material is a design foretaste. (v) A defined model liturgy can be considered a design method: it is possible to define a design path through the construction of a precise liturgical process based on a deep ontological and disciplinary review, rather than relying on a creative extemporaneousness.

Model Building and Construction Site

The relationship between model and method is part of the way in which the model is here intended: the path is step by step paved by models, that scale to scale lead to the design solution. Even if the production of illustrations that the design project relies on do not depend on the mock-up materials, and even if they play the same role of models in reducing personal arbitrariness, it is absolutely necessary to be aware that the material for models manufacture influences the design project itself. In fact, the use of plaster as construction material, constitutes the remaining part of the proposed methodology. The production process of Renato Rizzi's models, in fact, entirely anticipates the operations necessary for building the project; it determines, and necessarily affects, its nature. The conscious choice of plaster, due to its light refraction properties, to the delicacy of its materiality, to the evocative power of its single block, determines the process of model construction. Since the model is a step towards the realization of the project, it should be coherent to the building principles of the final "real" architecture.

The construction of the cardboard mold for plaster casting employs many techniques belonging to the onsite construction process. The mold must be: robust enough to withstand the stresses of the plaster cast, well-built to avoid detachment during the hardening of the liquid plaster, shuttered and un-shuttered (opened), and it is necessary to be confident with construction of centering and covering. It is necessary to be able to think in negative for properly realizing the construction drawings of the molds; in fact, it is necessary to produce the negative shape in order to reach the final result, that is the positive model(Fig. 8.4).

The plaster is in powder form, and it must be mixed with water at the right temperature until the necessary saturation, that is related to the type of mold and its opening method. The mold must be vibrated, and leveled at the appropriate time. The plaster has a drying time that should be included in the time schedule (Rizzi et al. 2014). This technique requires to face and solve the construction problems from the very beginning of the design project, anticipating what will occur in the construction site. It is relevant to stress the double mission of models: the plaster model is a design method, and at the same time a simulation tool that anticipates the actual activity of construction. The method consists of a logical-aesthetic sequence

Fig. 8.4 Cardboard positive and siliconic rubber mold

of figures, and a unique construction method applied along the path that driven by the design method itself. The greater the relationship consistency between the two is, the greater will be the effectiveness of the final design solution.

Professional Experience: Gdańsk Shakespearian Theatre

The *Gdańsk Shakespearian Theatre*[1] is the latest built work by Renato Rizzi. The entire design process was carried out using the method described above. About hundred models, mostly in plaster and partly made of cardboard (especially for the architectural details, due to purely technical reasons), anticipated the construction of the building, checking from scale to scale the coherence of the design figures development. The experience of the design method applied from scratch to construction, has highlighted the intrinsic benefits of this particular way of operating.

[1]Gdańsk Shakespearian Theatre, Gdańsk, Poland. Design project by Rizzi (2014).

The constant composition and constructive validation of the individual parts of the building, allowed to keep the integrity of the solution and to ensure the success of construction even in the most critical moments, i.e. the delicate phase of transmission of drawings to construction companies, which naturally tend to reduce costs, and thus accordingly the overall quality as well. This is not a statement against construction companies, but only an observation of a trend derived from common professional practice, independently from the good or bad intentions of the actors involved. In fact, lowest bidder contracts, together with bureaucratic procedural mechanism, do not pursue or encourage the goal of the maximum architectural quality. For this reason, the design method based on the physical building of the design solution up to the 1:10 scale, is a kind of safeguard for ensuring the design project success. Somehow, models are more exhaustive than drawings, and even if the information they provide can be quantitatively less numerous, their effectiveness is generally greater.

The design project for the Gdańsk Shakespearian Theatre began in 2005 with an international architectural competition; in September 2014, the theater has been inaugurated. About twenty models, from 1:200.000 to 1:100 scale, were made for the competition, including territorial and architectural ones.

The competition panels (Fig. 8.5) were made for two thirds of pictures of models. During the definitive and executive design phase, the remaining amount of models has been realized, aimed primarily to strength the relationship between the design figures and to check the final spatial configuration. The models realized for the definitive and executive phase were from 1:250 to 1:10 scale. Around 300 architectural drawings (not including plant components, structural elements, etc.) were delivered as part of the final design, plus 93 photographs of models, which have been an integral part of the materials for guiding the construction. The executive design project included images that became mandatory references for the building construction.

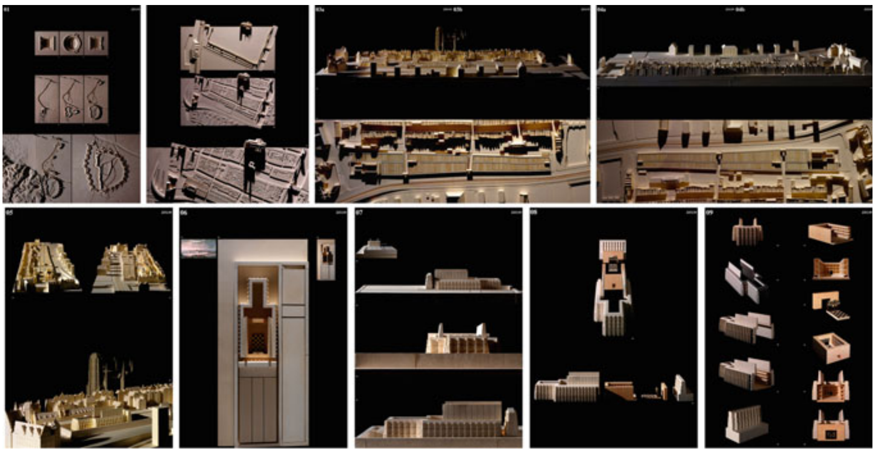

Fig. 8.5 Gdańsk Shakespearian Theatre competition panels (*credits* Renato Rizzi)

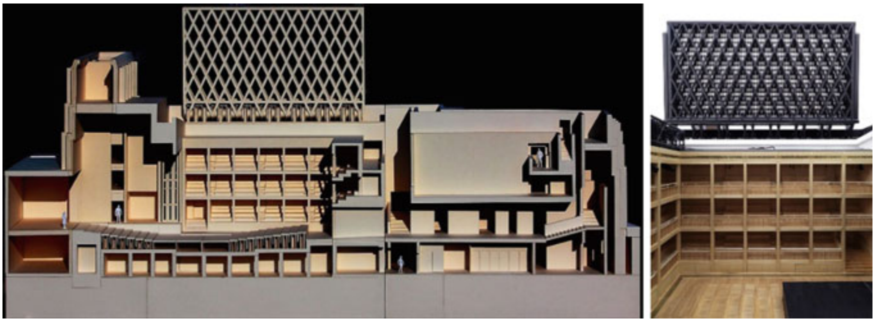

Fig. 8.6 Gdańsk Shakespearian Theatre model and realized work (*credits Left* Renato Rizzi, *right* Matteo Piazza)

The entire complex of the theater and its administrative area were built at a scale of 1:50, including interiors, stairs, floors, as well as what is no longer visible after the final assembly of the model. The whole process was documented with photographs of the model, its parts and the assembly sequence; the result is almost a manual for the building construction and component parts assembly. The main body of the theater itself has been studied at a scale of 1:25, in a longitudinal section. After construction, the photo of the theater interior with opened roof leads immediately to the image of the model (Fig. 8.6).

The three-dimensional richness of the certain components of the design solution, such as the wings roof reticular structure, or the articulation of the rhythmic scans of steps and ribs in the external composition of the walls, can be attributed to the use of models. Other forms of representation would hardly have returned this spatial complexity in the same manner. The tridimensional relationship between interior and exterior is almost impossible to be perceived on site at once, but it is readable in the model.

The relationship between the medium (model) and the final solution (the architectural artifact) is more solid if the medium can minimize the cognitive-imagination forms of compensation that distance the model from reproducing the final design realization. The medium of drawing implies a two-dimensional reduction that would surely produce a different form of space knowledge. Compared to the use of technical drawings, the model based approach, namely the model as a generator of a different type of knowledge, necessarily implies the fact that the final result is to some extent a consequence of the medium itself, and that it is sometimes more exhaustive in disclosing spatial complexity; this is evident in the consequences of the particular figurative vibration density in certain specific areas of the theatre, for instance the fence or the vibration of steps and ribs in the heart the inner wing magical plane of the roof enclosing a chessboard. The relationship between the issues mentioned above (three-dimensional reticular structure of the mobile wings of the roof—monolithic vibration of the brick wall) is to be related to the fact that rhythms and measures were defined through the models done at different scales. The images do not exist without the model. Although not visible in one single image, the thickness of the internal threshold (mobile roof) reverberates its corporeality of the outer skin (hard shell).

Hejduk (1985b) in *The Flatness of Depth* talks about the same relationship. The difference is that the author does not refer to a realized architecture. The key-point is not to define which form of representation gives back better results, but to be aware that the medium can not be intended as different from the design purpose; in fact, it is not possible not to consider the consciousness of the medium itself, that leads to the final goal, since we can not experience the final result until it will be realized. In short, the more the representation is appropriate for the design purpose, the easier the design process will lead to realization. The model has to be built, as the building. There are many different ways to build, but the greater the coherence between the model's construction technique and the building's one is, the more the process will be coherent with its final aim.

Research Experience

The way in which representation choices influence the final design project had been also explored based on the work of John Hejduk during the author's Ph.D. research in architectural composition. In particular, the research was focused on the project known as the Cathedral (Hejduk 1997). Plaster models were used as investigation method (Figs. 8.7 and 8.8). The same approach applied in the profession in one direction, from design conception to realization, from the existing place to the design solution, has been explored in the reverse sense. Starting from the design project-or more precisely the documentation that John Hejduk left about his project —and considering it as a realized architecture, I went backward in order to explore and understand the composition reasons and the archetypal principles of the project.

In this attempt, the coherence between the medium (plaster models) and purpose had been underestimated, and had been pursued beyond the limit of the coherence between the representation technique and its purpose. Soon, in fact, it became clear that the architecture of John Hejduk were not suitable to be represented using plaster as model construction material.

The formwork gives shape to plaster, that is a negative mold of the final result, which may contain the desired form. To be precise, the mold does not have to contain only, and this is the point. It should also give the possibility to be opened for removing the contents. The difference lays here: representation coherence depends on architectural composition properties. In fact, the technique can fill up and overcome distances, allowing to go beyond the limit of one modality of construction or representation, but this is an excess, an unnecessary virtuosity. Indeed, almost all the model presented here are in plaster, and just some little parts are in painted cardboard; the difference between reality and trick is so inappreciable to be non-substantial. Once the *Bishop House* (base of 5×5 mm for each house) was realized in plaster, the problem was no longer to be able to build it, but simply to do

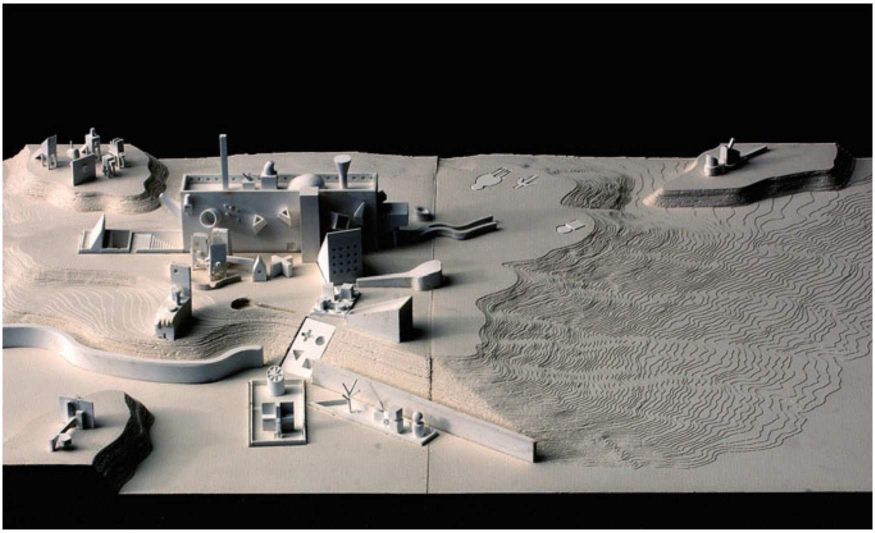

Fig. 8.7 Cathedral model (*credits* The author)

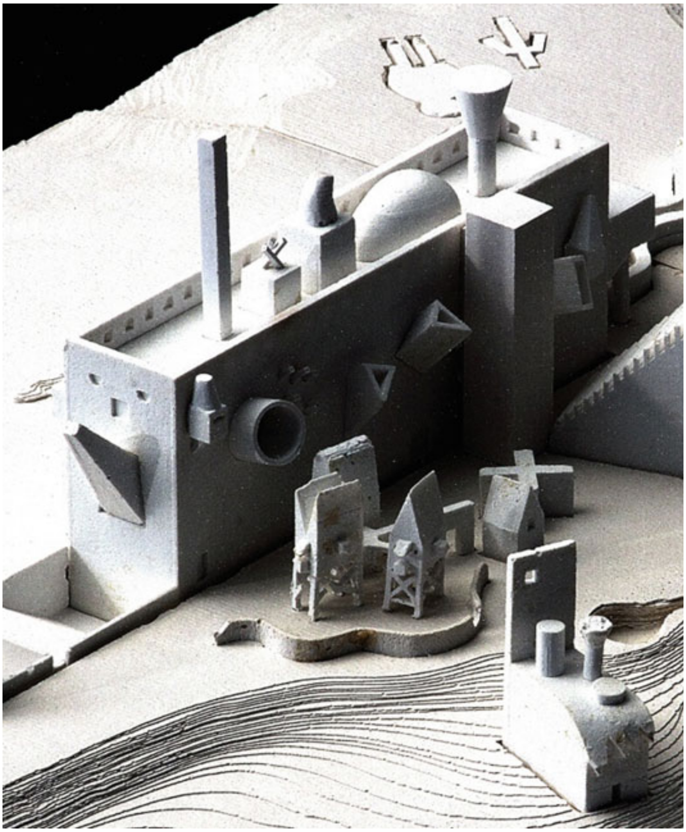

Fig. 8.8 Cathedral model. In the center, the three divided parts Bishop House (*credits* The author)

it. Barriers had been overcome by technique. More in detail, the simply solution of white colored cardboard was enough. I experienced at the same time two things: first, the plaster was not the right material to represent John Hejduk's architecture, thus the research had to take another direction; second, perhaps more important, the technique had overstretched the goal. The medium had overcome the purpose demonstrating that this was possible, even against the nature of the represented things. The medium was not anymore a medium, but a purpose in itself.

The attempt to retrace the known path with plaster models, had been demonstrated as the wrong way. The method, although objectively valid, has to be declined within the character of what the model has to represent. The relation between medium and purpose can not be rescinded. Otherwise the technique, separated from the purpose, due to its authentic essence rather than to the human intention, finds anyway its own way, indifferent to the maker purpose. Once again, the technique can not differ from the character of what it attempts to show. The more the medium and the purpose are coherent, the greater the effectiveness of the representation and its usefulness as part of the method will be.

Conclusion

Cristoforo Colombo "*believes, just landed, to be where absolutely is not. Until near the end of his days, (until fourth trip) will be convinced that he had reached China. And this because his only concern is to match what he sees with the model he has in his pocket, the map prepared by Paolo dal Pozzo Toscanelli, that he received through the king of Portugal. So is the world that must, to work, coincide to the model and not* vice versa*. This is precisely the essence of modernity: first is the model then reality*" (Farinelli 2001).

The relationship between model and building, medium and purpose, representation and reality, contains the theme of experience. Since it is possible to experience a model or an architecture, it is also possible to refer to a design method based on models able to express their relationship with architecture. Experiencing brings the relationship to a condition of reality, such as the model does with architecture. In this sense, the model is as real as the building and as the relationship between them. We can conceive the world as a representation, as Schopenhauer taught. However, sometimes we should also think that representation is part of the world. Maybe, the world is simply made of representations, not metaphysically but concretely, since each representation is at the same time a concrete part of this world.

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Chapter 9
Architectural Modeling in a Fab Lab

How Computer Numeric Control (CNC) Machines and the Open Source Approach Are Changing the Way to Realize Architectural Models and Design Projects

Alessandro Capati

Abstract New technologies and the open source approach of the fab lab movement are changing the way of making and designing objects, and even buildings, all over the world. Innovations in software for architecture have changed our perspective on architectural design, and similarly procedures based on Computer Numerical Control (CNC) machines manufacturing are changing our approach to construction. In fact, thanks to these technologies, it is possible to experiment a new kind of modeling, while rediscovering the great support of architectural physical models during the design process beyond its role of final presentation media. The chapter firstly introduces a general overview on the fab lab approach and the specific case study of Barcelona; it then presents a comparative analysis of additive, subtracting, and cutting technologies of modeling, namely: laser cutting, 3-D printing and milling.

Keywords Fab lab · Architectural model · CNC machines

Introduction: What Is a Fab Lab?

Fab lab is the abbreviation of fabrication laboratory, and it identifies "*a small-scale workshop offering (personal) digital fabrication*" (Menichinelli, 2011); in the words of Neil Gershenfeld, the professor who founded the first fabrication laboratory at the *Massachusetts Institute of Technology* (MIT), "*it is generally equipped with an array of flexible computer controlled tools that cover several different scales and various materials, with the aim to 'make almost anything'*" (Gershenfeld, 2005).

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Neil Gershenfeld leads the works at the MIT *Center for Bits and Atoms*, that studies the relationship between software and hardware, virtual and physical, design project and its realization, tangible and intangible, together with the usage of innovative machines and sharing knowledge approach. Hence, it is not surprising that in this environment the first laboratory for digital fabrication, where 3-D modeling meets the physical tridimensional production, arose.

Fab labs are places where everyone has the opportunity to improve his/her knowledge through the making of things, with a learning by doing approach. Among the characteristics of a fab lab, the key one is its non-conventional approach that should be shared by each structure. In fact, every fab lab must subscribe a charter, published on the structure website and in the laboratory itself, containing few simple rules to follow that guarantee to become part of the global fab lab movement (The Fab Lab Charter, 2012). For instance, public access to the fab lab is essential, this a crucial step for the democratizing process typical of these laboratories: proving access to tools for personal expression and invention; hence, a fab lab must be open to the public, at least part of the time each week, for free. Furthermore, the laboratory should be part and collaborate with the larger, global fab lab network. This implies that it is crucial to take part of a worldwide knowledge-sharing community, that is animated in several ways; for instance, it is possible to attend to videoconference, or to the annual fab lab meeting, and of course it is a network for fostering collaboration and partnering with other laboratories, through workshops, projects or similar. Finally, a list of open source and freeware software are accessible online: the idea is that all the laboratories might share their knowledge and collaborate across international borders by speaking the same language. Every fab lab has its own single identity, but it is important to have some rules that at the same time give importance and identity to the movement.

In the past century we were used to an aggressive patenting approach after an extensive knowledge sharing during history. In our time, the open source movement is generating a paradigm shift towards principles of open design and free software, in one word, towards a sharing approach. It is possible to notice that professionals in the architectural and engineering fields are more and more open to a collaborative development approach (Ratti, 2014); this process is fostered and supported by the rapid diffusion of 3-D making, that supports a fast sharing of ideas and concepts presented in a tridimensional visual manner.

It is clear that, in the last decade, there has been a rapid increase of websites for sharing files and tutorials. Part of this growth was related to the making approach, that fosters the self-made production of objects thanks to the reproducibility granted by *Computer Numerical Control* (*CNC*) machines. This wave of change related to the open source approach is similarly influencing the design field, and the community of designers who share architectural and structural design projects is growing rapidly (see for instance OpenDesk, WikiHouse, Open Architecture Network). Several tools and resources are already available for producing 3-D models and high-quality architectural renders; today, thanks to the collective intelligence and the manufacturing technologies, it is easy, fast and effective to make architectural scale models as well. As internet is the virtual space that enables knowledge sharing, fab labs are the physical places of this exchange, places where collaborative design projects can become reality by using machines with a creative and open approach.

Architecture and Fab Labs: The Barcelona Case Study

The *Fab Lab Barcelona* of the *Institute for Advanced Architecture of Catalonia* (IAAC) is a relevant and emblematic case study that demonstrates the close relationship between architecture and digital fabrication. Here, the first fab lab of Spain took place, thanks to the intuition of the Director of IAAC *Vicente Guallart*, and the work of a professional from Venezuela, *Tomas Diaz Ladera*. The center, that has become a platform for knowledge exchange between scholars and students, investigates the possibilities of digital fabrication as an integrated set of skills to be given to students but also to citizens, in order to democratize the design process and to innovate the modes of production. Of course, this kind of process contributes to drive the research towards new kinds of solutions and ways of expression in architecture, and it will finally probably lead to drive the change of the construction sector as well. This Catalan fab lab is one of the most important all over the world, a reference for the *maker* movement. By putting in evidence the importance of digital fabrication for the design process, it became a unique case within the panorama of the schools of architecture.

A relevant work developed by the Spanish group is related to the design project of the *Fab Lab House*. This house, that is the result of the collaboration between IAAC and the MIT *Center for Bits and Atoms*, was submitted in 2010 in Madrid to the *Solar Decathlon Competition*, an international competition that aims to foster design and houses construction powered exclusively by the sun. This house represents not only a novel concept of solar house, overcoming the traditional building with solar panels on top and other technologies inside the envelope, but even the first application of CNC technologies on construction, from the design conception to the realization. The *Fab Lab House*, produced at IAAC by a team of students coming from all over the world, was designed in order to be built by parts assembled on site; during the design process the model produced in the laboratory was in scale, so the physical mock-up was an exact copy of the final realization. According to the fab lab philosophy and the democratization of production, the goal of the *Fab Lab House* was to design a house that was innovative, sustainable, and economic, and that could be carried out by everyone everywhere in an easy way. In fact, it can be produced by using CNC technologies starting from shared design projects, that can be simply downloaded from the Web and modified according to the personal needs (Fig. 9.1). The conscious use of these technologies allows to shift the design and construction traditional perspective into one that considers citizens as creative and productive actors, and not only as final consumers (The Fab Lab House 2011).

Fig. 9.1 The Fab Lab House, exterior and interior (Forgemind ArchiMedia | MisoSoupDesign X IaaC—http://forgemind.net/phpbb/viewtopic.php?t=22058)

Technologies for Modeling

A big fab lab generally has an extraordinary equipment: large format machineries, molding and casting, laser cutting and engraving, video conferencing, vinyl cutting, electronics productions, 3-D scanning and printing, beyond specific software and hardware for programming and designing; unfortunately, not every fab lab has the possibility to provide all these tools. Anyway, it is always important to be aware of machines behavior and features in order to properly support design thinking, evaluation and communication related to architectural or urban design projects. Tools limits and potentialities have a direct impact on design outcomes, and history teaches us that these often lead to new ways of expression (Gebhardt, 2007).

The technologies mostly used in fab labs for making architectural models, operate on three main manufacturing processes: additive, subtracting, cutting. *Additive manufacturing* is a method that works by depositing material in layers, and it is generally named *3-D printing*. *Subtracting manufacturing*, on the contrary, removes material in order to obtain objects; this process is also known as *milling*, and three axes or more are needed for achieving a good result. The third method does not remove nor add anything, but it cuts materials in parts, which can then be assembled; there are different technologies of *cutting machines* such as water cut or plasma cut, but the most commonly used is the *laser cut*.

Below, I present a comparative analysis of the characteristics of the different tools and methodologies associated to possible models outcomes. By comparing these approaches to making, it is possible to depict a synthetic framework that can support the definition of the proper tool to use according to specific needs and phase of the design process.

Laser cutting is able to cut materials thanks to high-power laser technology, typically a CO_2 laser. The cuts follow a vector drawing and are controlled by a computer (Fig. 9.2). With a laser cutter it is possible to cut several materials, such as Plexiglass, wood and plywood, cardboard, or rubber, but it is not possible to cut PC or PVC due to their pollutants fumes, and glass or metal for the intrinsic characteristics of these materials; with other kind of *Computer Numerical Control*

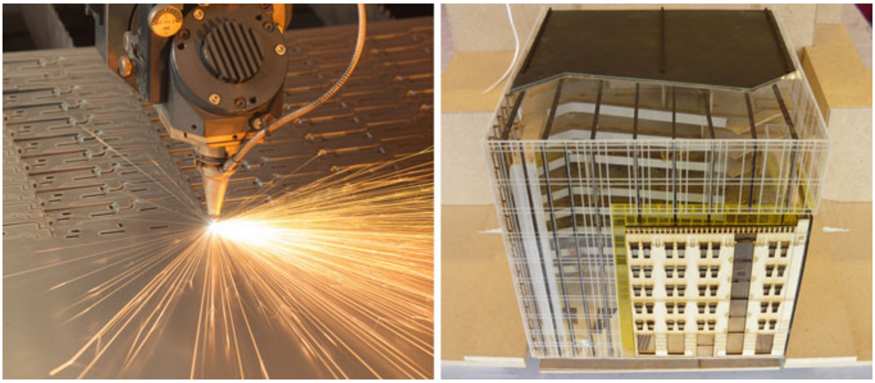

Fig. 9.2 Laser cut at work (*left side*) and 3-D architectural model by laser cut (*right side*: Fablab Den Haag—https://www.flickr.com/photos/cabfablab/3619777473)

(CNC) cutter, like plasma, or even better water cut, it is possible to cut almost everything with a huge thickness.

Designing being conscious that the production will be done with a specific machinery is crucial; for instance, knowing that the product will be produced with a laser cutter essentially drives to a bi-dimensional based design; in fact, the process of the machine reminds the one of drawing on a plane surface. Hence, to create a construction using a laser cutter, it is important to well focus that the construction will be made by joints and nuts, in order to enable the assembly. The diffusion of parametric architecture and software, such as Grasshopper, is contributing to the spreading of this kind of tools. In fact, these permit to control complex forms and structures, in scale models as in reality. Grasshopper is a software for professionals, but it is meaningful that a big software company, such as Autodesk, developed some applications to improve user capability to make things through digital fabrication; this is for instance the case of *123-D Make*, a simple tool which allows to easily transform a 3-D model and to reproduce it defining the number of slices, directions, or other elements; these kind of user friendly solutions enable everyone to approach model making, without the need to refer to an expert.

The laser cut is helpful for architectural modeling because it is direct and simple to use, it works with cheap materials and it is highly precise, so that it is also possible to draw with laser. In fact, cutting machines are used also in construction, and that is changing the way we design and conceive facades and shells of buildings: it is now possible to design something that will be exactly reproduced in real scale by machines, and that will be directly assembled on site (Beach 2015).

3-D printing works with successive layers of material that are laid down on a surface under computer control; for this reason, it is also named *additive manufacturing*. A large range of materials, that moreover are always evolving, can be printed, but the most widely used are plastics, such as PLA and ABS, or powdered material. With professional 3-D printers support material, machineries that blows the material away by washing after the manufacture, it is possible to produce printed object without errors and with perfect structures, and it is almost possible to realize any imaginable form. To print a model, it is possible to use common 3-D modeling software, such as Rhino, 3-D Studio Max, Blender and others; nevertheless, software that exports to. *stl*—the format file for printing—are becoming more and more frequently adopted. In any case, it is important to remember that when we design something that has to be printed, it is necessary to think in solid bodies and not in surfaces, as it happens in construction.

3-D printing is considered as the next manufacturing *Big Thing*; infact, since its arrival, it brought a revolution that changed the relationships between products and production. It is even possible to envision that, in the future, there will be a small factory in our house or close to it, and that we would not need to buy something as we do today, but instead it will be possible to simply download a file and print the object out. In the architectural and design field, this process enables to make scale models creation easier and faster for verifying design projects. It is probably not exaggerated to envision architectural offices using 3-D printer as a common design tool, as it happens nowadays with printers or plotters.

As occurs with every new technology, 3-D printing does not only allow to make part of the work easier and faster; in fact, while affecting procedures and processes, design thinking is changing as well. As a matter of fact, what we could just imagine before is becoming real: 3-D printing is making possible to realize forms and structures not conceivable until today, thus opening new possibilities while widening our abilities (Fig. 9.3). Unfortunately, today 3-D desktop printers are affordable but not yet reliable enough, while professional printers are expensive, with limited dimensions of printing and high costs of materials, and this of course contributes to slow down the entire process of change. Moreover, 3-D printing is modifying the way we conceive constructions; it is not a case that in several laboratories all over the world, researchers are studying how to print out the constitutive parts of a building directly in the construction site, almost without workers. We can thus easily assume that at the large scale digital fabrication will bring massive changes in the construction sector.

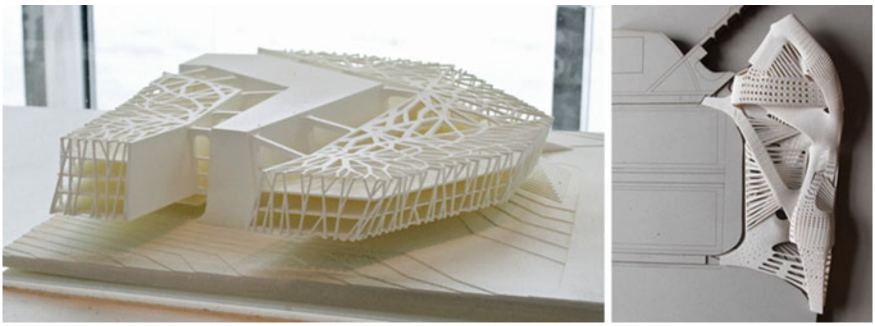

Fig. 9.3 3-D printed "Rapid Architecture" (*left side*: Jon Olav Eikenes—https://www.flickr.com/photos/jonolave/4385225489) and 3-D model by Yuanyang Nour, Studio Jonas Coersmeier, photo by Zirui Roy Zhuang (*right side*)

Milling machines use rotary cutters, that generate small circular movements around the cutter axis, in order to remove material; this tool is generally able to cut in different directions with different angles, but this depends on the number of axes

Fig. 9.4 3 axis CNC milling at work (*left side*: https://gmik.files.wordpress.com/2008/09/2-1.jpg) and landscape milled 3-D model (*right side*: Chair of Prof. Cristopher Girot, Swiss Federal Institute of Technology—http://girot.arch.ethz.ch/tag/innovation-landscape-architecture/page/5)

Fig. 9.5 One main office, dECOi Architects, Boston (*left side*: Ph.Anton Grassi—http://www.decoi-architects.org/wp-content/uploads/2011/10/OneMain_dECOi-Architects_036.jpg) and 3DS culinary Lab, Oyler Wu collaborative (*right side*: http://www.oylerwu.com/3ds-culinary)

Fig. 9.6 Architectural model by Alessandro Capati and Manuela Gualtieri; the model has been made only with CNC machines as 3-D printing, laser cut, milling machine, water cutting

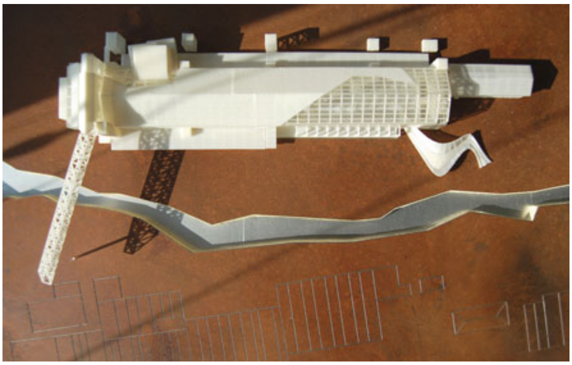

Table 9.1 Table showing differences and characteristics of the main digital fabrication facilities of a fab lab (*credits* The author)

Technology	Manufacturing	Materials								Software	Advantages	Disadvantages
		Plexiglass	Wood and plywood	Cardboard	Rubber	Foam	Plastic	Metal	Others			
Laser cutting	Cutting									CAD and CAAD (AutoCAD, 123-D Make, etc.) Vector graphics (Illustrator, Corel Draw, etc.)	Ease of use High precision Drawing the surface Cheap materials	Burned surfaces Construction by joints and nuts Limited materials
Milling	Subtractive									3-D modeling (Rhinoceros, 3-DStudioMax, etc.) Procedural modeling software (Grasshopper, etc.)	Free forms modeling Surfaces accuracy (especially if 5 axis) Cheap materials	Large amount of scrap No empty solids Difficult to model bearing structures
3-D printing	Additive									3-D modeling (Rhinoceros, 3-DStudioMax, etc.) Procedural modeling (Grasshopper, etc.) Additive fabrication (Autodesk Netfabb, etc.)	Ease of use Free form modeling Perfect modeling of bearing structures	Limited dimensions Materials cost

each tool is able to work with. In fact, it is possible to find on the market a wide range of machines with different characteristics. The process of controlled material removal is known as *subtractive manufacturing*, in contrast with the processes of controlled material addition, typical, for instance, of 3-D printing. It can be useful for several types of productions, from small scales components to larger parts (Fig. 9.4). Wood and plywood are materials typically used with this kind of tools, but in order to model large surfaces, foam is generally the best material to adopt; moreover, milling a piece of foam is easier and faster than milling a piece of wood. In order to produce a durable surface, it is possible to coat it with polyurethane foam, polystyrene foam, or other kinds of foam.

Different 3-D software can be adopted to model the reference drawing for the milling process. Rhino 3-DM files, for instance, can drive the milling in order to produce a model out of a volume of raw material. This technology is particularly suitable for producing solid freeform shapes (Fig. 9.5); in fact, it is able to manufacture highly accurate products, especially if the machinery can work with 5 axes (Fig. 9.6). On the contrary, it is difficult to model voids within a solid, and the same can be said for structural elements; moreover, while milling a large amount of scraps is produced .

To sum up, it is possible to synthetically compare the key characteristics of the cutting, subtractive, and additive manufacturing possibilities as in the Table 9.1.

Conclusion

The use of conventional drawings and other kind of visual representations, such as plans or renders, can be fruitfully integrated by physical 3-D models. These can support design thinking, evaluation or communication even with the lay public, thanks to the real volumetric configuration that makes easier the understanding of the three-dimensionality of an environment. Today, thanks to digital manufacturing and CNC machines, it is possible to consider architectural physical models as a direct output of digital 3-D models: virtual and physical objects or spaces are on a converging path, and this is a great opportunity for supporting the design process in all its phases.

In particular, the production of digitally manufactured models from the early phases of the design process, can produce a positive and significant impact on the architectural solution development. In fact, referring to physical tridimensional models provides a peculiar insight that adds a major creativity and concreteness to the design ideas; indeed, the possibility of manipulating a model can play a crucial role in improving the understanding of the tangible outcomes of a design project. This increases the analysis capability of the designer and favor the understanding of private or public customers. In other words, it represents a strong form of communication that, while easing comprehension, it indirectly supports a learning process by linking flat images to the related volumetric configuration. Fabrication is widening the toolkit of designers and it favors experimentation; in fact, due to the digitalization of making, modeling do not require a professional manual skill anymore, and the process of making is increasingly becoming easier, faster and accessible; this should encourage the application of digital manufacturing in design from the very beginning of the process, i.e. the conception phase.

Furthermore, digital fabrication facilitates research and findings of novel forms of expressions, especially in terms of freeform surfaces (Aigner and Brell-Cokcan, 2009); hence, it is possible to argue that, as already happened in the past, technology is influencing architecture. As a matter of fact, parametric design made possible to generate amazing structures, and now large-scale 3-D printers are enabling to increase the complexity of these solutions in practice, widening the possibilities of construction technologies over the limits known until today. Thanks to the growing fab lab movement, these technologies are every day more affordable, so fab labs might become a new reference for architecture, especially if CNC fabrication will become a generalized solution adopted from the early stages of design.

Finally, the open source approach typical of the fab lab movement could lead architects and designers to work in a shared way; this would be another great revolution for design, that would move towards a more collaborative and democratic approach. Nevertheless, this is a process that is already part of the social and cultural evolution we are living, and undoubtedly the sharing approach is increasingly spreading in several sectors. Web-platform where to share knowledge about making are also growing rapidly, and this collective collaboration is exponentially expanding the capabilities in different ways, i.e. from design conception to production, from construction companies and professionals to privates and final users.

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Chapter 10
Daylight Simulation

Giulio Maria Podestà

Abstract Architects simulate the daylight with two main objectives: design and assessment. In the design process, the evaluation of the lighting environment due to the natural light can help the designer team to decide the orientation, the building masses, the type of envelope, the type of light redirecting devices, etc. This is a very interactive process, where design team generates many different solutions to be evaluated in respect to visual comfort and energy performance. In the assessment process, the evaluator seeks the compliance of the design to the norms (e.g. LEEDS, etc.). The evaluator is a professional that applies the rules of the norms to evaluate the performance of the building under investigation. During the design process, often have collaborators—analysts—are hired to perform high-quality lighting simulations. The design team requires the result of the evaluation as soon as possible and with an accuracy correlated to the scale of the design phase. This is possible if the analyst is, permanently or temporarily, inside the design team. In the compliance process, instead, the evaluator documents every steps of the analysis process, because every assumption must be described and every simplification justified. The text presents procedures, tools, methods, and case studies for supporting the design or compliance phase in daylighting simulation for architecture.

Keywords Daylight simulation · Physical model · Architecture

Introduction: Daylighting Tools

The tools, available on the market, reproduce the building under investigation with a mathematical model or a physical model, eventually on scale. The mathematical model based, that is a computer simulation tools (e.g. DIVA for Rhino, Lighting Analysis for Revit, Ecotect with Radiance, IES VE, COMFEN, Sefaira, Openstudio, Ladybug and Honeybee for Rhino, eQuest, Designbuilder, etc.) are the most

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common in the architectural practices. Physical model base tools (e.g. heliodons, artificial skies, solar simulators…) are instead commonly used in the university laboratories, and are recently expanding in the major architectural lighting design firms.

Most of the mathematical tools, that is software, work very satisfactory for the compliance evaluation, because the software can be easy tailored on the requests of the norms and every step of the process can be documented at the requested level of detail. Further, the analyst is a professional that do daylight analyses nearly all the day and can spend time to learn tools with steep learning curve. This is similar to what happen in the field of structural analysis with the use of finite element analysis software and ventilation analysis with the use of computational fluid dynamic software. Software, thanks to their user interface and large availability seems simple to use. Unfortunately, when the accuracy of results is required, any time you have to make design decision, the user has to know the software inner mechanism of calculation and of course its limits. This explains why many designers incorrectly believe to be able to evaluate the daylighting (and the electrical lighting) with ease, and in very fast way.

Currently, many large firms (those with more than 500 designers) to evaluate daylighting during the design process (Anderson, 2014) employ a small group of analysts with a big and solid IT infrastructure, that is equipped with a lot of hardware and software specifically optimized to evaluate at the highest speed the setting conditions. The professionals of this small group of lighting analysts are rented in the early design stage to the design team and support the inner evaluation process (Fig. 10.1). They can answer to specific questions, such as: where should

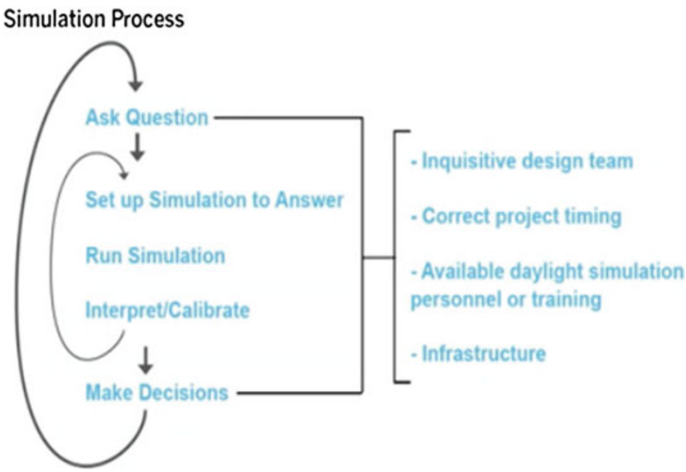

Fig. 10.1 Kjell Anderson, LMN Architects, Seattle. Greenbuild International Conference & Expo 2014. Importance of time, usability and accuracy (from 16:48 https://www.youtube.com/watch?v=gE4Fs9b1XWI)

desks be located according to daylighting levels? What is the optimal geometry to balance daylight with envelope performance between alternative scenarios?

Thanks to the deep knowledge and the availability of a first class IT infrastructure, the analysts can find answers in maximum 30 h.

Instead, the physical model based tools are very fast, near real time, because the interaction between natural light and the scale model is simply reproduced and not modeled. They are the ideal tools in the design process phase. They also permit to evaluate directly, without intermediation of numeric simplification, the visual comfort of a particular solution. For their innate accuracy, the researchers use them to evaluate and validate old and new algorithms. However, their high cost of purchase and maintenance restrict their availability to laboratory of major universities. However, the ongoing electronic advancements in the field of robotic, lighting and controls, is reducing the cost of maintenance thus enlarging the user base. Recently, some of the largest lighting and building service engineer firms in the world are being equipped with new physical model based tools.

Simulation Workflow

Regardless of the purpose of the simulation and the tool that will be used, the workflow of any daylighting simulation usually goes through a number of standard steps: (1) design of the experiment, (2) construction of the model, (3) instrumentation, (4) simulation, (5) collection of data, and (6) analysis of data. The process starts when the design team develop an architectural design concept (or alternatives of design solutions) that need to be evaluated with regards to daylight performance and the luminous environment resulted from their design and how it affects important issues such visual comfort, daylight availability, energy consumption, etc. These questions are communicated to the daylight analyst, who could be a member of the same design team or works in a separate entity, usually through a design workshop. The analyst must understand clearly the questions that need to be answered by simulation and select the best (i.e. most representative) performance parameters that can help to answer the raised issues.

Once all the requirements are communicated clearly to (and understood fully by) the analyst, s/he can proceed to the design of the daylight simulation experiment. For example, we can imagine that the design team wants to identify the zones that could be lit by natural lighting, with sufficient lighting requirements, and have good views in a building located near the equator. The analyst in this case can evaluate illuminance levels on the task surface at the height of the desk in chosen critical dates (such as the summer solstice) and the quality of the occupant views. Two important decisions are usually made at this point: selecting the measurement metric (e.g. illuminance level in terms of Lux) and the method of simulation (computer or physical tool). The selection of the metric is very important because it determines the significance of the answer and the time taken by the simulation.

The chosen metric defines the type of sky luminance distribution to use, and helps in the selection of the best tool in terms of speed and simplicity of the simulation.

The next step is the construction of the model. The model can be a mathematical model in CAD software, or it can be a physical model of a building produced to a certain scale, that should be of course suitable to evaluate the luminous environment under study. The CAD model must be enriched by materials and often requires improvements to optimize accuracy and simulation speed. This sometimes requires to redevelop the model from scratch. This step cannot be automated, and it usually requires a great deal of knowledge and experience. For physical-model based tools, this is the most expensive step in terms of time.

The instrumentation of the model is the third step of the simulation workflow. In this step, the analyst places real or virtual sensors in the model to measure performance variables; which is normally illuminance. Usually this step is done quickly in the case of computer simulation, while it requires longer time and greater efforts in physical-model simulation tools. However, if the instrumentation is planned thoughtfully during the model construction, this step can be optimized to achieve accurate results with a reasonable amount of time and effort.

The simulation is the step where the tool selected makes the most difference. Mathematical model based tools are the longest ones and require a good IT infrastructure. It is the step where the analyst must understand what has to be done in the finest details, and has to continuously compare that the simulation output is congruent with the output of another alternative method (e.g. manual models). Physical model based tools are the simplest and fastest step. In fact, these do not require any knowledge by the analyst, and the accuracy is only correlated to the precision of the model and the quality of the instruments available. The collection of measured data is an automatized—or at least simplified—step, thanks to the use of analysis software such as spreadsheet software or other specialized packages (Matlab, IDL, etc.).

In the last step of the workflow, the data analysis, the analyst studies result and synthesizes the outcomes to answer the questions of the design team. Generally, the answer is long and structured, in order to allow the design team to start working and evaluate the complex and nonlinear lighting phenomena against other project variables, such as form, costs, and so on. This workflow is continuously repeated during different design phases, in order to evaluate different parts of the building, or in the same design phase to compare different scenarios. For instance, in a design phase aiming at defining building orientation and masses, the designer team could elaborate four different scenarios. The analyst can classify these considering the daylight autonomy, and thus suggesting a privileged solution. The designer team can then opt for the second classified because of shape and not-so-bad performance, or in alternative evaluate other scenarios obtained by the modification of the first classified. The paths for the design process are of course infinite, but each step can be supported by a scientific (repeatable and documented) lighting analysis that support the improvement of the outcomes quality derived from choices.

If the steps of the workflow are common to the all tools available, the content of each depends dramatically on the tools available. Now, we focus our interest on the physical model based tools because, as we saw before, these are potentially the best for supporting the design process.

Physical Model Based Tools

Simulations run on physical models have two main advantages: direct perception and real-time speed. Hence, the results can be evaluated by the designer team directly, while the simulation is running, similarly as it would appear in reality. This is very powerful because cameras and screens today available are limited in capturing and reproducing real environment in terms of brightness, field of view, etc. Furthermore, the interaction between the light and the model is physically replicated, as in the real world, and thus happens in real-time. The physical model based tools available are different in terms of ability, accuracy, size and cost. From the designer point of view, we can classify them according to their ability to evaluate different natural lighting aspects.

The main physical model based tools today on the market are: heliodons, artificial skies, solar simulators and color sky simulators, as follows (Table 10.1).

The heliodon simulates the sun light, and it represents the simplest physical model based tool. The reproduction of the apparent sun movement can be achieved in three different ways, depending on the tool: (i) by moving the light; (ii) by moving the model; (iii) by moving the light and the model at the same time. The motion can be manual or automatic with the use of a robotic platform or arm. With the heliodon, the analyst can perform sunshade study, where it is possible to investigate the interaction between the geometry of the setting and the sun path; typically, these are evaluated at the three major dates: equinox, and winter and summer solstices, and at four different hours: 9, 12 AM, 3 and 6 PM; this is done in order to get twelve simulations that are representative of an entire year. The heliodon in outstanding in evaluating geometric relationships (sunlight penetration and shadow lines); the model requirements are geometric accuracy of the design solution inserted in its urban context, while the surface finishing is secondary. Rarely the heliodon, if not used together with other devices, is used to measure the light level inside the scale model. The simulations are generally experienced directly and documented with photos and/or videos.

Table 10.1 Main physical model based tools (*credits* The author)

Tool	Parameter/metric	Analysis	Measurement device
Heliodon		Sunshade	Photo, videocamera
Artificial sky	DF, DA, DGI, DGP	Daylight	Luxmeter, photo, videocamera
Solar simulator	U-factor	Spectrum	Spectrophotometer, thermometer, luxmeter, photocamera
Color sky simulator		Chromatic	Videophotometer, spectrophotometer, luxmeter, photo, videocamera

The *artificial sky* is another tool, more complex than the heliodon; it reproduces the light coming from the sky vault only. This is the workhorse of the physical based model tools. There are different models of artificial sky: mirror box, full dome and virtual dome. The mirror box is able to reproduce the standard overcast sky quite accurately, and thus used to determine Daylight Factor (DF). It is the cheaper and more compact of the artificial skies. The *full dome sky* is able to reproduce other type of skies as well, such as: clear, intermediate, statistical, weather based; thus it is able to determine, in addition to DF, the Daylight Autonomy (DA) and glare. It is expensive and large, but it is the fastest and the more realistic. It is ideal to assess, in real time, lighting perception in terms of glare in complex and unusual situations, and other aspects of the light environment. The third type of artificial sky is the *virtual dome*; this is more recent, in fact it was introduced in the early nineties, and it reproduces the sky vault with a scanning process. It makes use of a heavy robotic and fine control systems in order to reduce costs and space consumption. Potentially, this is the most accurate tool, but the direct perception of the simulations is not possible. In fact, the simulation outcomes can be evaluated only through a computer screen, after a process of combinations of multiple simulations. The missing direct perception of the light effect makes this a tool for scientists and not for designers. In short, the simulations done in the artificial skies are directly experienced, with the exception of the virtual dome sky type, and data is captured with lux meters; secondary the outcomes recording is done with photo and video cameras.

Another more accurate physical model based tool is the *solar simulator*. This is a tools commonly used in engineering and physics departments of companies devoted to develop and design photovoltaic technologies, special coatings, plastics for outdoor use or sun cream protectors. Starting from the beginning of the third millennium, the most advanced research facilities in architectural design began to use this kind of simulators. These are able to reproduce a nearly collimated beam of light with a quantitative spectrum similar to the direct solar radiation on earth. Their reliable performances in time and space allow researchers to study complex fenestration systems, where material, with characteristics changing with the wavelength of the incident sun light, are used. Thus, for the first time, this tool enables to directly evaluate in real time how a particular coated glass panes or a thin film influences the transmitted and reflected sunlight. This kind of simulator represents an opportunity, never seen before, to study, in the early phase of design, extensive complex fenestration systems that make use of the latest products available on the market, e.g. the materials coming from the latest development in the field of the photovoltaic industry. The simulations run with this tool are directly experienced and captured with spectrophotometers, that is sophisticated instruments able to measure the spectrum of the incident light; secondly, the recording of outcomes is done with lux meters, photo and video cameras. The solar simulators can be also used for evaluating thermal properties; in this case, the best sensors are thermometers and thermographic cameras.

Another advanced physical model based tool is the *color sky simulator*. This simulator reproduces the light color coming from the sky vault, increasing the realism and the accuracy. It is the best tool every time the designer wants to investigate the color of the building surface. The simulator can be considered as one of the types of the standard artificial sky described before, but it has a more complex control and lighting system. The color artificial sky is the most immersive tool and makes novel chromatic designs easy to evaluate by direct perception. The best measurement device for capturing and recording the experiments using the color artificial sky is the video photometer, a special video camera accurately calibrated to measure luminance values. As with solar simulators, spectrophotometers, lux meters, photo and video cameras are helpful.

The six steps of the daylight analysis workflow are: (i) experiment design, (ii) model construction, (iii) instrumentation predisposition, (iv) running of the simulation process, (v) data collection, (vi) data analysis. Among these only the steps: 2, 3 and 4 require special consideration, as described below.

The first concern regards the model construction; in fact, the accuracy and properties of the scale model geometry and surface directly affects the reliability of simulations. Table 10.2 describes the relationship between the goals of the analysis, the proper scale model and the main tool to use.

The purpose and the available budget should be balanced and will of course have an influence on the scale—and the quality of its details—of the model. The paradox is that, in an ideal condition, the model should be the smallest as possible in order to reduce the simulation parallax error, and at the same time, the largest as possible to

Table 10.2 Relationship between the scale of the model and purpose of the analysis (re-elaboration of Schiler 1987 and Bodart 2006)

Simulation outcomes (investigating the effect of…)	Purpose	Scale		Main tool
		Smallest	Largest	
Site conditions in terms of daylight and sunlight access, or distribution to the building	Assessing the building response to existing conditions	1:200	1:100	Heliodon artificial sky
Shapes, sizes, locations of windows, skylights, structural elements and general shapes of interior surfaces based on quantity and quality of daylighting	Developing an enclosure system in order to relate exterior conditions to internal requirements	1:50	1:5	Heliodon artificial sky
Enclosure and internal components based on the quantity and quality of daylighting	Defining envelope treatments	1:25	1:10	Artificial sky solar simulator color artificial sky
Spectrometric, photometric and qualitative outcomes of the design solution	Interior spaces	1:5	1:1	Artificial sky solar simulator color artificial sky

increase the details and the relative geometric accuracy, allowing sensors and camera placement. Hence, a good balance between the two is relevant, and it depends on resources at hand and the specific objective of the design phase. In any case, it is important to carefully plan and design the model construction process before starting its fabrication, so that it can serve the purpose of simulation. A valuable scaled model design project must accommodate the sensors in the right locations, facilitating the use of borescopes and/or micro-cameras in different directions; this can enable to take effective views from inside and outside the mock-up. Moreover, the model should provide a high modularity/flexibility level in order to allow to evaluate different scenarios reusing most of its parts. From the experience collected by several researchers the *Daylighting Network of North America* (DNNA) of the *Department of Energy* (Schiler 1987), it is possible to summarize some rules of thumb that can support designers/analysts in selecting the best scale and level of detail of models, based upon the simulation purpose (see Tables 10.2 and 10.3).

Table 10.3 Models' scale in relationship to the purpose of the analysis (re-elaboration of Schiler 1987 and Bodart 2006)

Simulation outcomes (investigating the effect of…)	Required details	Modularity
Site conditions in terms of daylight and sunlight access, or distribution to the building	Building and site geometry Accurate building and site reflectance (windows can be drawn on surfaces)	Building massing
Shapes, sizes, locations of windows, skylights, structural elements and general shapes of interior surfaces based on quantity and quality of daylighting	Accurate geometry of building envelope and major interior partitions Accurate geometry of window and skylight openings (no fenestration detail) Accurate interior and exterior reflectance General massing of interior furnishings Window and skylight translucency for the diffusion properties	Shape and location of windows and skylights Shape of structural elements Shape of the major internal surfaces
Enclosure and internal components based on the quantity and quality of daylighting	Accurate interiors of windows and skylights and relevant exterior fenestration elements All surfaces have to be representative of transmitting quality and surface character Interior furnishings should be modeled as closely as possible	Fenestration assemblies Glazing Interior surface finishing
The proposed final design in terms of spectrometric, photometric and qualitative	As much as possible	Minor details

The proper equipment for every modern model-making laboratory is a 3D printer and a small CNC machine (see Chap. 9). When analysis purpose is general, designers can use simpler and less expensive models. These models are usually built of Styrofoam boards, fixed with glue or tape with the windows simply cut in the boards, without depicting many details. The use of 3D printers increases the models geometric accuracy, and speed-up construction, easing the hardest step of physical based tools daylight workflow. The models produced by 3D printers are accurate enough for the highest precision analysis; furthermore, these are very easy to use, in fact the designer can print out a 3D model in the same way s/he prints a drawing on paper. This process allows the model maker to reduce the number of tasks, e.g. the selection of tools, the change of raw material, the calibration of the machine, etc. The only required operations are to structure the model in order to be printed in parts, and consequently to assemble its parts together. When it is designed with modular components, the process allows to make large mock-ups in order to evaluate different scenarios. The precision of the model is in the order of 0. 1 mm (CNC machine); hence, if the measurement tolerance on real building is 2 cm, this means that we can work respectively with a scale model of 1:200 made by a 3D printer or of 1:2000 made by a CNC machine.

The modeled surfaces must correspond to the real final surfaces, in terms of light reflection, absorption and transmission (the permitted tolerance is 5–10%). If chromatic evaluation is required, the color of the material must be very similar to the real one (e.g. a piece of marble for the floor, plaster for the ceiling, etc.). Moreover, windows glass pane and the skylights should be modeled in relation to the required accuracy, in fact, for instance, these can be omitted for mass studies. Plexiglas (PMMA or PC) can be used for envelope studies, while real glass is recommended for solar simulator studies. A couple of parallel mirrors can be used to indefinitely extend the space between them, but this technique can only be used under overcast sky. For 3D printed models, the surfaces must be treated appropriately in order to reproduce the real surface reflectance. This can be easily accomplished with spray painting and some manual treatment using paper sand.

The biggest difference between models built for daylighting studies and the ones built for other architectural studies is that the light distribution must be accurate, that is, it must come from the appropriate source only, such as windows, and not leaked from a crack between the model components, e.g. between floor and wall. Hence, all model construction joints should be covered with black tape, such as electrical or other truly opaque tape (Fig. 10.2). In addition, non-opaque material, such as foam core panels, must not be used to mimic solid building components, such as walls, or, when used, they must be treated to block light transmission, e.g. by laminating the non-opaque materials with opaque surfaces like aluminum. A procedure to check light leakage is to reverse the lighting process by placing a light source within the model and then locate it in a dark room.

The light sensors placement in correct locations and orientation, should be planned according to the design needs. In fact, in order to have accessible sensors' locations, the model construction should be planned carefully. Moreover, the plan should also envision sensors' wires paths, in order to avoid crisscrossing. Tapes or

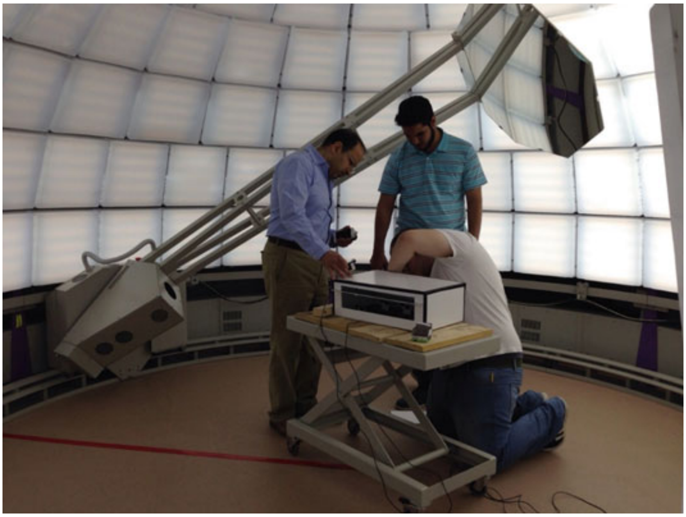

Fig. 10.2 Instrumentation with luxmeters of a simple scale model, optimized for daylighting simulation, in betanit LED full dome artificial sky (in the photo Prof. Khaled Al-Sallal with his master students at University of UAE) (*credits* Khaled Al-Sallal)

model hidden spaces can facilitate the wire placement. Positioning of borescopes and cameras within the model (Fig. 10.3) should be easy and allow to check if the framed view is the desired one. In some cases, it making holes in the walls is needed for placing cameras at the correct eye level. After fixing everything and

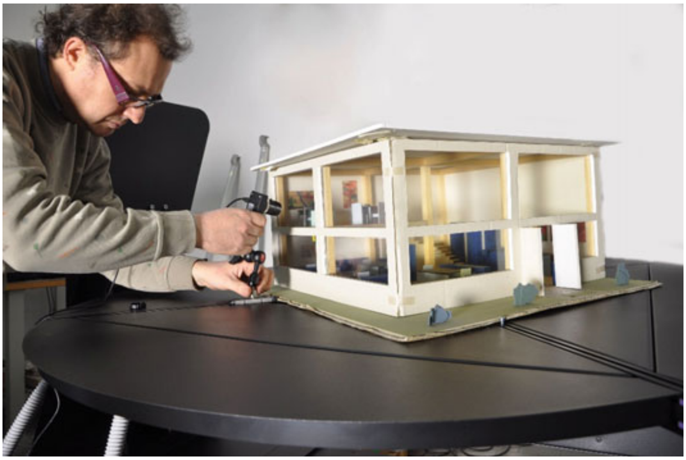

Fig. 10.3 Instrumentation with camera of a full color scale model in a virtual dome artificial sky (*credits* The author)

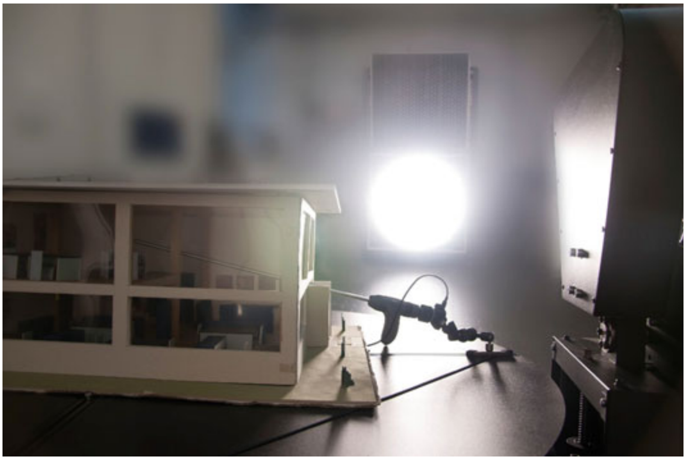

Fig. 10.4 Simulation of a sky in Betanit virtual dome artificial sky (*credit*s The author)

before taking the measurements, the user must double check if all sensors are on the correct places and with the correct orientations.

The simulation operation depends heavily on the chosen kind of tool; however, some steps are in any case standard, i.e. turning on and calibrating the device (if required), making a first lux meter reading (it is useful to calculate factors such as DF), placing the model on the proper support, preparing the required instrumentation, configuring the simulator (e.g. type of sky in a dome artificial sky, light level in a mirror box, etc.), launching the simulation (Fig. 10.4), and finally collecting data; moreover, it is important to repeat the last three steps for different light environments, or the last five steps for comparing different scenarios in terms of geometry and/or material.

Conclusion

To conclude, and to present the applications of methods and tools in practice, it is useful to illustrate some practical examples as explanatory reference, as follows.

Case 1

Study of the performances of a mall atrium fenestration in Saharan Region.

After the definition of the building masses by the design team, it is necessary to define the skylights location and the atria clerestories of new large mall in the Middle East. In this region, the weather is very hot and the main problem is to limit solar gain; in fact, reducing it diminishes the *Heating, Ventilating and Air Conditioning* (*HVAC*) system cost, and contributes to minimize discomfort glare, that otherwise will reduce space usability. We can assume that the analyst defines the maximum illumination level at 3000 lux; this can become a design requirement that enables to verify potential excessive glare during summer solstice and, at the same time, to minimize HVAC peak power cost. A simple cardboard model, without glass, is enough to run simulations. The different solar shading devices can be reproduced with a 3D printer for speeding-up the process and for reaching the proper model accuracy; these can be mounted on a frame applied in different areas of the model. A modular design of the solar shading devices can reduce the model cost and speed up the construction.

The needed instruments are: a simple video camera inside the atrium for documenting the study and a series of 8 lux meters located on different places of interest in the atrium space. The simulation can employ a heliodon to study the sun penetration during the summer solstice. The video camera output allows to identify, for each scenario, the time when the sun entrance is at maximum level, and it also support the identification of the lux meters' optimal placement in the more critical locations. The values registered, can be corrected by a reduction factor that takes into account glass transmittance, and then, these can be compared. Finally, the different scenarios are ready to be classified and documented with images taken by the camera and presented to the design team for discussion and development.

Case 2

Best fenestration design of a classroom in a temperate climate.

A design team needs to explore what could be the best design of fenestration for classrooms with limited floor-to-ceiling height. Occupant view and visual quality of natural light have to be guaranteed even in the most distant position from the outside wall. The best metrics for this case are DF, DA, Discomfort glare index (DGI), and Daylight Glare Probability (DGP). A simulated environment, that facilitates the measurement of these metrics, can be best provided by an *artificial sky*. A mirror box might be enough to measure the DF, while for DA, DGI and DGP it is better to use a (real or virtual) *dome artificial sky*. Instead, for discussing the performance outputs with the design team, the best tool is the real *full dome artificial sky*, where the analyst can show the results directly on the model, in particular the glare discomfort. The model can be built as in the application described before, but not for the finishing of the fenestration systems; in fact, the light shelves require the manual application of a reflective films (aluminum foil or specular Mylar). The instrumentation does not present particular difficulties. Standard photographic techniques with post processing software (e.g. Photosphere), or video photometer for higher accuracy, a can be used for glare analysis. Instead, the DA simulation requires more complex set-up than the ones used in the previous cases; in fact, the analyst has to evaluate the illuminance levels throughout an entire year. This is possible by making several measurements with turning on only one light patch at a time; the data collected should then be post processed to calculate the DA.

It is evident, that for serious, reliable and accurate predictions of daylight conditions, professional tools and approaches are needed. It is relevant to notice that, so far, this kind of procedures are applied only by important architectural firms during the design phase. Of course this is due to the cost of tools and consultancy. Nevertheless, the prediction of performative solutions and the awareness of the design cumulative outcomes is a relevant aspect.

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Part IV
Mapping and Simulation

Chapter 11
Mapping Venice. From Visualizing Venice to Visualizing Cities

Andrea Giordano

Abstract This research underlines the close relationship between communication, representation and sharing data; it shows also how new media gather these three features linked to cultural sites. The scientific analysis can be improved by multimedia processes starting from a correct data acquisition (archival documents, laser scans and photogrammetric surveys) and passing through the organization of information in 3D models that can be implemented by interoperable platforms. The new digital opportunities make the researcher able to communicate the data through the design of apps, interactive systems for multimedia devices, web platforms and immersive reality, another important goal is the integration of the 3D models as means of analysis into the conservation process of the architectural asset.

Introduction

Considering the basic meaning of the term "communication", as "sharing or exchange information, ideas, or feelings", we could assert that behind the act or the instance of communicating there is the way we *share information*, through speech, gesture, signs, symbols, telecommunication systems, publishing and broadcasting.

On the other hand, aside from its simplest meaning as "presenting again" the term "representation" includes the important features of knowledge, illustration and interpretation, as well as the communication of information, ideas, or feelings. The two words—"communication" and "representation" that we are taking into account—imply, and necessarily require, notions of sharing knowledge, a concept that is inherent in the etymology of "communication", in the sense of "making common" and "pooling" part of something that is owned, allotted to, conceived or contributed by a person or, in ideal conditions, by a group. In a world that is constantly

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changing this consolidated process requires a new gesture that are enabled *by* the use of emerging visualization tools and new technologies.

This research project intends to analyze the close relationship between communication-representation-sharing data, and how new media—also involving mapping operations—can facilitate this process.

In other words, tracing the development of *Visualizing Cities*, an international research program created by the pilot project *Visualizing Venice*[1]—that involves the University of Padua (IT), Duke University (NC, USA) and IUAV (IT)—, we would like to demonstrate how the documentation and the understanding of cultural sites can be addressed as a multimedia process passing through the digital representation of the shape, the condition and the appearance of historic monuments.

Using examples from Venice, Padua and Carpi, it is important to show three distinct phases for this kind of inquiry:

1. Data acquisition: archival documents, laser scans and photogrammetric surveys can be processed and organized through 3D modeling that can be implemented by interoperable platforms.
2. Data communication: the information gathered with the methods listed above can be conveyed through the design of apps and interactive systems for multimedia devices, as well as web platforms. This process entails designing and testing augmented reality and 3D models for multimedia devices and the implementation of immersive reality.
3. Sharing: integrating the models as means of analysis into the conservation process of the architectural asset by the virtual reconstruction of architectural features.

What Is "Visualizing Cities"

Visualizing Cities is conceived as a new type of research project that investigates the history and the development of historical sites, trying to operate beyond the normal historical practice in five ways. As first focus, Visualizing Cities wants to be collaborative and interdisciplinary, in the knowledge that the shortage of an interdisciplinary approach and common understanding could undermines the ability of researchers and specialists to solve the core issues (Lowry et al. 2004). The use of visualization is the second step from an operational point of view. So, if we agree with Aristotle's words, that tradition generally hands down this way: "First, have a definite, clear, practical ideal; a goal, an objective. Second, have the necessary means to achieve your ends: wisdom, money, materials, and methods. Third, adjust all your means to that end", it is fundamental, for improving this research, to focus on the use of visualization to discover relationships and to amplify thought, in the expectation that using vision let us to think (Card et al. 1999). In Visualizing Cities, for this reason, the third core matches the deep connection between Information and

Communication Technologies—ICT. The contribution of ICT is important not only for specific targeted research projects—we are going to consider later in this text why and how "3D modeling", "Interoperability", "GIS-BIM", "Dissemination", etc., have all together a deep relation with ICT. Now it is important to stress that ICT, on one hand, improve the economic growth, the work and multi-factor productivity (Schreyer 2000); and, on the other hand, it promotes the right coordination of cultural diversity involved, having a positive influence on decision-making and on communication: "ICT mitigated the negative impact on intercultural communication and supported the positive impact on decision-making", using effective technologies for intercultural communication "included e-mail, teleconferencing combined with e-Meetings, and team rooms" (Shachaf 2008).

The fourth topic involves the concept of "open-ended": only starting from the original and multiple meanings of this notion (such as "not having fixed limits; unrestricted; broad" or "allowing for future changes, revisions, or additions", and also "having no fixed answer"), we can understand that the issue of the "Open-ended" concept has numerous appropriate answers fitting with the spirit of our research. According with a study conducted by Shimada about a new proposal for teaching mathematics, the Open-Ended Approach provides students with "experience in finding something new in the process" (Shimada et al. 1997). The Open-Ended Approach started in the '70s and, since then, many teachers have developed open-ended problems and lesson plans using open-ended approaches: "In responding to such (open-ended) items, students are often asked not only to show their work, but also to explain how they got their answers or why they chose the method they did" (Schoenfeld 1997). Also for our research we can recognize similar outcomes that can be here summarized: all participants are actively involved to express their ideas more frequently, providing responsive and cooperative atmosphere, comparing with and discussing about solutions. This open-ended approach, applied to the work of analysis of site and architecture, provides a fertile ground also for the mapping inside Visualizing Cities, meaning the representation of urban sites as the expression of a map of different kind of cultures and features, freely proposed and explained by each participant in the project.

Each of these four focus can provide researchers with a reasoning experience, debating on and analyzing their solutions not only in presence, but also with the effort of developing meaningful problem situations.

The fifth and last topic of Visualizing Cities is about the concept of space and its dynamic transformation, with a focus on the long-term spatial-economic metamorphosis of cities as an archetype for a wider international phenomenon of urban development of metropolises across the world. In this case, we want to "study the origins and course of urban development process by identifying and explaining which (collective) arrangements, including their ambient factors and the visual representations of the city and urbanity, have influenced this metamorphosis in a decisive manner" (El Makhloufi 2013). In this attempt it is important not only to concentrate on formal analysis of spatial, architectural and urban history transformation process but also, according with Jacob Paskins (2015), on general architectural and urban histories without skipping over the social consequences—and the political fallout—of urban transformation.

If the target is to create a tool that will make accessible all of the most important published primary sources (iconographical and textual) related to the urban history of a city as a part of digital reconstructions, we have numerous modes for the interpretation of a historical site. In fact, the ways as the explanation of an urban transformation has been achieved have changed over the last two hundred years. Explanations have come in many forms and at many levels and are greatly influenced by what are usually taken as leading questions, which themselves have varied significantly since the early nineteenth century (Lightfoot 2013).

However, Visualizing Cities deals with how a city changes, with a descriptive work complemented by questions of clarification and of consideration that try to explain aspects of changes in time and space. Not denying the traditional tools of representation and analysis of architectural history (plans, elevations, sections), the strengths and weaknesses of representing processes of change involve architecture and time, buildings "in motion", the "Lives of Things", but most of all new frontiers for historical research on visualizing transformations. Mapping the Cartography of Venice with GIS; shifting from GIS to BIM and hBIM; implementing potential tools such as Apps and devices for augmented reality: all these actions are becoming predominant, and not only for the visualization of our Cultural Heritage, but also for enabling the creation of effective representations of the dynamics of change and the visualization of movement within urban space in ways that can engage a broad sector of the public (Presner et al. 2014).

How "Visualizing Cities" Works

The adopted methodology is extremely simple, it is set on three consequential steps: starting from the identification, gathering and organization of primary and secondary sources, then switching to data processing and elaboration, and finally ending up with the outcomes.

Visualizing Cities primary sources are the "first hand evidence" left behind by scholars, intellectuals, thinkers or observers at the time of events. "Primary sources originate in the time period that historians are studying. They vary a great deal because these data may include personal memoirs, government documents, transcripts of legal proceedings, oral histories and traditions, archaeological and biological evidence, and visual sources like paintings and photographs" (Storey 1999). In our case it is fundamental the Archive research of documents, all available in original format, in microfilm/microfiche, in digital format, or in published format: preliminary set of maps, cadastral maps, cartographies, drawings, old photos and aerial photos of the whole city that have to be collected. These primary sources provide our first-hand testimony or direct indication concerning a topic or a place under investigation of the city. These materials have to be systematized and ordered

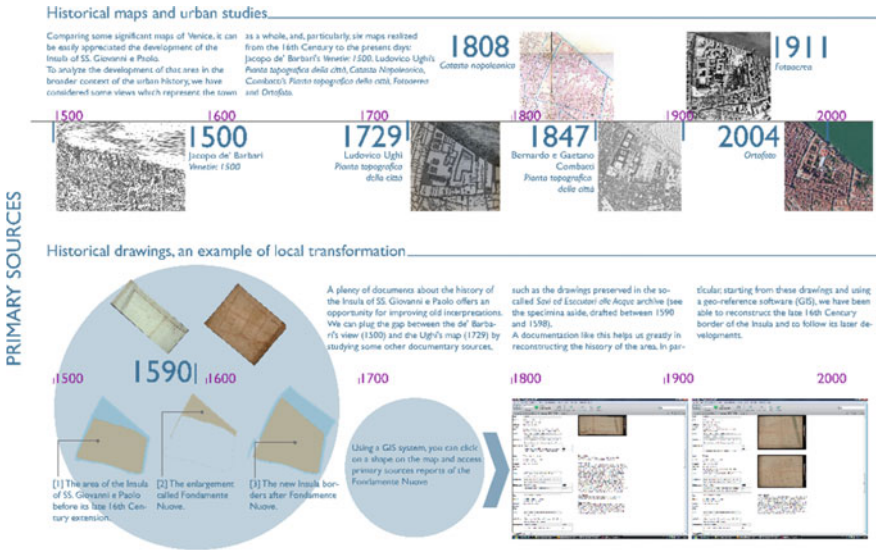

Fig. 11.1 The organization of the primary sources: the insula of SS. Giovanni e Paolo (Image by A. Ferrighi).

in a timeline, where each item is marked with a precise historical date, systematizing a first chronology of the documental progression of the place (Fig. 11.1).

At the same time, secondary sources are all the bibliography related to the case-study, but also all the geometry and measurement data achieved by Surveying/Scan operations, such as traditional survey, new photographic processes (photogrammetry), and 3D laser scanning (De Luca 2011; Cundari 2012; Brinker 2013; Giandebiaggi et al. 2014). All these operations implicate "the reconnaissance" and the first understanding "as built" of the area that have to be surveyed. It is very important to be perfectly aware about the right strategy of survey to adopt, in order to obtain the highest number of measurement data that have to be later processed considering that the achievement is to produce virtual model of the city portion considered.

This introduces the second operational step: data processing and elaboration. A selected part of the city, (in this case the insula of SS. Giovanni e Paolo in Venice) have to be identified and isolated from the maps, it has been redrawn in CAD/BIM and aligned with GIS over a modern map (Volk et al. 2014; Terpstra et al. 2016). In particular, it is possible to adopt and experiment with processes both of Reverse perspective and of Scan to BIM (Building Information Modeling). In the first case, through the use of current digital technologies we can reproduce, virtually, the city represented in paintings that—if they properly employ the geometric-mathematical rules of perspective—qualify themselves as reliable documentary sources, suitable for the reconstruction of urban images in a given historical period. This is certainly the case of the Venetian views produced by Canaletto: as we know from the wide literature about this painter, he followed perspective rules and used the *camera obscura* for his works of art. However, it is interesting to note that his paintings are treated as experiments to expand the virtual space represented, in reference to the real one, trying to provide the observer of a dynamic perception—if not a "filmic" one—often contradicting the canonical use of geometric-perspective systems and tools (Giordano 2014). In the second case, from data to 3D modeling, we create a multitude of "deliverables" including an interoperable BIM, realized with accurate 3D Point Clouds, and we face up as well to the visualization of simultaneous changes and deviances for every architectural aspect and/or urban place. Then all buildings, canals, streets and the insula have to be identified and marked on each corresponding historical map. Usually it is possible to link different maps to create and outline the urban transformations, achieving a database of historical documents (drawings, paintings, engravings, texts), built and linked to GIS data (Borin et al. 2015; Ferrighi 2015). Database and maps have to be stored in a relational database and made available on a dynamic website to allow online access. All collected data and their digital versions of each historical document are available on a timeline view (Fig. 11.2). This make us able to create a data browsing, so that all the geo-localized data can represent a solid basis for further, additional layers of information, linked to: Humanities (art, literature and music—paintings, pictures, photos, statues, music, novel); Religion (charities, orders, hospitals); City Administration (public buildings, political decisions, demography); Everyday Life (people, shops, crafts, entertainment, myths and legends); Thematic Examples (evolution of urbanization, popular myths and legends, water—lagoon and sea, wars, history of the buildings). As a consequence, all the historical events, linked to urban space can be organized in a flexible and scalable platform that could become the data source for the development of innovative applications. However, there is a main issue: how do we manage this huge amount of visual and historical data? The answer is *Divide et impera*: **time** and **space** filters can be the first and "easiest" way to group and split information into smaller and more manageable data sets. Then, the last elaboration entails operations of data tagging and filtering.

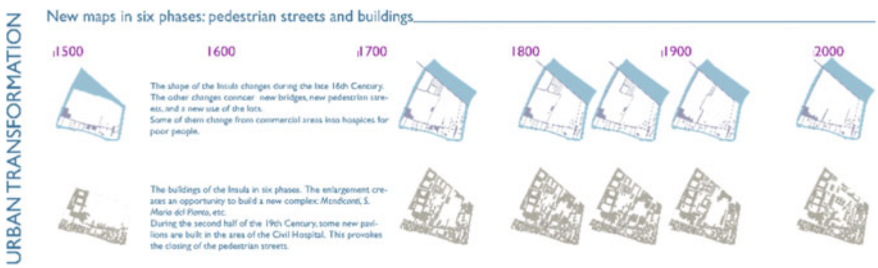

Fig. 11.2 Geo-localizing data to represent a layered information: the insula of SS. Giovanni e Paolo (Image by A. Ferrighi).

Output and Conclusion

To define the Visualizing Cities output is very simple, taking into account the meaning that we usually use in technology and computer science, “Data transferred from a computer system to the outside world via some kind of output device” (Blackie 2013). Subsequently our outputs are:

- Interactive models that can become the representation of the “Passage of Time” (Fig. 11.3) using BIM 3D models of buildings for:

– A full view of something that can’t be seen from street/water level;
– A full exploration of parts that are not freely accessible;
– Prototypes “to touch” the past—and often no more “existing”—reality;
– Images and videos, to represent a story-telling;
– Interactive sliders, to “virtually overlap” historic maps with the actual ones;
– Augmented reality, to “augment” views of a physical, real-world environment with computer-generated sensory input such as sound, video, graphics, 3D models or GPS data.

All these outputs are implemented to stimulate the implicit tendency of our cognitive system to perceive and easily remember the urban and architectonic transformation of a city (Zacks et al. 2001).

Finally, future steps consist in

– Data mapping of the whole cities involved.
– Collaboration: a platform opens to external contributors, especially for content of the last century.
– Integration with other computer systems and compliancy to archive standards (Dublin Core, etc.).
– Social networks: integration with social networks, especially geo-localization based ones.
– Present time information: commercial shops, means of transport, advertising, museums, etc.

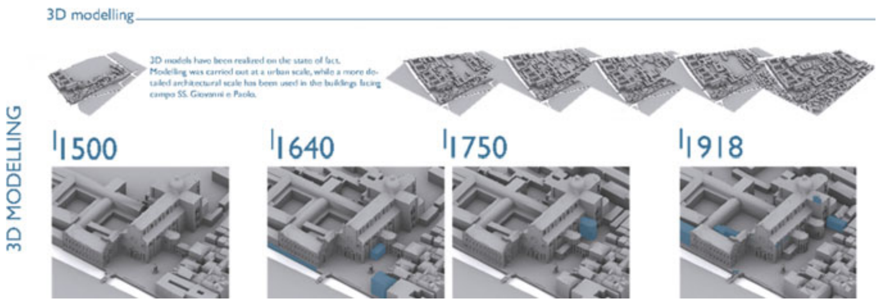

Fig. 11.3 The interactive representation of the “Passage of Time”: the insula of SS. Giovanni e Paolo (Image by A. Giordano, C. Monteleone, I. Friso).

- Calendar of city events and their historical relation with the city (e.g.: Festa del Redentore).
- Making a commercial app out of the prototype (business plan, copyright issues, etc.).
- Rent-your-tablet: hotel distribution of tablets with a preloaded copy of VC app.

More generally the aim of this research is to focus on a conscious image of the city and architecture. For this reason, mapping the city becomes an important tool for urban policy, for new forms of knowledge, marketing and—"least but not last"—for the individualization of "good practices" in urban project and design. This is possible because today the new technologies create maps that can be considered as sensors that provide information and real-time feedback about the changes and the uses that people make of urban spaces. This is why the new role of mapping, settled in Visualizing Cities, underlines how the mean dynamic features of cultural sites can be represented in three principal steps: starting from the collection data (documents as well as measures); passing through the creation of a 3D digital models, implemented with all the information useful for specific goals; representing with advanced digital tools (apps, websites, augmented reality) to vehicle knowledge. This strategy, obviously, constitutes a very powerful tool also in the urban project because it makes the designers able and aware about all the possible needs, skills and forecasts that the complexity of the city needs to be faced.

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Chapter 12
Listen Through the Map

Role and Improvements of Digital Cartography in Exploring the Urban Sonic Environment

Valerio Signorelli

Abstract Throughout history, cartographic representations have been employed as medium to collect, describe and comprehend the spatial relationships between the physical and social forms of the urban environment. Over the last decades, the improvements in information technologies have brought to digital mapping solutions able to renovate the traditional two-dimensional supports into interactive, immersive and multimodal media. In this context, the soundmap, a multidisciplinary device used to describe the sonic environment, is one of the cartographic products that has taken advantage of these improvements. Digital mapping solutions allow us to collect and listen to geolocated sound recordings of the urban/rural environment, therefore, they provide new means for describing the perceptive auditory experiences. The role, usages, future perspectives and challenges of the soundmap will be highlighted to understand how, and to which extent, these cartographic media can and should be enriched in order to describe the urban ambiances in their multisensory, temporal and spatial dimensions.

Keywords Sonic environment · Soundmap · Digital mapping

Listen up!

In the late sixties, the research group of the World Soundscape Project, established by Murray Schafer at the Simon Fraser University in Vancouver, embarked upon an intriguing discussion centered on the role of the sonic environment in our visual-driven culture, highlighting the disadvantages and risks of the noise control approaches (Schafer 1977a). The terms of acoustic ecology and soundscape, the latter conceived as auditory analogy with the term landscape, were at the core of their research (Truax 1984). The group explored the changes of the urban and rural sonic environment through sound recordings and methods such as the soundwalk

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(Westerkamp 1974; Paquette and McCartney 2012); it provided a specific lexicon to describe the sonic features using notions such as keynote sounds, sound signals and soundmarks, lo-fi and hi-fi soundscape (Schafer 1977a); it tested novel forms to represent the sonic features in their spatial and temporal dimensions (Schafer 1977b; Wrightson 2000). Over the last fifty years, the sonic studies have been continuously enriched by researchers coming from various disciplines that have refocused, widened, hybridized and renamed the notion of soundscape according to their research interests and disciplinary background (Geisler 2013; Grimshaw 2011; Payne et al. 2009; Kang 2007; Adams et al. 2006; Augoyard and Torgue 2005; Pocock 1989; Porteous and Mastin 1985).

Nevertheless, in urban practices, the range of opportunities offered by these research seems to be neglected and subordinate to quantitative noise control approaches limited to specific sound sources and average indicators (Signorelli and Radicchi 2014; END 2002/49/EC 2002), however, the state of annoyance and stress caused by noise pollution can be hardly defined by average indicators. Subjective appreciation of the sonic environment and its positive effects, often neglected to evaluate the well-being of individuals, should consider other quantitative and qualitative variables, such as the range and type of sound frequencies, loudness and sharpness evaluations, type of sound sources and their temporality, kinds of urban activities and users' cultural background (Grimwood 2011; Licitra et al. 2011; Payne et al. 2009; Faburel and Gourlot 2008; Berglund et al. 1999).

In other words, the sonic environment should be understood as a resource (Kang et al. 2013) rather than a disease that need to be cured (Truax 1984:105), or as a consequence of oculo-centrism design approaches (Zardini 2012; Signorelli 2013). By carefully listening to the urban sonic environment it is possible to comprehend the physical, social and cultural dimensions of the urban environment itself:

> […] the sound wave reflects every detail of motion of its source, its travel through an environment—reflecting from and being absorbed by all objects—is influenced by the general configuration of the environment. In a sense, the sound wave arriving at the ear is the analogue of the current state of the physical environment, because as the wave travels, it is changed by each interaction with the environment. Whereas vision allows us to scan an environment for specific detail, hearing gives us a less detailed, but more comprehensive, image of the entire environment in all directions at once. (Truax 1984:15)

Mapping the Sonic Environment

The survey conducted by the Noise Abatement Commission of New York in 1929[1] is one of the first documented analyses on the effect of environmental noise in urban areas (Thompson 2002:118). The noise measurements conducted in this study did

[1]The New York Times published a video that shows the means and methods employed for this research. URL: http://www.nytimes.com/video/multimedia/100000002151331/new-york-city-1929.html (Access on April 2016).

not use sound level meters, not yet available at the time, but an “ear-balance method” was defined in order to obtain an indication of loudness (Scott 1957). The outcomes were collected in a report containing both pictorial schemes (Brown et al. 1930:2–3) and a map showing noise complaints (Brown et al. 1930:30). Few years later, in Germany, recurring environmental noise surveys, conducted using sound level meters, brought to the earliest cartographic representations of environmental noise, such as the “maps of loudness” of Charlottenburg, a borough of Berlin, and Düsseldorf (Meister 1956). The noise map, as a strategy tool for urban planning, has been largely developed and recently reinforced by national and European regulations that provide detailed guidelines for their development and comparison (END 2002/49/EC 2002: Annex IV). However, current noise regulations, focused on specific noise sources (END 2002/49/EC 2002: Art. 7) and mainly obtained by computer-based simulations, they cannot render the whole complexity of the sonic environment[2]: neighborhoods with similar sound pressure levels can have different sonic ambiances that vary during the day (Balaÿ 2004).

In addition to the quantitative description of environmental noise, cartographic media have been used to develop soundmaps, as means for storing and communicating the qualitative and perceptive aspects of the sonic environment (Signorelli and Radicchi 2014; Kornfeld et al. 2011; Balaÿ 2003; Arlaud 2001; Schafer 1977b).

Soundmapping refers to the practice of editing and locating, on physical or digital interactive cartographic media, sound fragments collected by means of in situ surveys or retrieved from existing archives and linked by common subjects, with the aim to render the perceptual dimension of the sonic environment. The sound fragments can be converted into visual outcomes, through an interpretation process, or directly listen from the digital map. The earliest documented examples of soundmap can be found in the research conducted, in 1920s, by the Finnish geographer Johannes Gabriel Granö. Granö developed a specific methodology to describe landscape features through direct multisensory observations of the proximate environment and a series of hatched maps. This methodology, extended also to the visual, olfactory and kinetic senses, was use to analyze the Valosaari island in Finland (Radicchi 2013; Buttimer 2010).

More close to the urban scale was the study conducted by Michael Southworth (1969) at the end of the sixties. Southworth analyzed the soundscape of an area in Boston’s central peninsula by focusing on two main aspects: firstly, he evaluated the sonic identity considering both the “singularity” of the sounds emitted and the “informativeness” of the sounds, exploring their capability in communicating both spatial forms and activities taking place in a determined area; secondly, he analyzed the “delightfulness” of sounds, that is to say those qualities that cause one to consider a sound more or less acceptable. In addition, Southworth evaluated the

[2]In the last years, the problem of providing a detailed, and actual, description of the urban environmental noise, has been treated by the employment of low-cost ubiquitous sensors (Cerniglia 2015), and crowdsourcing methods (Ruge et al. 2013; D’Hondt et al. 2013).

relationship between visual and auditory perception to understand how physicality and spatial form affects the identity and appreciation of a particular soundscape and, alternatively, how sounds affect the perception of a city's form (Signorelli and Radicchi 2014). The outcomes of this analysis have been represented on cartographic supports using specific graphic notations (Southworth 1969:66).

A variety of soundmaps were also explored by The World Soundscape Project: such as the isobel map of the Stanley Park in Vancouver, a map that joins the points of equal sound level; the Sound Profile Map of the Holy Rosary Bells in Vancouver; the yearly graph of natural soundscape in British Columbia coastline; a pictorial representation that shows the sound sources converted in textual notation; the acoustic horizon of Bissingen, in Germany, and Lesconil, in France. Some of these representations are collected in the research work Five Villages Soundscape (Schafer 1977b), a comparative study of the soundscape of five European villages (Bissingen in Germany, Dollar in Scotland, Skruv in Sweden, Lesconil in France and Cembra in Italy). The study's objective was to extrapolate useful information from the analysis of sonic environment in each town (Signorelli and Radicchi 2014).

The use of visual notation to describe auditory features, and in general not-visual phenomena, is an approach largely employed and still used today with effective results, as shown by recent research works (McLean 2014; Kornfeld 2011; Libro 2010; Szanto 2010; Balaÿ 2003; Arlaud 2001), however, this form of interpretation can lead to misleading results or difficulties in understanding for both expert and non-expert users.

Soundmap in Digital Mapping Era

Continuous improvements in information and communication technologies, together with the Web 2.0 approaches (Hudson-Smith and Crooks 2009) have brought to the development of notions such as digital mapping and cybercartography (Fraser Taylor and Caquard 2006) as well as they have improved and democratized the dissemination and use of digital cartography (Cartwright 2005:334).

Currently, new technical solutions are easily accessible to geolocalize sound objects and to share the final digital product, the soundmap, through online services. Starting from one of the first example developed by Stanza at beginning of 2000, *Soundcities*,[3] the phenomenon of online soundmaps is continuously growing (Mechtley 2013).

[3]http://www.soundcities.com/ developed by Stanza (Accessed April 2016).

Soundmaps have been developed for describing rural, natural environments[4] and urban environments.[5] Starting point are the sound recordings that can be collected from in situ surveys conducted by a variety of users (Waldock 2011) such as researchers and experts in acoustic disciplines,[6] or through recordings made by non-expert users obtained from crowdsourcing approaches[7]; through automatic extraction of sounds from structured or unstructured database (Janer et al. 2009); by real-time monitoring through distributed sensors networks and automated classification (Steele et al. 2013).

Soundmaps are multidisciplinary tools: the majority of them are intended as archives of sonic memories,[8] in form of temporal snapshots (Waldock 2011); other are used to collect the outcomes of research works,[9] including interview's extracts (Caquard et al. 2008) or directly used as research tools (Paraskevas et al. 2011) (Fig. 12.1). In the latter case the soundmap is not only a communication interface, but becomes an informative device for further investigation.[10] They can be used to address specific category of users, such as the audio tour for visually impaired persons proposed by Laakso and Tiina Sarjakoski (2010) or for developing artistic products.[11]

Among the variety of products shown above, that still represent a general overview on the heterogeneity of the soundmapping practice, could we consider the soundmap as an effective means to describe the urban ambiance (Thibaud 2011)? In other words, to which extent the digital cartographic media are able to render the multisensory dimensions of the urban environment, its physical aspects and the inter-sensory experiences and perceptions of the users? Which are the hindrances and potentialities of these tools?

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[4] http://www.naturesoundmap.com/ developed by WildAmbience (Accessed April 2016) http://www.mapize.com/soundmap_paiva/ developed by Binaural/Nodar (Accessed April 2016).

[5] http://www.bna-bbot.be/brusselssoundmap/ developed by Bruxelles Nous Appartient organisation (Accessed April 2016) http://www.lisbonsoundmap.org/ developed by Luís Cláudio Ribeiro (Coordinator) Universidade Lusófona de Humanidades e Tecnologias (Accessed April 2016) http://www.soundsurvey.org.uk/index.php/survey/waterways/ developed by London Sound Survey (Accessed April 2016).

[6] http://www.naturesoundmap.com/about-the-project/ developed by WildAmbience (Accessed April 2016).

[7] http://www.firenzesoundmap.org/ developed by Antonella Radicchi (Accessed April 2016).

[8] http://sounds.bl.uk/Sound-Maps/ developed by British Library (Accessed April 2016) http://map.europeanacousticheritage.eu/.

[9] http://www.cartophonies.fr/ developed by UMR 1563 AAU—research group CRESSON (Accessed April 2016) http://www.xeno-canto.org/ developed by Xeno-canto foundation (Accessed April 2016).

[10] http://www.soundaroundyou.com/ developed by University of Salford, Manchester (Accessed April 2016).

[11] http://citiesandmemory.com/sound-map/ (Accessed April 2016).

http://www.alexandria-streets-project.net/ developed by Berit Schuck and Julia Tieke (Accessed April 2016).

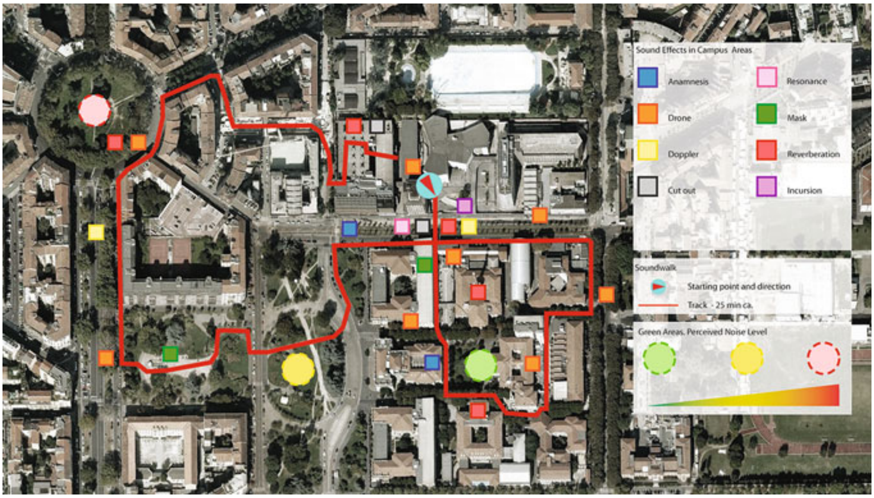

Fig. 12.1 A screenshot of the interactive soundmap developed within my Ph.D. thesis. It highlights the relationship between sound sources and physical environment using the *sound effects* defined by the research group CRESSON (Augoyard and Torgue 2005). Every icons on the map represent a *sound effects* that is described through a text, a photo and a sound recording. Through the map it is possible to move along a binaural soundwalk in order to perceive, in movement, the *sound effects*

Spatial Issues in Describing the Sound Ambiances: Towards Immersive and Low Resolution Soundmaps

These questions arise from the above analyzed soundmaps focused on a mono-sensory (auditory) description of the urban environment. In this case the basic map generally covers the role of mere support for the sonic environment that becomes a superimposed layer, spatially defined but disconnected from the urban environment itself. A disconnection between physical and perceptive form that, among other things, can be ascribed to a discrepancy in the spatial resolution of the visual and auditory elements. Specifically, a spatial misalignment of the sound fragments inserted in the soundmap, that provide a high level of detail that is irrespective of the scale used by the basic map. This misalignment can provide different lectures and misinterpretation of the information stored in the digital map (Monmonier 1991).

In order to deal, or at least contain the spatial misalignment issues, two approaches could be used: on the one hand, to improve the resolution of the visual information in order to match the detailed description provided by the auditory data. New technologies have already faded the boundaries between traditional 2D visualization and immersive 3D solutions in digital cartography, allowing us to multiply the points of view within the same media: we can directly and continuously switch between a view from above and a view from inside, or at pedestrian eye-level. A well-known example is provided by Google Street View[12] with the use of geolocated spherical panoramas.

A spherical panorama is a visual medium that can be obtained by the composition of multiple images, realized following precise methods and digitally processed using specific software known as photo stitching software, in order to obtain a single image characterized by an enlarged field of view. The use of the panoramic images for developing virtual environments is known since the '90s when the limited computational capabilities of the computer systems were not able to manage large three-dimensional urban models (Hudson-Smith 2003). Improvements in digital photography and computer technology, has made possible to easily produce these images using affordable cameras and open source software maintaining high resolution outcomes. Moreover, various devices were specifically created to accelerate the process of acquisition and composition of these panoramic images.

Recently, this method has been used to enrich the soundmaps: from research projects in which sound recordings were just an additional layer of the panoramic images, like the research project *Sound Around You*,[13] developed by the University of Salford, in the last years, thanks to the availability of high-quality and affordable digital audio recorders and soundfield microphones, also the sonic environment has started to be rendered as an interactive panoramic audio sphere[14] (Carter and Braasch 2014). Other remarkable examples are the projects *Night Walk in Marseille*[15] and *Pregoneros de Medellìn*[16] in Colombia. These two online products move forward the concept of the soundmap by developing interactive journeys using spherical panoramic images, spherical sound recordings, and storytelling techniques, a form of narrative cartography that enriches the description of urban places (Caquard 2013) and shown the potentialities and applications of current web technologies.

A further development of this method has been developed by the Author using a different technique based on game engine systems, software used to develop videogames (Signorelli 2014). The geolocated panoramic images are enriched not only with a spatialization of the existing sound sources, but also with static and dynamic three dimensional models that can "interact" with the spherical image itself (Fig. 12.2).

[12] https://www.google.com/maps/streetview/ (Accessed April 2016).

[13] http://soundaroundyou.com/ developed by University of Salford, Manchester (Accessed April 2016) a crowdsourcing platform in which sound recordings are presented together with panoramic images obtained by Google Street View service and user evaluation.

[14] http://soundcityproject.com/ developed by David Vale in collaboration with Rick van Mook and Caco Teixeira (Accessed April 2016).

[15] https://nightwalk.withgoogle.com/en/home (Accessed April 2016).

[16] http://pregonerosdemedellin.com/#en (Accessed April 2016).

Fig. 12.2 A screenshot of the interactive tool developed using the game engine system Unity3D (Signorelli 2014). The panoramic image is enriched with the spatialization of the sound sources and static and dynamic three dimensional models. The user can activate and deactivate both sound sources and virtual models

Nevertheless, if current technologies can easily improve the detail of the visual medium, also in online and mobile platforms, effective methods to reduce sound data resolution are still lacking. The aim is not to reduce the overall quality of the sound fragments, neither to degrade the original recorded signals, in this context the term resolution should be conceived as means to fulfill a mutual adaptation of the level of detail between visual and auditory phenomena. In other words, once sound recordings have been collected, is it possible to use a cartographic generalization process (Weibel and Dutton 1999) for developing the soundmap?

Starting from scale-dependent operations such as select, simplify, combine, smooth, enhance, displace (Tyner 2010) other operations can be conceived in order to provide new forms of representation of the sonic environment. Obviously this process cannot be applied indiscriminately on the entire auditory data. Interview extracts, that provide useful information to describe the sonic urban ambiances, as cited above, are less likely to be treated in terms of simplification. However, the multi-scalar adaptation of sound components can provide new form of classification of urban fabric through their sonic identity. We can provide, at the same time, general and detailed descriptions of the sonic environment and discover hidden patterns in the complexity of the raw sonic data.

To the author's knowledge, very few research have been conducted on this aspect. Schwarz et al. (2011) provided an investigation in this direction introducing the term of SLOD (Sound Level of Detail), even if their focus was not in cartography but three dimensional virtual environments. However, this explorative approach clearly reveals the possible applications of a generalization process on auditory data.

Conclusion

In the last decades, digital mapping solutions have dramatically changed the way of treating and communicating spatial data. Improvements in communication technologies and computer performances have brought to blur the boundaries between traditional two-dimensional visualizations and immersive representations, providing innovative solutions to describe the physical and perceptual dimensions of the urban environment.

In this context, soundmaps have been substantially improved by the possibility to integrate and listen to sound fragments collected and shared by various actors. Nevertheless, despite the growing phenomenon of soundmaps and the purposes addressed, given the heterogeneity of disciplines involved, their use in urban practices is still marginal and not fully investigated (Signorelli and Radicchi 2014), compared to the noise map that tends to be the sole medium used to describe the sonic environment.

Role and improvements in soundmapping practice have been explored in the article. Specifically, two connected hindrances to the description of urban sonic ambiances have been highlighted: on the one hand, inter-sensory interaction between visual and auditory phenomena is still lacking in soundmapping practices, on the other hand, the high resolution of sound fragments, irrespective of the scale used by the basic map, defines spatial misalignments that can provide a misinterpretation of the information stored in the digital map. While various solutions are now available for improving resolution, appearance and level of detail of the visual medium, such as the panoramic images, as well as the game engine technologies, presented in this article, and therefore to obtain effective visual and auditory environments, an approach able to deal with multi-resolution auditory data is still lacking.

Further investigations are needed to deal with the latter and in order to consider the soundmaps, and specifically the basic maps used in this media, not only as a mere support of an auditory layer, but a more informative device able to enrich the toolbox of architects and urban planners. In other words, to consider the sonic environment as an actual resource in the urban planning practices. In this context, a deeper reflection on the inter-sensory interactions between visual and auditory phenomena, as well as practical applications of the operations described in the map generalization processes, well known in cartographic practice, could provide novel forms of representation for the sonic urban ambiances.

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Chapter 13
Application of Visual Simulation in Urban Renewal Projects

Anetta Kępczyńska-Walczak and Bartosz M. Walczak

Abstract It is observed computer techniques have become a very powerful tool for designers used not only for modelling 3D forms but, furthermore, as an analytical tool. Dynamically developing digital technologies allow to simulate different scenarios for urban and architectural designs and test them in a virtual environment to reach the consensus and, finally, choose the optimal solution. However, they can also be used for manipulation and forcing certain decisions. That is why, it is a designer's or urban planning team responsibility to make use of emerging technologies in a responsible and trustworthy way. The environment which requires some interventions or is not existing or is at the early stage of planning can be modelled, simulated and presented to enable public discussion and help making up decisions. Since in a democratic and participatory society the openness and public opinion are crucial factors in decision making process, it calls for implementing representation, simulation and communication skills in architectural and urban education. The chapter will focus on visual techniques applied in urban renewal design concentrated on the problematics of a housing estate from the 1970s. A typical modernistic layout, quality and ambiance of public and private spaces have been confronted with contemporary needs and expectations. The project itself was preceded by interviews with inhabitants and then, the concept was again consulted with them with the support of digital simulations in the form of visualisations and animations. The authors believe the results and conclusions derived from the study might serve as an example of a good practice in the environmental participatory urban design.

Keywords Urban renewal · Visualisation · Education

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Simulation in Architecture and Urban Design

According to the Merriam-Webster's Dictionary definition the common sense of the word 'simulation' usually refers to "something that is made to look, feel, or behave like something else especially so that it can be studied or used to train people". The same source provides, however, other explanations of this term: "a: the imitative representation of the functioning of one system or process by means of the functioning of another (…) b: examination of a problem often not subject to direct experimentation by means of a simulating device" (*Merriam-Webster's Dictionary*).

The above descriptions differ significantly and, what is more, rise a number of issues the Authors would like to discuss. First, it appears that simulation may refer to a representation appealing to senses and emotions of its potential users. The definition also implies the application in domains of education and research. Secondly, the simulation may be understood as a scientific method allowing to study complex problems in a laboratory environment. It means, however, that the results depend on a predefined set of rules—relationships, procedures and other variables. What is of great importance, these experiments or demonstrations can be conducted without using rare materials or expensive equipment. The method is also applicable when consequences of an analysed process may appear irreversible. Another crucial feature of simulation method is a possibility of time compression that allows to achieve results which under normal circumstances in a real world would be available in significantly prolonged time. Therefore, a simulation is commonly used by researchers either in order to verify their assumptions or to test prototypes.

When urban planning and design are taken into consideration all the above-mentioned issues and features of simulation are of key importance. There is a long-standing tradition of a town-planning process understood as a chain of survey, analysis, and plan. This approach was introduced at the beginning of the 20th century as a result of Patrick Geddes works. Being biologist by education and sociologist by profession, he saw the city as "an inseparably interwoven structure", or—in other words—a series of common interlocking patterns (Geddes 1917). Following this notion, Geddes suggested a comprehensive observation prior to the designing process, and highlighted this recommendation with a motto, hammered in a slightly medical manner: "diagnosis before treatment". He also indicated that such study should include, at a minimum, the geology, the geography, the climate, the economic life, and the social institutions of the city and region. The contemporary interpretation of this concept is that urban planners should begin with a definition of a problem. It requires data collection, analysis, initial proposals, their evaluation and finally the selection of the most suitable plan for the implementation. This process may be extensively supported by the use of digital technologies.

For instance, urban simulation models and their visualisations are used by planning agencies to evaluate alternative transportation investments, land use regulations, and environmental protection policies. Typical urban simulations provide spatially distributed data about number of inhabitants, land prices, traffic, etc.

It could be also a numerical model allowing simulation of accumulative results of proposed changes. However, the most common expectation is to provide an effective communication at all stages of designing process. In order to express their vision, urban planners commonly employ traditional methods (drawings and physical models) as well as digital technologies—used separately or jointly (Ishii et al. 2002). The visualisation methods should, however, reflect a wide range of parties involved at various stages of planning. In particular, a difference between requirements of professionals and the clients should be stressed here (Batty et al. 2000). The importance of the visualisation as a communication tool and research method in architectural and urban design has been reflected by a number of international conferences such as EAEA and SIMAUD. What is more, the subject was researched meticulously by scholars at least from the 1980s onwards (Pietsch 1999).

Therefore, we should remember that although the term "urban simulation" mainly corresponds to the use of behavioural or process modelling of dynamic changes in urban activities and landscapes it can be also used to describe 3D rendering of urban landscapes. In this respect, a correct spatial arrangement and interrelationship of volumes are key factors for a quality of redesigned areas and their appropriate use. In such case crude 3-dimensional block models are sufficient solution for designers to study proportions, scale and relationship between buildings—although such models lack any significant architectural detail and do not convey any compelling sense of the environment. While, on the contrary, the latter is of crucial importance when project ideas are to be communicated to clients, whether they are political decision-makers or the wider public. A good example of application of different typologies of simulation in combination to reach planning process stakeholders in order to communicate effectively design outcomes is the case of a comprehensive research conducted at the Politecnico di Milano on the redevelopment project of the Garibaldi-Repubblica area in Milan (Piga et al. 2012). Another example of the integrated approach to urban simulation might be the use of a luminous table during urban design courses at the MIT School of Architecture and Planning. The latter case is also interesting due to its educational dimension (Ishii et al. 2002).

Simulation as an Educational Tool

It was already indicated that simulation may become a powerful technique in architecture and urban design practice. What is more, it is becoming more extensively used in education. The best example is a flight simulator widely used in training of aircraft pilots. The simulation methods are also deployed in medical as well as economy and management schools. In the above-mentioned cases trainees are exposed to realistic situations (often of emergency nature) and are expected to deal "with matters of vital concern but without dire consequences should they make wrong choices" (Encyclopaedia Britannica). In this respect, it would be interesting to discuss how students of architecture and urban planning should be trained.

During the recent years, numerous studies have been published about new possibilities which are provided for architects who use computer aided design. Advanced tools and software, which in fact are within each contemporary designer's reach, allow to create and describe complicated forms and constructions. Thanks to new technologies, which made 3D designing possible, architects who solve complex spatial problems do not have to use complicated models as Antoni Gaudi used to do who constructed vault inverse systems by means of cords and plummets. Modern architects have at their disposal a wide range of programs which support designing, management, realisation and exploitation of the structure. BIM programs (Building Information Modelling) support not only the creation and transformation of geometry in the computer environment but they also control the construction of the structure, quantitative, materials, areas and cubage statements. Architects can also operate new methods of communication and information transmission, which are different from the old ones. The above-described pace of change should be reflected by appropriate modifications of curricula in schools of architecture (Kępczyńska-Walczak and Walczak 2010).

There is no doubt computer techniques have become a very powerful tool for architects used not only for modelling 3D forms but, furthermore, as an analytical tool. Dynamically developing digital technologies allow to simulate different scenarios for urban and architectural designs and test them in a virtual environment to reach the consensus and, finally, choose the optimal solution. However, they can also be used for manipulation and forcing certain decisions. That is why, it is a designer's or urban planning team responsibility to make use of emerging technologies in a responsible and fair way. The environment which requires some interventions or is not existing or is at the early stage of planning can be modelled, simulated and presented to enable public discussion and help making up decisions. Since in a democratic and participatory society the openness and public opinion are crucial factors in decision making process, it calls for implementing representation, simulation and communication skills in architectural and urban education. This issue will be illustrated with the outcomes of a semester project conducted in 2015 at the Institute of Architecture and Urban Planning at Lodz University of Technology, Poland.

The general task for the semester project was to propose some interventions in a chosen problematic area in Lodz in order to transform it into more liveable place. The predefined subject of the course was a housing estate from the 1970s—a typical example of this kind erected in communist countries in Central and Eastern Europe. Described estate is situated in the Eastern part of Lodz—Dabrowa. The area consists of more than 80 multi-family and multi-storey prefabricated concrete buildings. The housing is complemented with associated commercial and service facilities located in nodal points of the estate what is a noticeable characteristic of the way housing estates were planned at that time (Fig. 13.1). There is also a cultural centre for the local community. The total area of the whole housing estate is approximately 28 hectares.

Students were subdivided into 7 teams of 4–6 persons each. Each group was asked to focus on a particular site within the housing estate and to identify a major

Fig. 13.1 The Dabrowa Estate map with marked design tasks described in text. *A*—"a space between blocks of flats"; *B*—"the case of an elephant" (*Credits* The Dabrowa Estate administration with additions by authors)

problem of the given area. For the purpose of this study two sub-areas have been chosen (Fig. 13.2) and the work of two teams are presented. It is necessary to stress here, the chosen case studies reflect the direct involvement of the co-authors of this chapter in the projects as supervisors. Another crucial issue at this point is the Problem Based Learning (PBL) as a pedagogical method applied to this task. The concept of PBL is not to give students a list of "to do", on the contrary, it is them who define a problem or problems, plan further steps and work out solutions (Kępczyńska-Walczak 2013). It also means that design is becoming more a process than one single answer. Supervisors should not expect a particular effect (often presumed by teachers a priori) since it is believed there can be more than one correct solution to a given task. The topic of PBL as a method will not be expanded here because it is out of scope of this study. However, the readers may find more explicit description and case studies, including Dabrowa housing estate, in a recently published paper (Kępczyńska-Walczak 2016).

The project was conducted in co-operation with the housing estate administration. Their representatives attended the final presentations. Therefore, students were aware that their proposals should be presented in a communicative manner. However, some of them considered it necessary to use simulations not only to visualise the project outcome but also as a tool in design process.

Hence students started their task with finding a problem and the only defined element was the subject area/location at Dabrowa housing estate, they had to investigate what actually was the problem of a given site. Described initial stage recalls the already discussed method, advocated by Patrick Geddes as the most

Fig. 13.2 The Dabrowa Estate soon after completion in the early 1970s. *Source* a postcard from the period, available at: http://fotopolska.eu

suitable approach to urban design process. A typical modernistic layout, a quality and ambiance of public and private spaces have been confronted with contemporary needs and expectations. That is why the project itself was preceded by interviews with inhabitants to understand not only visual characteristics, but also intangible values as well as obstacles difficult to distinguish by strangers. The results of this very early stage of gathering data and collecting impressions occurred surprisingly rich and gave an immense input to making further decisions. The following case studies deal with particular sub-areas and represent slightly different approaches, so they are described separately to better understand the involvement of simulation tools, ambiance and perception of the places.

Project A: "A Space Between Blocks of Flats"

As it was mentioned earlier, students were subdivided into teams and each team was asked to focus on a particular site within the housing estate in order to identify a major problem of the given area. One of the teams, formed by four Polish students and one Spanish student, was assigned a problematic green area surrounded by four five-storey buildings (Fig. 13.4) (Bem et al. 2015). The topic was formulated as "A space between blocks of flats". Students were expected to analyse the site thoroughly, identify its problems and then propose how to solve them by the means of urban and architectural design. During the initial stage group members were investigating the area and analysed transport, environmental and social aspects. Identified site features included a number of trees extensively shading facades with balconies and decreasing the quality of light in flats, as well as poorly maintained footpaths without any hard cover. Students indicated also a low architectural quality of buildings, erected in late 1960s and early 1970s in order to accommodate as many people as possible with little respect of aesthetics. Since this is essentially residential vicinity, students decided to focus on people living there, including daily frequency and the way of exploiting the area. They tried to observe how this place looked like during different moments of a day and what social groups of people lived there. What is more, some useful information was obtained by interviewing residents. The questionnaire included five questions on the quality of life in the area, safety issues, positive aspects and disadvantages. To evaluate the results properly it was important to know if the interviewed person was a new inhabitant or not. It appeared a great number of elderly people had been living there since the housing estate was erected. During a conversation with local people students noticed not only a number of elderly persons, but there were also families with small children. The interviewed inhabitants complained about limited number of parking places, poor lighting, lack of places to sit down and rest. Students learned also about a playground being in a poor condition and for this reason rarely used. What is more, they got to know the area was usually unfrequented by the dwellers. It was, however, commonly used only by people taking a shortcut in order to get to their blocks. The information obtained from residents was confronted with an opinion expressed by the director of the housing association.

As a result of the extensive site analysis students were able to define the problems of the area explicitly. They understood the whole site was almost all the time in shadow during the day and, moreover, without any artificial lighting at night which is not engaging to spending time there. They indicated darkness, a chaotic arrangement, poor maintenance (litter, decaying playground), lack of places for leisure as principal obstacles discouraging people to spend their free time in the area. What is more, they defined stakeholders to make simulations of the area improvements in response to the identified problems and people's needs. To achieve this, students decided to improve the area with the aim at encouraging people to spend more time in the open air. The idea was to create a cosy and safe neighbourhood for inhabitants who live in the nearest blocks. They proposed a design of a nice surrounding with a modernised playground, benches, and some more small interventions (Fig. 13.3). The project consisted of six major tasks described below.

- A new building ("Common Cave")—The main idea was to create a place, where inhabitants could gather, know each other better and benefit socially. The team proposed a semi-underground structure offering a good shelter during poor weather conditions and a nice place for informal meetings. On a slightly elevated rooftop, umbrella could be installed to protect people from sun during summer time. The terrace was also designed in the way to allow a visual control of the children spending time at the playground. Parents could sit and relax, but at the same time having their children in their care.

Fig. 13.3 Two visuals showing the range of intervention including community meeting place, recreation facilities and improved appearance of buildings. *Source* Bem et al. (2015)

- Benches—Open-air furniture was another crucial part of the project. Proposals for benches evolved significantly. Finally, students agreed to design four types of outdoor seats. All benches were designed in a uniform manner with the use of concrete and timber.
- Lighting—In response to numerous complaints on the unpleasant darkness of the area at night, students proposed special lamps matching with the architectural style of other elements, providing more light and, what is more, respecting the Dark Sky programme requirements.

- Blocks of flats ("Orange Oasis Borders")—Students planned to improve and refresh the appearance of the late-modern blocks of flats. Furthermore, they aimed at linking them visually with other features designed by them.
- Playground ("Tutti Frutti")—Since the residents and the estate administration alike indicated the need for a refurbished playground, a particular attention was given to this subject. During the first phase of the project students came with the idea of changing location of the playground and moving it to the further end of the plot. Finally, they relocated the playground closer to the nearby kindergarten. The aim was to accommodate a rich number of various facilities and to create a place where children could play safely.
- Pavements—After a brainstorm meeting students decided that the best idea was to create new paths between trees with a set of benches alongside. They agreed that they did not want to have too much concrete there, and that the greenery should be kept to the maximum since residents underlined this issue as one of the advantages of the neighbourhood.

To justify the proposal and achieve additional feedback, students decided to interview residents once more. This time inhabitants were shown above-described design and asked to express their opinions (Fig. 13.4). It appeared that presented simulations of envisaged urban and architectural interventions were in line with expectations of stakeholders. For the team it was important to satisfy residents of Dabrowa and show them the site potential and a chance for a better surrounding and better living.

Fig. 13.4 One of residents being interviewed by students. *Source* a video by Bem et al. (2015)

Project B: "The Case of an Elephant"

This project was conducted under the same rules which have been extensively explained in the previous section. In this case a group of five students was asked to focus on another location at the district of Dabrowa in Lodz. The site in question is a small green space between two multi-storey blocks of flats along major street with public transport (buses and trams). Students investigated the site in the same manner as the other group. As a result of their survey, interviews with residents and administration of the housing estate, they were able to learn a lot about the problematic site.

The most striking feature was an elephant made of concrete and originally designed as a slide for children. It soon became obvious for students, that this animal-like figure was however something more for all residents of the area than just a playground. It was placed on the spot as early as the beginning of the housing-estate development, i.e. in the late 1960s. Over the following years the elephant became actually a kind of a landmark, building the identity of the space and the whole neighbourhood. Occasionally, there are special events organised by local schools to celebrate the elephant. Some of the residents called it "Gosia—a mascot of the district".

Another important aspect noticed by students was a path passing the site, which in fact was a crucial part of pedestrian routes network in the whole neighbourhood. Therefore, the elephant had another meaning—the interviews with residents revealed that they were using it also as an orientation point. Apart from the location and the elephant the site lacked, however, a particular character and had no specific use.

The whole original concept of the housing estate was focused on good lightening and ventilation of flats. However, the "floating" space has occurred repetitive and boring. What is more, it has been poorly designed and maintained.

These notions allowed students to formulate the principal problems and propose methods of their mitigation. The group pointed out that the nature of the site and its context required to sub-divide the design into three levels of intervention, which are described below:

- Urban scale—a system of public spaces connected by an element which gives coherence, functionality and that guides pedestrians. To achieve this goal, a metaphor of a river was developed by students: "(…) there will be a birth of the river and a mouth, two different points connected by the chain of public spaces. (…) As every river, ours also has a birth, in the Maksymilian Maria Kolbe church and a mouth in the Podolski Park, the two biggest open spaces of the neighbourhood and the most frequented by people in their free time." The concept revealed to be even more suitable for the site with notion "that elephants really enjoy to be next to the water in the rivers" (Mrowczynski et al. 2015) (Fig. 13.5).

Fig. 13.5 Visual explanation of the importance of pedestrian route and its metaphor as a river *Source* Mrowczynski et al. (2015)

- Intermediate scale—"between the buildings". It is a public space in a central and articulating position. The aim was to create a space for everybody, and not for just one group of residents/users. The site consists of two zones—a transition area related to this major pedestrian route, and a recreation place for the residents of all ages. The metaphor of the river was further developed: it was given a bank in a form of a continuous bench and some rocky shapes designed as multi-purpose furniture. And, of course, there are elephants resting by the watering place (Fig. 13.6).
- Building scale—a community space in the building used just by the residents which operation and maintenance is their responsibility. The roof-top community gardens were proposed for residents of two houses flanking the site. Privacy, sense of belonging, compensation of the disadvantageous location by the noisy street and major pedestrian route were crucial factors in a design process.

Fig. 13.6 The elephants—a concrete one as a local landmark; elephants by the river; students design as a link between the new concept of the pedestrian route and the traditional perception of the site. *Source* Mrowczynski et al. (2015)

Each of these project tasks required different analytical tools and visualisation methods. The peculiarity of elephant stimulated students' creativity. It not only helped to create a comprehensive design scenario but also to develop convincing visuals referring to emotions and sentiments of the local community.

Summary and Conclusions

These experimental projects appeared a success in terms of representation and communication of a design concept. The main idea to design for people and consult the problems with inhabitants showed the role of participatory design, which is crucial in a democratic society.

The Project A itself was preceded by interviews with inhabitants and then, the concept was again consulted with them with the support of visualisations and animations. The simulations of urban transformation of the area in the form of animations helped to communicate the project since sanitised two dimensional technical drawings are not readable for laymen. Another crucial issue is a great attention put on creating the atmosphere of the place. Hence, students considered the emotional links of residents with certain elements of the estate (Project B—the elephant), the need to improve the aesthetic quality of the neighbourhood and their desire to be able to live socially in open air in the evenings (Project A and B). They prepared a set of visualisations representing the ambiance of redeveloped sites (Fig. 13.7) proving the places may become attractive and welcoming also after dusk. It is worth noticing, it means as early as 4.00 p.m. in the winter time.

Fig. 13.7 Two visuals showing the proposed interventions in the nocturnal lightning ambiance. *Source* Bem et al. (2015); Mrowczynski et al. (2015)

Both projects represent an urban design approach where people wellbeing is the core issue. That is why at the early stage it was crucial to learn about the environments and take into account the way local community experience places. Since prefabricated slab housing estates from the late 1960s and early 1970s, built in Central and Eastern Europe communist countries are difficult subjects in general, it was a challenge to grab and represent existing atmosphere and design the renewed ambiance of such places.

People are getting used to places they live, especially when they have no perspective to move, which was proved by the series of interviews with residents. This outcome helped simulate environments, on the one hand meeting contemporary lifestyle and needs, on the other hand considering values of the past still important for inhabitants. To some extent, it was a search for connecting the past with future to sustain the ambiance of the place and local intangible values. It is illustrated in Project B which respected the fact that inhabitants of this estate used "elephant" more accurate than GPS to navigate in the area. The word "elephant" has become a common word in their vocabulary. And all has happened just because in the 1970s a concrete sculpture of an elephant was situated there and its remains have been staying until today…

To conclude, the environment which requires some interventions or is not existing or is at the early stage of planning can be modelled, simulated and presented to enable public discussion and to help make up decisions. Since in a democratic and participatory society the openness and public opinion are crucial factors in decision making process, it calls for implementing representation, simulation and communication skills in architectural and urban education.

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Part V
Frontier Tools

Chapter 14
Outdoor Augmented Reality for Urban Design and Simulation

Chiara Calabrese and Luciano Baresi

Abstract Augmented Reality has been around for a while, and given the advent of many mobile devices, it can now be seen as an interesting technology for providing users with useful, real-time, and appealing extensions of the reality around them. This technology can then be used in many different domains: in this chapter we report on our efforts for developing a suitable tablet-based solution for the analysis and simulation of big urban projects. Our solution also contributes the use of beacons as reference for the proper rendering of the digital (augmented) parts on top of the real, existing ones. This chapter motivates the need for a new solution in the particular domain, explains our novel development, and provides a first, brief assessment. Our experiments have demonstrated that the use of augmented reality is not only possible, but can already be reality in the field of urban design.

Keywords Augmented realty · Beacons · Mobile app

Introduction

Augmented Reality (AR) technologies have seen a growing interest in the last few years (van Krevelen and Poelman 2010; Wagner and Schmalstieg 2009). There are several reasons behind this trend; the main one is that this technology has a natural integration with mobile solutions, and therefore the wide availability of wearable devices has boosted the range of applications that can benefit from AR. Despite the new opportunities for this technology, current AR applications are designed mainly for indoor use. This is due to the fact that outdoor applications present additional challenges and multiple constraints that limit their practical use (Azuma et al. 1999;

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Azuma 1999). Our work focused on overcoming these limitations of Outdoor Augmented Reality, in order to allow for new applications to flourish.

More specifically, this chapter presents a solution for applying Augmented Reality technologies to support the visualization of architectural projects in an outdoor environment, as support for urban planning. With our solution we aim at overcoming specific limitations in previous applications, which we will describe shortly, and improving the best solutions currently available. The most important requirements we addressed with this study are the accuracy of the pose of augmented content in the real environment, an immersive user experience, and the dynamic interaction between the system and physical reality.

The key enabler behind our proposal is the use of proximity technology and sensors to improve the Augmented Reality process. The result is an Android application used as demonstration of our studies. As the user experience is the ultimate measure of success in technologies such as AR, the feasibility of the proposed solution was empirically validated using several alternative projects that propose possible improvements to campus da Vinci of the Politecnico. Our application allows one to visualize them on smartphones and tablets, while freely moving in the augmented space, for a more effective understanding of the impact of the various projects on the urban landscape.

The use of augmented reality is not only possible, but can provide interesting results in the field of urban design. It can provide means to improve the design process, but also to improve the communication among stakeholders and ease the presentation of the project.

The rest of the chapter is organized as follows. Section "Augmented Reality in a Nutshell" briefly introduces Augmented Reality and its key characteristics. Section "Requirements for the Exemplar Application" describes the requirements at the beginning of our work, and provides a brief survey of similar, existing solutions. Section "Our Solution" introduces the solution we developed, while section "Evaluation" provides a first assessment. Section "Conclusions and Future Work" concludes the chapter.

Augmented Reality in a Nutshell

When we think of Augmented Reality we usually think of a futuristic technology made to impress the users, and this is in fact how Augmented Reality has been used so far. This powerful tool is used to insert digital content in a realistic environment and, therefore, it can be an effective invention for different purposes. With progress in research, people started thinking of how to use this technology in our everyday life, or at work.

To better understand what Augmented Reality is, we can start from Virtual Reality (VR), which is very close to AR to be often confused with it. In VR the user experience is completely redesigned. The user can only see a fully reconstructed digital world. This means that when the user is immersed in a VR experience s/he cannot sense the real environment at all, because everything s/he sees is part of a virtual world.

Augmented Reality is a technology that sits somewhere in a continuum between Reality and Virtual Reality. With AR the real world and the digital content share the same space. The reconstructed part, known as the augmentation, is the digital information added in real time, and the reality is a sort of background or context. The name augmentation highlights the goal of the digital content: augment and not replace the original user experience, by solely adding more information to the environment (Kipper and Rampolla 2013).

As the digital content is integrated with the true physical context in real time, supporting Augmented Reality can be more complicated than Virtual Reality. With VR the role of the developer is to rebuild an entire world from scratch, according to his/her own arbitrary rules. Instead, in AR, the developer has to ensure a good experience for the end user in the actual physical world. The main characteristic that defines an Augmented Reality system (Azuma 1997) is the interaction between reality and digital content in a real environment, in real time, and in 3D. Moreover, *digital content* and *reality* need to interact in a way that looks as realistic as possible.

Now that we have a more precise idea of what Augmented Reality is, we can summarize the ingredients required for building an Augmenting System. First of all, we need a computing system able to capture the scene and render the digital content, and this system may be mobile, or not. Also, we need the digital content, that is, the data to display (this may come in different formats: for example, images, text, videos). Last but not least, we need a reference. This is the key ingredient that will allow us to pose the digital content in the scene, according to a suitable criterion. Once all these elements are available, the augmenting process consists of: (a) recording the real scene, (b) analyzing it, (c) recognizing the reference within the environment, and (d) rendering the digital content in the environment with respect to the reference.

As previously stated, the reference is the key element for a precise definition of the interaction between reality and digital content, ultimately making augmentation of the environment possible. Both visual markers and GPS coordinates have been used as references. Both have individual pros and cons and only the context determines which of this alternatives is to be preferred. For example, if we are in a lab and we want to augment a single object or a picture, then our application has to specifically recognize that object or picture. In this scenario the use of GPS solutions would be meaningless, as it would be way too inaccurate to properly insert the augmentation correctly. On the other hand, if we are in an outdoor space, accuracy is not as critical, and we should be more interested in a technology that is easy to utilize properly outdoor and that also uses less resources than real-time picture analysis since connectivity can be limited and also we may not be able to plug our devices to charge it. This is why in this case the GPS reference can be a better solution.

Requirements for the Exemplar Application

Going back to our first goal, how can we use Augmented Reality when we are (re-) designing an urban area? First of all, we have to develop our use case, and design a good solution for it. When this project started, the researchers at the Urban Simulation Laboratory 'Fausto Curti' of the Politecnico di Milano were already studying the use of novel technologies for their project of *Città Studi Campus Sostenibile* (Piga et al. 2014). The aim of this project was to redesign the area of the city of Milan surrounding the university Campus of Piazza Leonardo da Vinci, with a particular attention to urban sustainability. The researchers wanted to find and test novel technologies to support the development process of urban design and also to improve the communication between designers on one side and interested third parties on the other.

In this scenario, Augmented Reality was chosen for its vivid and visible impact. It can change the way people look and evaluate an urban project, as it brings people directly inside the project. Designers, students, or just interested people not only can look at the overall project, but they can also explore it while there are at the place where it will be built. In particular, since we took into consideration the new design project of the area near the Campus, a good test for our application was the area of via Celoria, a street by the campus, redesigned to become a new focus in the area (Piga et al. 2015). The desired output of our study was an AR-based mobile application, capable of effectively augmenting this street, giving the possibility to the user to explore the entire space and look at all the possible alternative proposals for transforming it.

Given the aforementioned scenario/goal, we started studying the space where we were going to set our augmentation. As already highlighted, one of the key element of an augmenting system is the reference. Since we had to cope with a big, open space, we started using GPS coordinates and conducted a series of experiments to augment a small part of the Campus to better understand pros and cons of existing technologies. We first started testing Sightspace,[1] a known application that exploits GPS coordinates as reference. The outcome was that GPS coordinates are often not precise enough to augment urban spaces. Depending on the day, the error in posing the augmentation in the real space can be up to several meters. Under such circumstances the positioning of the augmentation may become so imprecise that the entire user experience is disturbed and hard to understand. This is unacceptable if the application is to be used in practice to communicate ideas and projects to the public.

Given the negative results with GPS coordinates, we went back considering a bi-dimensional marker-based reference system. The choice of this technology would have meant that to augment a real 3D environment we would have relied on a QR code or a picture that our application could recognize. In order to cover a wider space, an extension of this solution could have been to collect a number of

[1]LimitlessComputing. http://www.limitlesscomputing.com/sightspace.

images of the area which we wanted to augment, and use those images as reference. This solution has been used in other applications for augmenting outdoor spaces, like in project Archeoguide (Dahne and Karigiannis 2002; Gleue and Dahne 2001; Vlahakis et al. 2001), but this method adds other kinds of restrictions. For example, the fact that a bi-dimensional picture requires that the user stands exactly in front of it at a specific distance to allow him/her to capture the entire marker. It also requires the user to keep that same position during the whole experience, that is, while using the application, since the reference must always be on the screen. The freedom of moving around to explore a space, which is usually wider than the segment on the screen, is then compromised and the exploration of big projects precluded. These limitations convinced us we needed something new and different.

Our Solution

Nowadays lots of different companies develop tools and libraries for AR, especially for the mobile market. One of the most important is Metaio,[2] which provides the MetaioSDK, known to offer a wide range of tracking methods that allow one to develop applications able to recognize and augment a variety of different objects. What makes Metaio particularly interesting for us is its 3D tracking capabilities (Fig. 14.1). Given a 3D model of a specific object, Metaio gives the instruments to recognize that object in a tridimensional space. This kind of recognition has a fundamental importance for us, as it changes the way we can work with Augmented Reality.

The difference between this tracking method and a bi-dimensional one is that, after recognizing the object, the device has a way to take into account the width, the height and the breadth of the model recognized and, by consequence, of the space it is inserted in. With this knowledge, and by combining the 3D tracking with techniques of continuous recognition, we are able to make the user move around the 3D object—after recognizing it—and keep the augmentation alive (Maidi et al. 2011). The “usual” sensors that we can find nowadays in every mobile device, like oscilloscopes and compasses, can help understand how the user is moving in the real space. This way when the user moves, the application can move the 3D projection accordingly.

We have also to consider another advantage given by a tridimensional object, that is, there is no need to insert any object specifically related to our purpose in the space to augment. This capability allows us to take as model any tri-dimensional object that we can find in a real urban environment, as for example a building, and use it as reference for our augmentation.

Although this solution was a good enhancement with respect to what we were able to do with the solutions presented in section “Augmented Reality in a Nutshell”, still it was not good enough. The unsolved problem remained the initial

[2]Metaio. http://www.metaio.com.

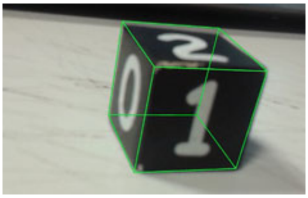

Fig. 14.1 Example of 3D tracking capabilities

moment when the user starts his/her augmented experience and must recognize the 3D marker for the first time. This recognition still had to be done from a fixed point defined at design time. As we said in fact the 3D tracking starts from the recognition of an object. In order to recognize that object not only we have to provide our application with a model of that object, but we also need the user to start her/his augmented experience in the exact position from which we captured that object. Another perspective of the same object would give us a different view of it and, of course, a different projection.

It is quite easy to see how this requirement did not give the user the freedom we were looking for. We then proposed two solutions to solve this issue:

- A simple one is based on the use of gestures to move the model of the 3D object around on the screen;
- A more complex one is based on the use of Beacons,[3,4] that is, external smart objects, as reference. These are small Bluetooth devices able to send a signal to all devices nearby. That signal transmits data about the specific beacon to the device, and the device is able to compute its distance from the Beacon by computing the strength of received signal.

After some first experiments, we decided to concentrate on the second solution and we started testing Beacons to better understand their behavior and see if we would have been able to use this technology to improve the initial recognition of 3D markers. At the end of our experiments, we developed a filter (Kalman 1960) to stabilize the measurements of the distance between mobile devices and Beacons, and we were then able to use the signal to compute how far the 3D marker was from our device, and how much we should have scaled the model on our screen to be able to recognize it from any arbitrary initial distance.

Evaluation

The tablet-based mobile app we developed, shown in Fig. 14.2, was then used for some experiments in our Campus Leonardo. We started the testing phase by using the projects that students developed to renew the area. This phase required a tight

[3]Estimote Beacons. http://www.estimote.com.

[4]Estimote Beacons, Android SDK http://www.github.com/Estimote/Android-SDK.

collaboration with the researchers of the urban simulation lab to iteratively and incrementally modify their projects to feed our application, and the application itself to cope with unforeseen situations and problems.

The application needs two different inputs:

A tri-dimensional model of the existing area, which would have acted as 3D marker for the recognition;
A tri-dimensional model of the augmentation, that is, the projects of buildings and installations foreseen to renew the area.

The initial models, as normal urban projects usually are, were a sum of the two, that is, both existing urban elements and new ones all mixed together. During the phase of preprocessing, we had to create a duplicate of the projects and use one of the copies to create the initial context, that is, the reference, by removing all the installations and elements that would have disturbed the recognition process. Similarly, we used the second copy for the augmentation, that is, for posing the new installations on the scene.

The two models had to share the exact same reference system to allow the application to add the second augmenting model at the same position as where the first model is recognized. In order to be able to do this operation we used another Metaio tool, known as Edge Configuration Tool, used to extract all the relevant information from the model we used in the recognition phase. This tool takes as input the model of the reference and the augmented content. The final output in constituted by two .obj files, one containing the surfaces and the other one the edges of the reference model. These two files were then used by two different algorithms to identify the models. Another part of the output of this preprocessing phase in the xml that contains details on the initial pose of the model with respect to the

Fig. 14.2 Our mobile app

augmentation. This file is used after the recognition to identify the right position to pose the augmentation in the space. As last output there is the tracking configuration file, even in this case a customizable xml is used by the system to regulate the extraction of the features during the model recognition. It also contains some of the attributes for using the edges and the surfaces modeled during the tacking.

We developed two different tests to demonstrate different achievements. The first test aimed to assess the precision of pose of our solution and the ability of the application to use buildings of considerable dimensions as reference. We then started from a CAD model of the building known as *Trifoglio* (a six-floor building in our campus) (Platonov and Langer 2007) and added the same model on top of it (Fig. 14.3). The results of this first type of test demonstrated that, if the model has sufficient feature to be recognizable, a building can be easily used as reference for the augmentation.

The second test we run was directly in via Celoria. Given the particular conformation of the street, where there are no buildings or installations that are visible from every perspective, we could not use the model of an existing building as we did with the previous experiment. For this second case we had to build an ad hoc 3D marker, a sort of totem, that we were able to move and pose in the chosen place. This totem helped us demonstrate two different uses of our application, called *static* and *dynamic* exploration, respectively.

In the former case (Fig. 14.4), we used the parameters of our tracking algorithm to create a sort of map of the explored environment starting from the recognition of the totem. So after recognizing the totem and setting the augmentation on the scene, the algorithm keeps tracking and mapping the area. The longer the user observes the area, the more points are added to the map of the space and the more robust

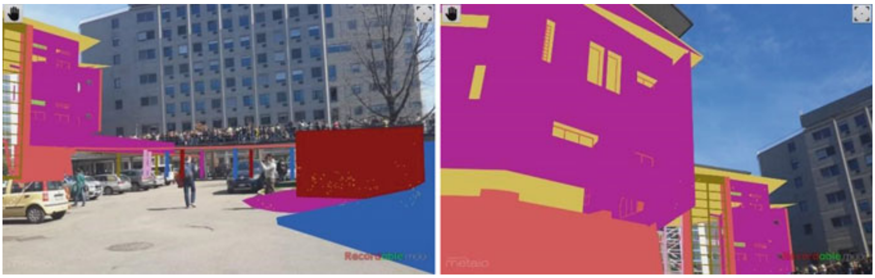

Fig. 14.3 Two snapshots of our application in front of building Trifoglio (Politecnico di Milano)

Fig. 14.4 Graphic description of static model exploration

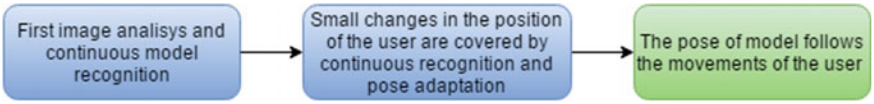

Fig. 14.5 Graphic description of dynamic model exploration

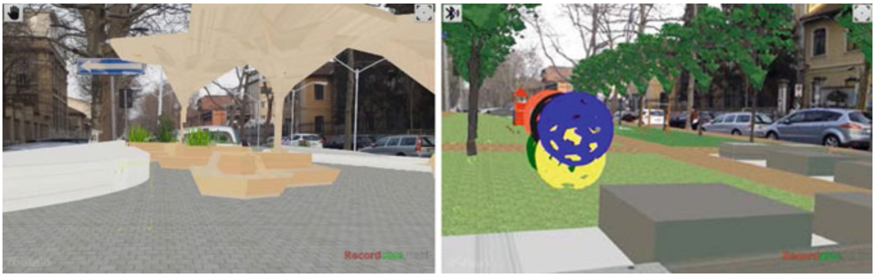

Fig. 14.6 Augmentation of via Celoria with the students' projects

the experience of the user becomes. This means that the user, while standing at the same position, is able to move the device around the totem and explore a wide area of the augmented space without risking a fail of the user experience.

In the latter case (Fig. 14.5), again the parameters of the algorithm helped us create a dynamic user experience. This time the algorithm does not extend the knowledge of the space by looking for other points to recognize, but instead it focuses on the continuous recognition of the model, and keeps updating and modifying the current state. This means that the user can move around the totem, but while keeping it within the frame of the camera, can move around the augmented space to explore the area exactly as if s/he were moving inside the project.

Figure 14.6 provides a couple of examples of how our app helped the students of the course in Urban Design contextualize their projects in the area of interest.

Conclusions and Future Work

This chapter presents an innovative solution for exploiting outdoor augmented reality for the design and simulation of big urban spaces. The proposed solution exploits a tablet to let the user look at significant portions of the environment and beacons to ameliorate the positioning of the augmentation in front of the reality captured by the mobile device. The experiments we have conducted have demonstrated that the proposed solution overcomes some of the known limitations in outdoor augmented reality. Specifically, we solved the problem of the initial pose and initial recognition of the 3D marker in a real space, offering the user multiple ways for exploring the augmented space. Our experiments have also demonstrated that the use of augmented reality is not only possible, but can already be reality in the field of urban design. It is important to recall that the analysis and adoption of new tools and solutions is fundamental not only to provide new means to improve the design process, but also to improve the communication among stakeholders and ease the presentation of the project. These are both crucial factors in urban planning, and both could benefit by technologies such as Augmented Reality.

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Chapter 15
Luminous Planning Table: TUI as Support for Education and Public Participation

Laura Cibien

Abstract After centuries of human evolution, we have developed elaborated skills to perceive and manipulate the physical environment around us. However, almost all these skills are not used while we interact with the digital world, especially in collaborative situations. Hence, there is a need to create new ways to put in relationship humans and computers, with the purpose to make the data tangibles and the use of computer so natural that we use it without even thinking about it. New interfaces have been designed to put in relation atoms and bit, mainly while dealing with simulations. Below, I will present the analyses of the implementation and application of these interfaces in educational and professional situations related to the architectural and urban fields. The aim is to understand how these tools can support comprehension, communication and sharing of ideas during analysis, design and evaluation of urban design projects. A series of case studies in educational and public processes will be taken into account.

Keywords Tangible interface · Urban planning · Urban simulation

Introduction

Urban planning is a complex process which includes aspects of social, economic, physical and spatial significance. These aspects are not independent and they interact with each other within the urban system. Even if computers have been used in architecture and in urban planning research for almost three decades (Mitchell 1996), only recently new interfaces are being developed to provide tools to actively analyze, plan and manage the urban environment, providing also real time environmental simulation, virtual reality, and urban simulation; those could be

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employed during the decision making process, conflict management, analysis and communications between stakeholders and "will allow questions to be asked that were not possible before, and better yet, answers to those questions" (Simpson 2001). The challenge is released to the increasing use of IT applications and production of devices, which require a design that knows how to take into account different possible contexts of use, the targets of users and new interaction technologies.

The acronym HCI (Human-Computer Interface) is used to enclose the set of created interfaces to enable the human-computer interaction and more generally human-machine interaction. In-depth study of these types of interactions cover aspects of computer science, psychology, cognitive science, ergonomics, design, information science, artificial intelligence and other fields. To better understand this big challenge, it will be resumed the history of Human-Computer interface, Graphical, Tangible and Natural User Interface, to today's technologies developed to find different ways of understanding and organizing cities. Some research initiatives, focused on collaborative approaches, pulling various analog and digital data collection and analysis tools, to mobilize a collective intelligence in a range of contexts around the world, will be taken in account.

Graphical User Interface (GUI)

The art and science of interface design are perhaps among the oldest human activity, dating back to the birth of the first tool used by primitive men. Since then the study of the interfaces has expanded, creating more and more complex devices, environments and objects of abstract information, up to the peak occurred with the advent of computers and devices during the last half century. However, most of these skills are not used while interacting with the digital world in which the interaction is mainly limited to the Graphical User Interface (GUI).

Normally the GUI interfaces are those whose applications are controlled through a series of graphical elements, called widgets, such as windows, buttons, menus and scroll bars. With the commercial success of the Apple Macintosh and Microsoft Windows, the GUI has become the standard paradigm for human-computer interaction.

The origin of the GUI can be traced to Bush (1945), a scientist who worked at Massachusetts Institute of Technology (MIT) during World War II. In his article "As We May Think", Bush proposed a management tool of information, the Memex, which would allow to record data on microfilm, making easy to access them, connected with hyperlinks and programmable. This idea has been developed by Ivan Sutherland, in his doctoral dissertation on Sketchpad (Fig. 15.1) at MIT in 1963 (Sutherland 1963), and Douglas Engelbart, a researcher at Stanford who in 1968 invented the first mouse.

The GUI represent information, bits, in form of pixels arranged on the computer display. These graphical representations are manipulated with generic

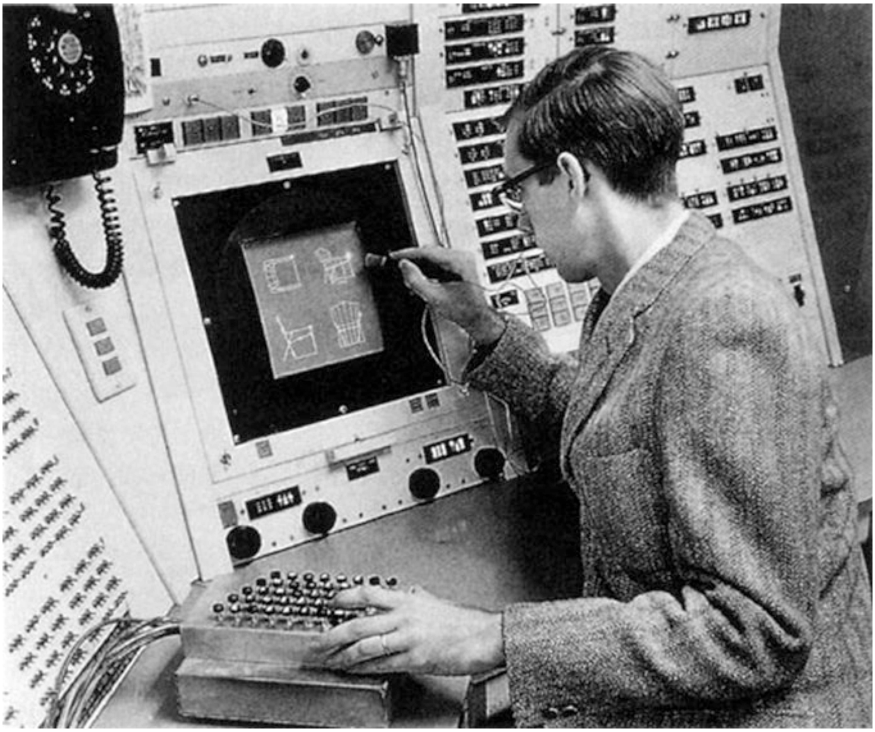

Fig. 15.1 Sutherland Sketchpad (1963) (*source* "Ivan Sutherland: Sketchpad Demo" (1/2) http://youtube.com/watch?v=USyoT_Ha_bA 6:44)

remote controllers, such as the mouse and keyboard. Due to the separation between the representation (pixels), and the GUI control devices allow to graphically emulate a variety of media. However, when we interact with the world of GUI, we can not take advantage of the evolution of our dexterity to manipulate physical objects. Some examples of post-WIMP (Window, Icon, Menu, Pointing device) interactions are: virtual, augmented reality, mixed reality, tangible interaction, ubiquitous computing, pervasive computing, context aware computing, PDAs or cellular interactions, perceptual and affective processing… All these new ways of interacting draw their strength from the fact that they were built on past knowledge of the users related to daily life, to the non-digital world. Each of them tries to make interaction with machines more similar to an interaction with the real world.

Augmented Reality (AR) and Ubiquitous Computing, in details, have begun to address the challenge by moving the space of the interfaces from the desktop to the physical environment, but these efforts have remained very attached to the GUI: many researchers have tried to export the GUI paradigm devices in space, losing the richness of physical and spatial interactions that should increase.

Augmented Reality (AR)

AR generates a composite scene in which the real world is “augmented”, virtually enriched with additional computer generated information. The aim is to let the user perceives a single real scene in a way that does not notice the difference between the real world and its “augmented” or virtually enriched reproduction. The first case in which this technique was used dates back to the mid-50s, when Morton Heilig, called the “father of virtual reality” in several books and articles, created and patented a simulator called Sensorama Simulator (Fig. 15.2), with images, sounds, vibrations and smells.

Fig. 15.2 Sensorama Simulator 1962 (*source* Feel 2012)

A limit of Virtual Reality is that its content must be constantly updated with present data not to became detached from the real world; the Ubiquitous Computing, which is the integration of human, computer, engineering factors and issues related to social sciences, wants to fill this gap being physically present in the real world. The main purpose is to allow the user to focus on his/her goal, without being concentrated on the use of the interface; the idea is to make computers silent assistants able to react to our habits and respond to our wishes (Weiser 1991).

Ubiquitous Computing

Ubiquitous Computing means about the opposite of Virtual Reality (VR): the last one puts people in a world computer generated; the Ubiquitous Computing instead puts the computer in the world of people. Similar technology can be considered the electricity that now has become a fundamental part, albeit invisible, of our daily lives.

The term "Ubiquitous computing" was coined by Mark Weiser in 1988, while teaching as chief technologist at the Palo Alto Research Center (PARC) of Xerox. Professor Weiser of electrical engineering and computer science has developed a new approach to the coordination computer activity with the physical interactions of the user captured by a series of devices that reside in the physical space. The first trials of its prototype took place during his university lectures: in the classroom a video camera had been set up, a recorder and two hidden computer to record everything that happened during the lesson, process them and upload them on the website, to give access students at all discussed materials.

Both alone and with John Seedy Brown, Weiser wrote some articles that represent the first documents, defining much of the discipline and highlighting its main interests and doubts. The first realizations linked to this theory were in the form of tabs, pads and boards, all built at Xerox PARC between 1988 and 1994. Mark Wiser describes it as follows:

> …its highest ideal is to make a computer so imbedded, so fitting, so natural, that we use it without even thinking about it. (I have also called this notion "Ubiquitous Computing", and have placed its origins in post-modernism.) I believe that in the next twenty years […] will come to dominate. But this will not be easy; very little of our current systems infrastructure will survive.

Computing, according to Weiser (1991), in 2000 was to enter into its third stage of evolution:

1950_Mainframe computing: a computer used by several users
1975_PC computing: a computer used by one user
2000_Ubiquitous computing: many computers used by one user

Subsequent work of PARC include the concept of "calm technology" exemplified by Live Wire prototype, whose aim was to create better integrated user interface with the physical device used by the user.

Tangible User Interface (TUI)

Tangible User Interface (TUI) originates from these arguments trying to make possible the vision of Ubiquitous Computing by Weiser weaving digital technology within the physical fabric of the environment and making the technology invisible. Instead of merging the pixels with an interface, the TUI uses physical forms that adapt to the user's physique (Fig. 15.3). Hence, TUI give physical form to digital information, facilitating the direct manipulation of bits. The goal is to increase collaboration, learning and decision-making through digital technology by exploiting the human ability to grasp and manipulate physical objects and materials.

The first TUI has been the Marble Answering Machine designed in 1992 by Durrell Bishop (Ghadirian and Bishop 2002), of the Royal College of Art student: a telephone answering prototype.

To make this new mode possible, Fitzmaurice in 1995 has created "Bricks": small tangible items directly related to virtual objects. Instead of just "show and tell", they have tried to create a tool that would allow the direct interaction of man with objects, in order to cover all the actual aspects of the design.

Most of the research related to "Bricks" focuses on the ways in which users interact with the physical object. When working with a single "brick" the displacement and rotation of the object correspond to the same motion graphic

Fig. 15.3 The ReacTable an electronic musical instrument example of tangible user interface, by Daniel Williams from NYC, USA https://www.flickr.com/photos/84466661@N00/539568298/ (creative commons)

attached to it. Using multiple objects together, instead, allows more complex actions, such as stretch, rotate or quickly define curved paths on the plane. This interface, linked to a simple paint program, Grasp-Draw, allows the user to create objects such as lines, rectangles, circles and squares and to scale, move and rotate objects using the bricks as tools. The use of physical objects such as control interfaces enables a greater number of users, including non-experts, to manipulate data in a collaborative way; each participant can observe, discuss and modify the work. Moreover, the TUI are usually constructed with known objects and thus usable by any kind of user.

Natural User Interface (NUI)

In 2006 were published the first articles on the Natural User Interface (NUI) which starting from the same theoretical basis of TUI, opposed to them by differentiating the concept of "manipulation" from that of "gesture". Christian Moore defined them in 2006: "*A Natural User Interface is a user interface designed to use natural human behaviors for interacting directly with conten*t" (Moore 2006). The NUI promise to introduce a more natural way to interact with machines by analyzing the nature of the gestures and movements to create systems able to read them and provide real-time feedback. To create such a system, however, there are several difficulties: the gestures of the people are very tied to their culture and habits, so it is unlikely to be indexed and, given the assumption that they must be natural, you can not provide guideline to explain what is been doing wrong if the machine does not get the expected answer. Today market, however, is leading to the touch screen interface and the gap between natural and routine is getting wider. Interaction through gestures seem an interesting new branch of HCI industry. Technological advances on the size, the power and the cost of microprocessors, memories, and other sensors make it possible to control the machines with small movements and hand taps and body. However, these types of technologies are merging quickly with the actions we take in our daily lives: computers, smartphones, tablet, home appliances, museum guides, every day we have to deal with them.

The Ubiquitous Computing is now reality in our society: from home banking to e- commerce, from home automation to smart-phone, almost every act of our daily life pass through a machine. Computers, televisions, and tablets have invaded our workplaces and our homes introducing virtual and augmented reality. It remains to understand which technology will prevail between GUI and TUI or how those will evolve. Most of the gestures are neither natural nor easy to learn, therefore the role of the "invisibles" NUI hardly will prevail: see an objects allows a greater simplicity of understanding and interaction, provides support for remember commands or location of digital objects, and it allows to check easily feedback and general outputs.

Understand how people use TUI rather than GUI, investigating complex issues, is important for two reasons: to better understand what we gain or lose going from a

GUI to a TUI for specific applications, and understand how knowledge of space is used in different manners using an interface rather than another, with the aim to improve human-computer interaction.

Case Studies

Nowadays, experts are still designing models constructed in order to assist in making urban planning process more flexible, by providing a means by which planning proposals could be visualized and alternative schemes for a site compared. Some relevant case studies of interactive interfaces designed for architectural and urban purposes will follow.

Luminous Planning Table (2000) (Eran et al. 2000)

The Luminous Planning Table (LPT) (Fig. 15.4), has been developed at Massachusetts Institute of Technology (MIT) by the MediaLab and the School of Architecture and Planning.

It originated from the prototype "Input/Output Bulb" (Underkoffler and Ishii 1999) and the luminous room (Fig. 15.5): a lightbulb which projects high resolution information and simultaneously collects live video of the region it is projecting onto, making possible tagging, wind simulation, shadow simulation, distance measurements, reflections,… their goal is the pervasive transformation of the architectural space, so that every surface is rendered capable of displaying and collecting visual information.

The LPT is a TUI for 2D and 3D physical and digital representations on several levels. Drawings, sketches, maps, satellite photos, and physical model, at the same scale, can be overlapped creating an hybrid space with various information that could enrich the urban planning process. The aim is to provide physical planners and urban designers with an interface to communicate their spatial concepts and ideas to a broader public.

Fig. 15.4 Luminous Planning Table, MIT 2001 (*source* Eran et al. 2000)

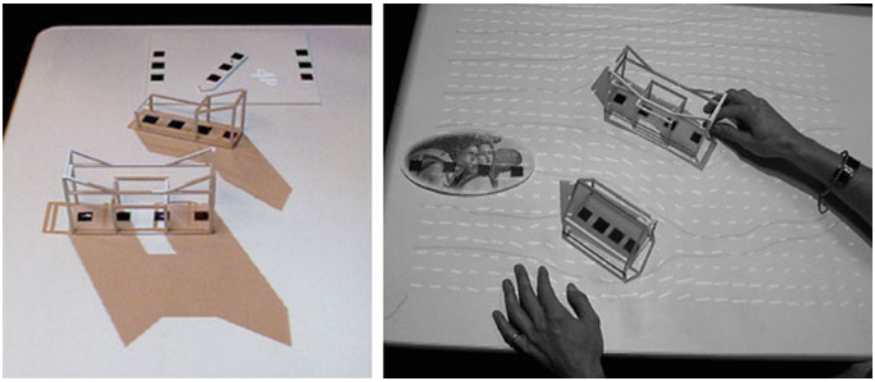

Fig. 15.5 Urban planning workbench (http://tangible.media.mit.edu/project.php?recid=73)

Fig. 15.6 MR tent, IPCity Project 2004–2009 (http://valeriemaquil.eu/?page_id=22)

The user is able to physically models its work, helping itself to understand the meaning of the spaces involved in its proposal. The elements placed on the table can be handled with ease, allowing non-specialists to participate in the process. The ergonomics of the table allowed the working group to work simultaneously on the project, helping the dialogue and the creation of shared ideas. The large physical size of the LPT enabled participants to engage together in the design process.

MR-TENT and the Color Table (2006) (Maquil et al. 2009)

The MR-Tent (Fig. 15.6) has been developed in the IPCity (FP-2004-IST-4-27571), a EU funded Sixth Framework Programme Integrated project on Interaction and Presence in Urban Environments. The aim of this framework is to apply mixed reality (MR) technology to urban renewal process to help multidisciplinary team and stakeholders to collaborate, explore, and discuss. The idea is to avoid planning mistakes by involving stakeholders from an early stage, improving communication in

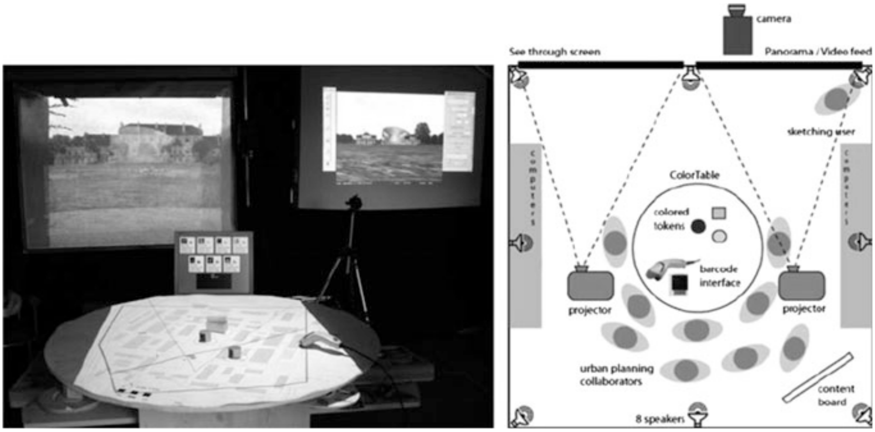

Fig. 15.7 Color table, IPCity Project 2004–2009 (http://valeriemaquil.eu/?page_id=22)

participatory workshop, trying to reduce confusion and improving trust, since urban projects are vastly complex and affects different actors and community politics.

The MR-tent is built on the site of the project: users can experience the real study area outside the tent, and inside can observe and evaluate together the provided MR space, supported by different tools:

- The "Color Table" (Fig. 15.7), a TUI which let the users interact with scale, temporality, boundaries, layers, and environments;
- a camera, placed over the table, to register and elaborate what happen over it;
- some tangible objects, supplied to manipulate the virtual model projected over the surface of the table: users can sketch, navigate, place and modify objects, and generate geometries;
- monitors on the walls, which show panoramic and subjective view of the scenario generated over the table, which can be saved and stored has memories;
- a software, called "urban sketcher", which makes possible to sketch, paint and draw over the monitor, helping communication;
- a monitor device, called AR scouting, designed to use AR outside the tent, overlapping real time data and reality.

The MR-Tent supports also the exploration and manipulation of soundscapes. Everyone has to be involved equally, intervening, commenting, and editing the objects on the table and choosing the point of view on the monitors.

Tavolo Luminoso (2010)

The "Tavolo Luminoso" is a TUI prototype built at the Laboratorio di Simulazione Urbana "Fausto Curti" of the Politecnico di Milano in 2010. The research has been carried out by the author, during her Master Thesis, and Francesco Secchi, an Urban Planner, under the supervision of Professor Fausto Curti and the Ph.D. Researcher Barbara E.A. Piga. The aim was to create an interactive tool for 2D and 3D workable models, which has to be portable, flexible, interactive, and user friendly. The three main step have been:

Investigate the availability of software developed to link real and digital objects, preferably with a graphic user interfaces ease to use, freeware licenses, and with access to the source code.
Build a physical interface suitable for 3D models and on which to project digital content, large enough to allow multiple users to collaborate, but to be easily portable.
Create a touch screen large as the whole interface to allow users to bypass the need for a PC while interacting with the digital content.

We achieved our goals with (Fig. 15.8):

1. ReacTIVision, a software developed from 2003 by a research group of the Pompeu Fabra University of Barcelona to realize a tangible modular synthesizer called ReacTable; it relates real object with digital ones through QR code called "fiducial marker". Thanks to the free license, a big web community established around the software, giving tips and producing new scripts to develop various tasks;

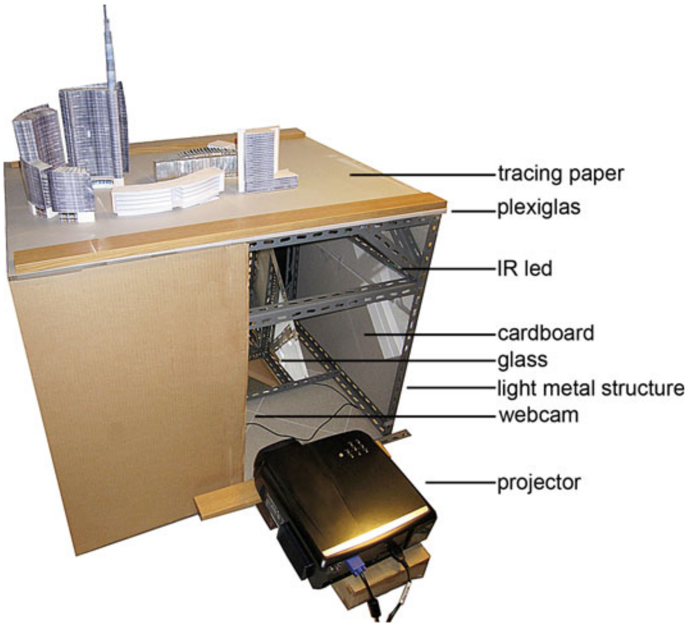

Fig. 15.8 Tavolo Luminoso, labsimurb—PoliMi 2010 (*credits* the author https://youtu.be/FADavOFp3nQ?list=PLcuVzk8EPrU_dRblJoWiCodIbDh0JF5Wq)

2. a table made by: aluminium section bars, a thick sheet of plexiglass covered with tracing paper, a mirror, a usb camera, and dark cardboard. The aluminium makes possible to assemble a light table easy to be disassembled and carried where wanted; the thick plexiglass is solid enough to sustain a 3D model and other "bricks"; the tracing paper stops the projection of the projector over the surface of the plexiglass, creating an affordable "monitor"; the camera above the plexiglass and connected to a laptop register what is happening over the surface of the table, giving real time feedback; dark carbon complete the table, by providing a shield to external lights which could interfere with the projection or the shoot of the usb camera;
3. the software CCV, an open source/Cross-platform promote by NUI group for blob tracking with computer vision, which has been used to link the finger to the mouse pointer. To help the camera distinguish projection and real object over the table we have mounted an IR filter over the lens and installed a strip of IR LED all over the border of the Plexiglass to let the IR light bounce freely inside the sheet. Once a finger is put over the surface, it stops the beam and let the camera recognize it and its movement over the surface.

We tested the interface with the material produced for the research over the case study Garibaldi-Repubblica in Milan: a photorealistic model 1:500 of the neighborhood, base maps, analysis, a 3D digital model navigable in Unity… We attached a QR code over each city block or building, in accordance with its size, and linked it to its digital reproduction. We made tangible "commands" by linking QR code to digital cameras, sunlight (Fig. 15.9) or base maps, to let the user interact with the digital tool through real handle object.

In 2010 we have needed a big effort to have the real model and information about the neighborhood. Processing speed and data storage capabilities were limited.

City Scope (2015) (Winder 2015)

MIT CityScope (Fig. 15.10) is an open source platform for shared, interactive computation developed by Ira J. Winder from the MIT Department of Urban Studies and Planning. The system integrates hardware and software platform that merges parametric, voxelized simulations with user-friendly tangible interfaces which place a special emphasis on augmented reality decision support systems (ARDSS) that facilitate non-expert stakeholder collaboration within complex urban environments. Wilder works with industry, academia, and public agencies to build executive-level tools for solving complex spatial problems. To represent different buildings have been used optically tagged Lego bricks. Changes to the city are visually revealed in real-time by changing color-codes projected onto the pieces.

Fig. 15.9 Tavolo Luminoso: shadow analysis (*credits* the author https://www.youtube.com/watch?v=Q3CM9Q2w1uI)

Fig. 15.10 Cityscope, MIT 2015 (*source* "Lego Scanning Technology Invented by MIT by Ira Winder" https://www.youtube.com/watch?v=3jvmoj7pLZU&feature=youtu.be 2:59)

As part of a cooperation between MIT and HCU the first urban model of this kind was built in an interdisciplinary student-workshop using Lego bricks as well as traditional materials. Then it has been used, between the other, as AR Decision Support Tools and for mobility project. It has been tested with different scale models, and a touchscreen interface to illustrate the potential effects of different plans on a regional scale. A goal is to provide models available for the public to explore—and see how their own lives might benefit or suffer from certain plans. On the touchscreen, for example, users can visualize big data about a specific part of the city, as how many jobs they can get to from that spot via proposed public transportation. The aim is to "*make the urban planning process more transparent by getting everyone involved—not just experts…*" (Winder 2015).

Final Remarks

During the last decades the primary focus of most of collaborative systems has been to achieve better productivity in various sectors, supporting processes and well defined actions. Today's society is characterized by increased professional specialization, continuous changes in the market and emerging technologies for information and communication. The knowledge required to formulate and solve complex problems is not the sum of the knowledge of each participant, but the result of a process of knowledge exchange and construction of social interactions, that can be defined "social creativity". Providing tools, devices and space where to share, communicate, and plan together, can stimulate this process.

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Chapter 16
Mobile Devices and Urban Ambiances: How Connected Wearable Tools Change the Ways We Perceive and Design Public Spaces

Myriam Servières, Gwendoline L'Her and Daniel Siret

Abstract New mobile digital devices raise new questions on architectural and urban design processes. They suggest new ways of dealing with projects in situ, organizing virtual and real data, acquiring information about shapes, materials, climate, lights, capturing specific *genius loci* of the site, as well as creating interactions between multiple stakeholders and users of urban areas. The set of available tools (smartphones, tablets, wearable devices, etc.) has not been yet deeply studied according to this prospect. How can these tools transform the understanding and the analysis of in situ environments? Modify design processes? Give shape or even create particular environments? The paper discusses these issues. It displays ideas for applications of mobile devices on architectural and urban design, wondering what such tools do change in our relationships to the city and to other people in everyday life. Lastly, it sees if the built environment can be affected by the effects of new digital mobility, especially focusing on the renewal of citizen participation process.

Keywords Augmented reality · Urban design · Mobile app

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Introduction

Cities are mutating integrating new technologies, becoming *smart* and embedded with computers. Townsend (2014) defines smart cities "as places where information technology is combined with infrastructure, architecture, everyday objects, and even our bodies to address social, economic, and environmental problems".

These technical transformations of cities are perceptible at citizen scale too. Citizens are mutating too. In 2012, 80% of the world population owned a mobile phone.[1] This corresponds to about 5 billion of phones and among them 1.08 billion were smartphones. This number is supposed to continue to grow in the next years.[2] In parallel, connected devices (as tablets, wearable computing tools etc.) use is also growing with "some 50 billion networked objects" connected to the Internet by 2020 (Townsend 2014). Maybe soon, almost everybody will be connected to a network.

Mobile tools here can be seen as physical sensors (giving position, direction, orientation, temperature, luminosity). They can record, allow communications, representations, be a sketchbook, a notebook, a measuring tool, a processing tool, a tracking tool, etc. In a broader sense mobile tools can also be seen as "social" sensors. They allow the connection to the user networks in mobility giving him or her the ability to be at the same time in a physical place and in a digital world. He or she can then share all his or her records/thoughts about a place and become a "citizen as sensor" (Goodchild 2007).

Captors/sensors give access to various information to interact with one's surrounding. Captors/sensors mean all electronics wired tools, private or public, visible or invisible, mobile or even fix in smart cities interacting in public space. Data access is at different scale. First, people can monitor themselves through wearable devices. Then data are also accessible at city or territory scale. Mobility is also through scale and through data.

These new mobile digital devices raise new questions on architectural and urban design practices linked to urban ambiances. Urban ambiance or atmosphere is understood here as a sensible configuration in a specific place and time, within a build environment dealing at the same time with physical phenomena, social interactions and a cultural background.

New mobile tools suggest new ways of approaching projects in situ, organizing virtual and real data, acquiring information about shapes, materials, climate, colors, lights, capturing specific *genius loci* of the site, as well as creating interactions between multiple stakeholders and users of urban areas.

These new abilities of the captors/sensors embedded in our mobile devices make real the idea of a sensible urban environment design going over the fix image frame to allow a dynamic interaction in situ with sound, light, climate, even kinesthetic

[1]http://www.go-gulf.com/blog/smartphone/ (accessed 2017/1/5).

[2]http://www.emarketer.com/Article/Smartphone-Users-Worldwide-Will-Total-175-Billion-2014/1010536 (accessed 2017/1/5).

modalities defining urban ambiances. At the same time, being connected to various networks, socials networks, *apps* and on-line data opens new ways of thinking for architects, engineers, sociologists or even artist working, maybe together, on an urban project.

The set of available tools has not been yet deeply studied according to this prospect. How the collaborating stakeholders involved in the design of an architectural or urban environment can use these new tools? How can they transform the understanding and the analysis of in situ environment? Create new needs? Revise design practices? Produce their own hybrid environments at the interface between real and virtual world? Give shape or even create particular environments? How these connected devices transform urban ambiances? What are the new forms of interaction and communication they will produce in urban space? What are their impacts on urban daily practices and on urban design? What technical and political issues arise from their multiplication and interactions?

In the following, we will first see what a digital mediation to design urban ambiance could be. Then we might wonder what such tools do change in our relationships to the city and to other people in everyday life. Lastly, we will discuss how the built environment is affected by the effects of digital mobility especially focusing on the renewal of citizens' participation processes.

Digital Mediations to Urban Ambiance Design

Mobility to Interact with Ambiances in Urban Design

With the advent of smart cities and mobile tools, we experiment a join evolution of urban environments and personal devices, all connected together in new networks. The main advantage of mobile tools is what (Camacho-Hübner 2014) calls their "augmented mobility". This mobility allows new experiments of being in a city with access to Internet or networks in general. Digital space and urban space can interact together thought an "interface that gathers, combines and customizes a multitude of heterogeneous information" (Camacho-Hübner 2014) and enrich the mobility.

On-site interaction in mobility is the key to mediation with urban ambiances. To have a first insight of this question, an interdisciplinary workshop called Mobiance was organized in 2013 in Nantes, France. Twelve master students from various areas (engineers, architects or designers) were invited for several days of work. They were organized into four multidisciplinary teams. The objective was to design new possible use cases of interactions with cities in terms of urban design due to new modalities offered by mobile tools. As young persons, they were supposed to be more comfortable with such devices [as the higher smartphone penetration rate is in their age group (see footnote 2)] and a part of them were familiar with urban issues. They were asked to produce scenarios of new uses of mobile tools for urban

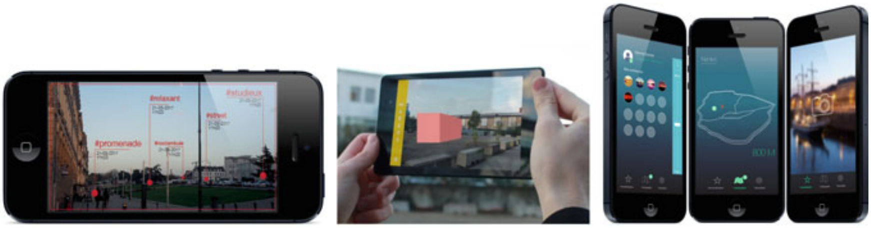

Fig. 16.1 Concept views of *Spacemood* (by Lola Mahieu, Mathilde Orain et Sylvain Toldo) (*left*), *Makers* (by Camille Barbo, Maxime Picard et Paul Vanbergue) (*center*) and *Pathfinder* (by Maxime Coude, Nicolas Houel et Gwendoline L'Her) (*right*) applications

design in relation to ambiances. The results of the first Mobiance workshop were scenarios where mobility was the core[3,4] (Fig. 16.1).

The *SpaceMood*[5] proposal described a geolocated network where ambiances become tangible. According to this proposal, the "spirit" of a place can rely in a collaborative stamping. An application would allow a user to tag a place by a *hashtag*, following the same principles as those used on social networks. This label would mainly be a word or a group of words that expresses the user's feeling, but labeling could also go beyond words. Indeed, mobile tools allow to associate geolocated pictures that participate in the identification of a place, or receive some environmental information also geotagged, as temperature, wind or sonic levels.

The *Makers*[6] proposal is a collaborative game where citizens become part of urban development decisions in a virtual world. This virtual world is based upon the real city, at least at the beginning of the game. When traveling into real space, players could have access, through their smartphones, to areas of the virtual city in their fields of vision. This would allow them to comment or even change the virtual public space, its architecture and atmosphere. The application would consist of two components: a playful component for transforming the virtual world, and a citizen consultation component dedicated to real development projects. Thus, someone wishing to associate people in the development of local community would rely in the later component of the application.

According to the *PathFinder*[7] proposal, local authorities lack information on the way urban citizens perceive ambiances of the city. The proposal aims at filling this gap. Thus, it proposes local services for collecting physical and sensitive data related to the atmospheres of a place at various times. Besides, the device hosting the application—a smartphone for instance—registers physical geotagged data of

[3]http://www.ambiances.net/workshops/nantes-2013-mobiance-outils-mobiles-ambiances-design-urbain.html (accessed 2017/1/5).

[4]Images and proposals are under Creative Common License (Attribution—Non Commercial).

[5]By Lola Mahieu, Mathilde Orain et Sylvain Toldo.

[6]By Camille Barbo, Maxime Picard et Paul Vanbergue.

[7]By Maxime Coude, Nicolas Houel et Gwendoline L'Her.

any given space. Users of the application enhance data in a participatory way. Each user can thus give his or her assessment of a place, in the form of a photograph that will indicate to the community that the place was appreciated at this particular time, in these conditions. This is the passive use of *PathFinder*, a mode by which the application stores and learns the user preferences through his or her walks and places where he or she stays most often.

Each proposal resulting from the Mobiance workshop addresses urban design through ambiances in a specific way. According to *Makers*, ambiances are a quality of the urban areas, among other ones, mainly defined by the uses of space. The game implicitly assumes that the ambiance results from the layout of places, while the mobility of the players is the key factor to determine their influence. For *SpaceMood*, an ambiance is a kind of spatial distinction that occurs at the inter-section of personal appraisal of places and physical data collected over the daily journeys. Urban design would then consist in identifying places where appraisals are considered poor, in order to improve their layout. In *PathFinder*, ambiances are not a motor to urban design but they become a communication medium for city heads who can bring citizens who share the same sensibility to discover new places.

Obviously, the three proposals take advantage of the mobility of the devices that support them. *Makers* and *PathFinder* applications go further by promoting their own mobility. This approach may have some drawbacks, by implicitly devaluating certain places, due to a necessary leveling of the ambiances around consensus statements. Similarly, strong distinctions in ambiances can lead to spatial segregation that run counter to the stated objective.

According to the teams, urban ambiances can be characterized by a twofold system of data: firstly, physical sensors are spread all over the city collecting numerous quantitative physical parameters such as temperature, sonic levels, brightness, wind direction, activities, and so on. On the other hand, the resulting data is qualified through annotations of personal feelings that give them meaning and singularity, like subjective assessments based on words and pictures.

Technical Evolution with Various Limitations

Imagining new uses of digital mobile tools, as the ones presented in the previous part, opens unforeseen possibilities, "but expecting that access alone will create opportunity is no longer appropriate" (Townsend 2014). Indeed, peoples need to be trained to use them. "Information should be at the same time accessible and comprehensible in terms of content, but also in its form for the citizen to be able to transform the message into information" (Mericskay 2013, p. 275). This new mediation, without attention, can create new kinds of exclusion.

At the same time, people who are familiar with connected mobile tools can share data and offer their subjectivity to others, like in the three proposals presented before. Apps like Instagram, Vine, Twitter, Tumblr and others, gathering and sharing data creates added value to the network itself. The resulting observations carried out in each of the proposals are therefore not the average of all opinions but the status of a collaborative process in progress. Such collaborative modes, or crowdsourcing, raise ethical and legal issues. All the produced and acquired data can be centralized and related with the users movements in what (Boullier 2000) calls a "fantasy of total knowledge" that becomes possible in nowadays urban environments. The prospect of a centralized and hyper-supervised world raises major ethical questions, which were mostly ignored by the teams during the Mobiance workshop. It seems that for the concerned generation, students and young professionals under thirty years, tracking of individuals is a necessary evil if it is placed in the service of the common good, controlled by a vaguely defined public authority.

The digital ambient world presented before changes our relationship with the city and with other people in everyday life. Mobiles tools change the way we perceive our environment through ubiquitous and mediation possibilities. "Our city and territory experience is enriched with the semantic added by all the person that came there before us. We can almost be in a state of permanent *déjà-vu*. Do we still have personals territories? Do we still construct our living space through a physical traveling experiment or do we live them through a small touch screen?" (Camacho-Hübner 2014). Mobile tools change the actual urbanity as it will be seen in the next part, and also the collective practices as it will be seen in part 4.

Digital Ambient Urbanity, a Change in Everyday Life

An Augmented Urban Experience?

Following the same scheme, the second Mobiance workshop was organized in October 2015 with 12 others students (engineers, managers, urban planners). The focus then was not on use cases but on interaction between human-sensor communication interfaces and users in public space. The question was how to filter, aggregate, contextualize and disseminate relevant information in a context of multiple and continuous flow of data. Students had to envision specific urban situations and to build, illustrate and present a coherent and relevant scenario at the end of the workshop. They were asked to consider captors/sensors interaction and uses with no technical limits, and they were pushed to work with various sensory modalities: light, sound, kinesthetic, vibration, odor, etc.

The proposals resulting from this second Mobiance workshop emphasized the emotional dimensions of urban digital experience. The four proposals presented four different ways to express and share emotions without worrying about their dissemination and reception. Students imagined scenarios where people would be immerged into ambient visible/sensible emotional fields. Intimacy vanishes to allow collective interactions with people's moods or emotions, even if a free will still exists to some extends. The mobility does not give new meanings to urban world, but it allows sharing more emotions. In such fantasy world, like in current real one, the attention becomes a limited resource. With the overload of information, we need to filter it. As (Citton 2014) explains, we come from an economy of attention to go to an ecology of attention. Not to be overwhelmed, we need to have a sustainable interaction with our environment and not only a valuable one. This will be even more important if these data are emotions as imagined in the workshop.

Transformed Interpersonal Relationships

We can carry our own personal world inside the actual world, or as defined by Boullier, we inhabit an “habitele” (Boullier 2011, 2014). We live in several worlds at the same time. In town we need to move physically to change our environment; with a smartphone we can do it even without moving. The smartphone is an “augmented habitele” that augments our urban experience.

Boullier gives the example of an “habitele” that changed the shape of the city: the car. The next question is now: how the connected mobile devices will change the shape of the current and future cities?

Mobile media devices have changed the way of getting around in urban areas (Camacho-Hübner 2014). These new uses are integrated by traditional urban stakeholders into their strategies for urban design: public spaces are adapted with connected bus shelter and carpooling areas, aid to navigation tools are developed using geolocalization, route generator and service disruption notification systems are available. Public institutions try also to find ways to regulate new controversial uses, which appear with digital technology. Mobile media devices allow access to information at the right place and at the right moment so that people can interact and take decisions. On the contrary, they can virtually escape from their actual environment.

New Uses and New Relationships to the City: What About Citizen Empowerment?

Located Knowledge and Mobile Digital Devices

By immersion citizens perceive places and gain knowledge about the city. This non-professional expertise is gradually being added to urban design with dialogue and consultation processes, as noticed in (Bedel et al. 2015). Mobile media devices could change temporality and visibility of these processes. Firstly, the technical tools take part as intermediaries to describe the place with personal expressions like words or photography as illustrated in the second part. They also enable to take measurements with the available mobile sensors and applications.

Technical sensors can make visible some environmental factors, which are inaccessible for human senses. Furthermore, the specificities of the place can be unveiled by social interactions too. With IT networks, a citizen can directly and in situ obtain further data as different point of view and comments, upcoming events or past situations, which could be imperceptible on-site. By combining, capturing and sharing data, mobile media devices are intermediaries that can get an influence on the temporality of social interactions as discussed in part 3. These located interactions between human and mobile media devices have become an urban phenomenon and they generate urban data.

Analysis of these data, their confrontation with expertise and personal convictions shape located knowledge. This knowledge specific to a place is produced sometimes ex situ by a third party when the data are being shared. It gives the possibility to recycle or distort the use of data and it raises controversies. The located knowledge can also be shaped directly in situ by the citizen who makes his or her own analysis of the collected data. The interactions between human and mobile media devices lead to a hybridization of the design process mixing request and sharing. Implementing the located knowledge into urban design questions the new status of citizens in urban public action.

Local Public Action and Citizens

In the Internet age, the distinction between a layman and an expert, based on recognition of knowledge and the access to media, is shifting towards a distinction between amateur and professional, based on the different nature of commitment. Both notions of amateur and layman are to be put into perspective within an area of competence. People as individual assume actually several social aspects, which shape a set of skills but also proper agenda and interest. One can be at the same time inhabitant, professional, activist, etc. These transformations are facilitated by the technology, and they bring about a redistribution of stakeholders' roles and the emergence of new kinds of expertise (Joliveau et al. 2013).

In urban design, inhabitants' expertise has been taken into consideration through public participation spaces like workshops or public inquiries. Public participation has been generalized with decentralization policies and the adoption of the principles of sustainable development. However, public participation processes remain highly controversial, considered either as citizen empowerment or democratic alibi. Some professionals advocate that new mobile digital devices will enable to get more feedback from the citizens, whereas for other professionals the risk of a strong public participation is to extend decision-making's time and so to reduce the capacity to adapt the public action (Bedel et al. 2015).

Over the last decades, urban design processes have evolved from city planning to strategic approaches through the notion of urban project. Local public action is led by an authority which "collective action capacity depends on the capacity to mobilize constantly the stakeholders, groups and institutions which constitute the city and to articulate their resources" (Pinson 2009). The same author notices that the democratization of decision-making process "has been limited to the stakeholders and interest groups with public acting resources".

Mobile Digital Devices: A New Tool for Local Public Action?

The dynamics of transformation of urban public action lead local authorities to imagine new participation processes. Some of them take advantage of mobile media devices. This supposes to question the form of public participation and how citizens mobilize themselves in order to take part in urban design and management processes. Could mobile digital devices become an instrument for urban public action?

As defined by Lascoumes and Le Galès (2004), "an instrument for public action is a technical and social device, which organizes specific social relationships between the public authorities and (some) citizens or organizations depending on the representations and the meanings which it carries". For example, reporting mobile apps like FixMaVille[8] use an open outsourcing strategy, which means that a citizen can contribute to describe a located situation for further urban services interventions. However, in this case, the interaction between the citizen and the city is limited to a simple report. This kind of applications raises controversies because the distinction between report and denunciation is sometimes thin.

"[The professionals] do not wish to see another mobile app who look like a gadget. But they would like devices which could bring a real and useful advantage for their urban project" (Bedel et al. 2015). The mobilization and the commitment are recognized as a recurrent difficulty of participatory devices according to professionals. By using a new media to support public participation, they hope to renew the panel of contributors and the topics for discussion. The cohabitation of different forms of citizen commitment going from simple contribution or request of information to a collaboration with the decisions makers, could become a lever for opening the public participation.

However, (Bailleul 2008) has shown that the use of digital technology in urban marketing strategies is not well perceived and damage the public participation process. The risk is that mobile digital devices for urban design become tools for city's communication. On the opposite, mobile devices and the viral effect of social media can encourage mobilization and network action (e.g. lobby strategy) that can be used by advocacy planning stakeholders. According to Mericsksay (2013) in that case, the technology is not used for a contributive strategy. It is used by a single citizen or a small group of citizens to send an alert or to raise issues into the public debate, so the power balance in the urban political arena could change.

[8] www.fixmaville.fr/ (accessed 2017/1/5).

Concluding Remarks

Today we are observing the raise of an *augmented public space* merging knowledge from the information and communications technology side (ICT) and architecture and urban design side. The design of the future cities can be seen as the intersection between ICT and architecture. The interface elements from both sides should be designed in a way that facilitates navigation to augment urban experience (Camacho-Hübner 2014).

As noted by Bailleul (2008), a new balance has to be found between citizens becoming experts and sharing their expertise, and public authorities. "If we accept the idea that the city is a partially auto-organized complex system then a new equilibrium state may arise from these new practices mainly based on individual interaction maximization. Then, in this new equilibrium state, the function of the 'ICT urban planner' or 'urban operating system developer' need yet to be invented" (Camacho-Hübner 2014).

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Rainisio Nicola Ph.D. in Psychobiology, is an Adjunct Professor in Social and Environmental Psychology at the University of Milan, Department of Cultural Heritage and Environment, where he also taught Psychology of the Environmental Communication. He conducts studies on the relationship between psychological well-being and places, and has participated in several projects funded by research grants from national and international institutions (i.e. Designing spaces and scenarios for Milan Hospitable City). He also cooperates, through lectures and consulting activities on the socio-spatial perceptions of refugees, with public agencies and local associations, as a member of the Laboratorio Escapes (Laboratory of critical studies on forced migrations). He's author of many international publications on these topics, and reviewer for the Estonian Research Council.

Rossetto Andrea Andrea Rossetto, graduated in Architecture in 2005 at IUAV, received Ph.D. in 2013 with a research on John Hejduk. From 2001 to 2014 he worked with prof. Renato Rizzi, both in the professional and academic fields. The focus was based on the definition of architectural design principles and on representation, from the architectonic to the landscape scale. The results of this research include many awards in architectonic competitions, that led to the construction of the Gdansk Shakespearian Theatre, and many other landscape researches. He is now is working on landscape and environmental topics, shifting the focus from the academic-research field to concrete professional one. Last publications include: Rizzi, Pisciella, Rossetto, Il Daimon di Architettura—Manuale, Mimesis Milano 2015 and Rizzi, Pisciella, Rossetto, Il Daimon di Architettura—Parva Mundi, Mimesis Milano 2015.

Salerno Rossella Becoming Doctor of Research in "Survey and representation of Buildings and Environment" in 1991 with a thesis on the representation of landscape. Researcher since 1992 now is Full Professor of Theory and Techniques of Representation in the School of Architecture, and Society of the Politecnico di Milano. The outputs of her research have been published in essays and volumes closely linked to the field of representation although related to interdisciplinary approaches to architecture and environment. Her scientific contributions are mostly on Representation of the territory, Cultural Landscapes, Urban Simulation. She has taken part in several international and national research programs and is currently Head of the Ph.D. Program in "Territorial and Design Government" of the Politecnico di Milano.

Main educational exchanges with the DESS at the École d'Architecture de Versailles, the Université Lyon III, the École d'Architecture de Lyon, the École d'Architecture de Paris-La Villette, the École d'Architecture de Grenonble, Universidade Technica de Lisboa, Bauhaus Weimar Universität, Escuela Técnica Superior de Arquitecura ETSA, Madrid, TU Delft.

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Signorelli Valerio An Architect by education, Valerio Signorelli is a Research Fellows at the laboratory CRENAU—ENSA Nantes. He holds a Ph.D. in Territorial Design and Government from the Department of Architecture and Urban Studies (DAStU) at the Politecnico di Milano (2013). His research interests focus on urban design, sensory urbanism and digital simulation tools. He works on the mutual influences of the sensory stimuli (mainly visual and auditory ones) in urban ambiances and the qualitative representation of the everyday users' experiences through innovative digital technologies.

Siret Daniel Daniel Siret holds a Ph.D. in architecture and is a researcher for the French Ministry of Culture and Communication, at the School of Architecture of Nantes. He is also Head of Ambiances, Architectures, Urbanités Lab (UMR CNRS-MCC-ECN). His work deals with the ways in which sensory dimensions are taken into account in the built environment, especially with regard to the architectural and urban expression of solar radiation. He was a visiting scholar at the Fondation Le Corbusier (2005), the Canadian Centre for Architecture (2012) and New York University (2013).

Thibaud Jean-Paul Sociologist and urban planner, is senior researcher at CNRS. Researcher at Cresson (Research Center on Sonic Space and the Urban Environment, UMR1563 Ambiances Architecturales et Urbaines). His field of research covers the theory of urban ambiances, ordinary perception in urban environment, social anthropology of sound, sensory ethnography of public places. He has directed the CRESSON research laboratory and is currently the co-director of the International Ambiances Network (www.ambiances.net). Jean-Paul Thibaud has published numerous papers on urban ambiances and has co-edited various books on this field of research.

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