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Giacomo Chiesa

Technological Paradigms and Digital Eras

Data-driven Visions for Building Design

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This book is dedicated to Tat and Chloe.

Foreword

A current trend in the construction sector is designing and operating buildings increasingly "sustainable" and "smart", responding to worldwide, European[1] and national standards based on the assessment and certification of environmental, social, and economic performance. This trend is as well responding to market needs for invigorating an otherwise almost dying demand for new constructions. This situation poses new challenges to architects, engineers and builders as well as any other operator of the construction sector.

In particular, these challenges can be characterised mainly by the following aspects.

- An accurate and detailed knowledge of the physical context of the building under design, including climate, geomorphology, energy network and material flows.
- Availability of calculation and simulation tools able to model and predict the building's performance in terms of environmental impacts and functional operation efficiency during its expected lifespan. Such tools shall have, differently from the majority of the mostly diffused current ones, a parametrical and holistic approach to allow designers for checking while designing, since the earliest stages, the effect of any choice on the future performance and, reciprocally, evaluating formal options as a consequence of specific environmental and functional requirements.
- Availability of hardware, and relevant operating knowledge, concerning the smart control of a building, automatically and by its users, in order to make its use the most efficient in terms of energy consumption and environmental impact.

[1]See, in particular, the series of standards developed within the CEN TC 350 working groups on the assessment of sustainability in buildings and engineering constructions at both levels of building and product.

The present publication by Giacomo Chiesa offers answers to all these aspects, through analyses, methods and tools, which are original and based on a scientifically robust background.

His contribution includes an investigation of the state of the art of theories and methodologies, on which elaboration and management of data for urban and building design are based. Within this framework, he sets guidelines for a future perspective, within which building performance simulation during the design process, with particular reference to energy and environmental aspects, is characterised by a new approach, non-deterministic, but circular and based on probabilistic models. In addition, a thorough analysis of procedures and instruments used to control the environmental indoor conditions of a building during operation is carried out, considering the most advanced application of AI and IoT.

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Preface

ICT and IT are primary sources of technological innovation in the building sector and in design practice which suggests the need to change methodological approaches and tools used in order to move towards feedback-based and explicit visions. It should be underlined that only with the new generation of instruments has it been possible to fully apply informatics-based approaches to design, even if this possibility has already been part of innovative visions since the 50s of the XX Century—see, for example, the design vision at the base of the Ulm School of Desing (1953–1968) and consider Maldonado's observations.

The proposed book is principally based on the performance-driven approach according to the Italian methodological approach (see Chap. 4). This method, named "metodo esigenziale-prestazionale", was discussed and partially regulated thanks to the work of researches principally from the architectural technology research field[2]. Nevertheless, even if the concepts of algorithmic design and programme-driven design were theorised in that period, only today can the applications of this method be brought fully into force thanks to higher computational power, access to new data and the presence of new tools including the connection between geometries and data (e.g. BIM, DIM and CIM). Furthermore, these new instruments require a revision and transformation of early prodromic visions into reliable approaches which are in line with ICT potentials and which are able to include future trends and possibilities.

This book aims at giving to architects a framework to read, interpret and be ready for the digital revolution in terms of re-design and re-engineering of current methods, tools and strategies. Furthermore, it aims at connecting the ICT world and its language with the world of architecture, and for this reason, it is also addressed to IT engineers and other experts who aim to enter the world of building. This is a new frontier in research, education and at different professional levels as has been

[2] See, for example, Cavaglià G, Ceragioli G, Foto M, Maggi PN, Matteoli L, Ossola F (1975) Industrializzazione per programmi. Strumenti e procedure per la definizione dei sistemi di edilizia abitativa. Studi e Ricerche RDB, Piacenza; and Ciribini G (1968) *Brevi noti di metodologia della progettazione architettonica*. Edizioni quaderni di studio, Politecnico di Torino, Torino.

underlined during innovative courses at university level, in several EU-funded research schemes, and in the increasing number of professional publications about smart/digital building and urban applications.

For these reasons, the book is principally devoted to professionals and early stage researchers even if it can also be useful for master degree students, from both building and ICT domains, as it aims at providing, on the one hand, a theoretical background and, on the other, simple sample applications of the hybridisation of these two domains. A method to interpret the current state of the art is, in fact, provided together with practical examples which are easy to understand and can be replicated by interested readers who would like to enter the digital paradigm in connection with the building world. The book is original because examples are not fully applied and interpreted to a specific case. Rather, they are conceived to relate visions to specific examples which are focused on the presentation of the potentialities of technological innovations while considering different aspects of hybridisation (eras), from the modelling to the materialisation worlds, including data-driven innovations (such as big data analyses) while giving readers the scope to adapt potentialities to all proprietary or open platforms without focusing only on a limited number of them.

Parts of the contents of this book were the subject of a previous publication—Paradigmi, tecnologie ed ere digitali—published by Accademia University Press, Turin, in 2015—while others were derived from my Ph.D. final dissertation—Monitoring Energy and Technological Real-time data for Optimisation (M.E.T.R.O.) innovative responsive conception for cityfutures—discussed in 2014 (Matteoli and Pagani 2010). Nevertheless, the manuscript has been totally upgraded and new chapters included.

The book is introduced in Chap. 1, followed by a state of the art in Chap. 2, which outlines the proposed methodological framework and organises references according to the highlighted digital innovation spheres (eras). Chapter 3 discusses the era of modelling, connecting real and virtual environments by discussing, a simple IoT application connected with a CAD environment, while Chap. 4 introduces the relation between the proposed vision and the performance-driven approach by analysing potential applications in shape parametric generation and optimisation according to environmental criteria. Furthermore, the idea of materialisation is also discussed thanks to the possibility to panel a surface to be produced by using computer numerical controlled machines. Chapter 5 is devoted to a brief presentation of the implications of diffuse sensing and big data analysis by focusing on a simple example of environmental diffuse monitoring nodes. Finally, Chap. 6 returns to the theory presented earlier including the conceptualisation of the platform idea, while Chapter 7 presents the most recently described digital implication (the Third Era) connected to data. In this chapter discussed data social implications are also briefly discussed.

Enrico Casetta is thankfully acknowledged for co-authoring Chap. 4.

Turin, Italy Giacomo Chiesa

Introduction

Background

Over the last 60 years, the world has changed radically. Following innovations in Information and Communication Technologies (ICT), the potential of design is changing thanks to new ways of reading in the field of computer hardware and software. Production techniques are rapidly opening up to a widespread production perspective through mass customisation techniques, sometimes of an amateur nature, such as open-source development environments characterised by bottom-up forces, implemented by hobbyists and makers. This open-source attention highlights the overcoming, in certain areas, of that stated in Gates' letter dated 3 February 1976, in which the founder of Microsoft accused hobbyists of stealing his software ("Most directly, the thing you do is theft"), effectively preventing the development of quality programs. In fact, despite the statements "Hardware must be paid for, but software is something to share. Who cares if the people who worked on it get paid?", the Linux operating system enjoyed extensive development and a large number of implementations, by experts and hobbyists around the world, due precisely to its free and unrestricted distribution. Similarly, many other programming tools and languages can be used free of charge, such as R, a "free software environment for statistical computing and graphics"—see also https://www.r-project.org/, viewed December 2018—and the more and more diffused Python, a programming language characterised to be quick and integrated—see also https://www.python.org/, viewed December 2018. At the same time, we have now entered the Third Industrial Revolution, as Anderson calls it, based on the concept of "give away the bits and charge for the atoms". Moreover, way back in 1950, Wiener, the father of cybernetics, warned against secreting data and information because the disclosure of every secret is only a matter of time and every discovery in this sense increases the need for a new and more powerful discovery.

Reflecting on the ownership of software and hardware would, however, be pointless if it did not have immediate repercussions on data revolution. In fact, it is possible to highlight the links with big data, open-source systems for rapid

prototyping and the new widespread interest in the production of components and software in the world of the Internet of things and smartness. Although the real revolution does not lie in the machines, but in the data, as we are reminded by Mayer-Schönberger and Cukier, IoT platforms can lead to predominant control by their owner (see also Pfister 2011). Possessing data and technologies risks increasing "the human use of human beings", from a point of view where people are used as the workings of a machine, losing the use of the full faculties of human beings and risking not being able to work out the right answers to our questions, as introduced by Wiener. At the same time, there is a scientifically proven need to further increase knowledge and skills in order to manage and popularise complex decision-making models, capable of assessing and optimising certain choices aimed at increasingly systemic and eco-systemic sustainability.

Topics

The city is becoming a complex reality and a place of hybridisation between the real and virtual worlds. Information and data, relating to complex urban and architectural processes in bidirectional flows, have become parameters of design and civilisation.

In this context, predictive models, quality analyses and process management are undergoing major innovation due to the dissemination of information and data flows from sensors positioned in the real world such as to allow real-time responses. The traditional scarcity of data gives way to an abundance of information that can be generated by sensors applicable to every person and every object. Managing the complexity of networks and smart cities interfaces with techniques for the creation, processing and use of data. At the same time, traditional ways of producing data through monitoring campaigns are being enriched by new potentials deriving from the use of widespread sensors and datapoints, which are less precise in terms of single measurement but allow an increase in the frequency and size of data sets. This implication becomes particularly important in the age of the Internet 3.0 (the Internet of things). Innovations in ICT concern the intrinsic potential of using large data sets to improve the performance of simulation, forecasting, modelling and materialisation systems from a perspective linked increasingly to hybrid (real–virtual) worlds and operating rating assessments. In this sense, these systems are configured as tools and information to respond to the increasing complexity of design. Implications related not only to design but also to assessment, operation, maintenance and optimisation thanks to the use of real-world data in models and simulations.

Over the last few decades, there has been a progressive spread of sustainable design and technology solutions to ensure indoor climate control (ICC) in architecture. At the same time, a new cultural approach to design based on sustainability has spread among many operators in the sector. The current frontier of innovation in ICC lies in the development and application of passive and hybrid technologies and systems (Matteoli and Pagani 2010). Moreover, sustainability policies,

including directives, laws and regulations, have, in recent years, been consistently implemented by the EU and by local and national governments, with an indirect effect on the growth of "environmental awareness" among end-users.

The applicability of passive and hybrid solutions for cooling and heating requires considerable attention to the local and climatic context as well as careful adjustments based on changing boundary conditions. This attention requires mature data, information and design and evaluation techniques suited to the management of complexity, also in view of the European directives on NZEB buildings (EPBD 2010/31/EU) and future net-positive buildings and their implementations—see, for example, the recent EU Directive 2018/844 of the European Parliament and the Council, 30 May 2018, amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency (European Parliament and the Council 2018).

Data field and digital design | theoretical implications

The networking of nodes capable of collecting, communicating and transmitting data is becoming a tangible reality for the cities of the future, characterised by different approaches based on the different methodologies used. Proprietary platforms, like those developed for the Internet 3.0 and the Internet of things (IoT), are high-quality tools which do, however, pose some risks to data ownership and access, especially in a public–private environment.

The text is organised into practical applications and theoretical speeches. The former support theoretical argumentation, focusing particularly on three macrothemes:

- the scientific model as a design tool, in which they convert innovative technologies and IT tools for virtual, real or hybrid projects. Growing awareness of the potential of digital media to support architecture is changing the design process by accompanying simple representation with the addition of other specific technical and decision-making functions. The design possibilities that can be achieved with digital technologies are studied on the basis of the effects and the complexity and extent of the implications, using the concepts of I, II and III era/scope of digital application;
- platforms, management spaces and design. Platforms are the physical or virtual space for decision-making and process management (design, decision-making, organisational), where skills and techniques meet in specific ways. Platforms house the management of the different phases that follow the processing of data from production to use, exploiting modelling and materialisation techniques. This is why platforms are configured as places for managing complexity.
- data and its ownership. This topic focuses on the implications that different ways of producing, using and disseminating data and information have on cities and their inhabitants, linking collective or individual interests with the openness or protection of the systems used.

The study reveals the need to assess the implications that ICT and digital technologies in general have and will have on the social fabric, and on the urban

and architectural fabric in their dual role of enabling and co-evolving, right from the earliest decision-making stages of implementation of strategic plans for smart cities.

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