

# Preface

This book is the result of a scientific challenge, the creation of a wide international network of experts with different background and expertise, from academic institutions and from the world of practice, that are pursuing the innovation in the fields of visual computing, descriptive geometry and digital design media.

The book collects peer-reviewed chapters dedicated to the emerging design tools and their new frontiers of knowledge where geometry is the starting point of generative design processes and a keyword for the understanding of our World heritage.

Riccardo Migliari in 2005 wrote a paper entitled *Has Perspective a future? (Has Man a future?)* addressing the “analogies between questions on the future of Man in the face of the disasters of the indiscriminate use of science and technology (during the era of the Cold War, but still of interest today) and some considerations on the future of the perspective (and the descriptive geometry) in the automaton era”. With the outstanding contribute of Migliari, disciplines related to descriptive geometry are living a great revival thanks to new horizons opened by digital media and visual computing potential. These studies support the architectural and industrial design practice bridging the conceptual development through Cad tools with the final fabrication needs, allowing the visualization, the construction and the invention of complex forms (Migliari, 2009).

Visual computing is a multidisciplinary environment for scholars, practitioners, makers and users engaging the traditional challenges of design. Its broad field of influence makes studies about the subject attracting and continuously related to the evolution of workflows. For this reason the book includes chapters that cover several topics like geometry, descriptive geometry, digital design media, digital heritage, perspective-based design tools, generative tools, stereotomic design, technology and digital fabrication.

## THE CHALLENGES

This volume, according to the several applications of descriptive geometry, addresses the paradigmatic formula geometry-visualization-construction-generation including the representation processes to visualize geometric design into the 3d environment, techniques of analysis, 3D data acquisition and prototyping.

The scientific challenge is to introduce the diverse emerging tools for the visualization of objects and shapes in the three-dimensional space creating the right framework to develop and build such complex shapes; a further challenge is to explore in depth the geometric environment with its relations, qualities, envisioning new expressions and new issues. This subject area is improving its impact into daily life and practice of designers since the introductions of several 3d printing technologies and low cost

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applications; so the book make possible the encounter of people that are using high-level processes for generation of 3d shapes, visualization of complex geometries and prototyping of surfaces and solids for building and product manufacturing.

The book is designed as a reference source for Visual Computing because design and industrial design applications need to be fostered by interdisciplinary researches and best practices about the emerging methodologies and tools. Technologies and tools are investigated in their specific fields of applications and represent a high growth industry that involves a variety of users in the contemporary society, including media and design, industry of building, industrial design and manufacturing, heritage valorization, data visualization, independent designers and community of makers. With such a diverse body of applications, the research in visual computing for design and cultural heritage is always evolving and new theories, methodologies, tools, and applications are being presented in the book.

The book is conceived as support to design practice in the field of industrial design, architecture, and heritage documentation and fruition. As Marco Gaiani wrote we are living a new age in the field of data computing because today “the development of digital technologies as the real-time rendering (RTR) of 3D models and the Web 3.0 (i.e. semantic web, geospatial web, web 3D) opened new scenarios of reading and interpretation of historic architecture, introducing new methodologies of dissemination and information not merely related to textual searches but based on the geo-spatial & space-temporal navigation methodologies (Gaiani, 2015).

This research and editorial project challenges the issues of innovation and assesses the impact of digital tools according to traditional techniques of design and building. By exploiting the geometrical properties of forms, designers developed templates and construction methods that transform shapes in artefacts through empirical methods or sophisticated generative processes. Architecture, for example, must make an extraordinary contribution to the science of stereotomy that is living a progressive renewal thanks to studies of ancient sources and use of digital tools for parametric design and stone cutting (Falcara, 2013). Crucial also is the role of descriptive geometry in designing and building the architectural space; for example techniques of perspective, distancing itself from the mathematical issues, become a projective tool to achieve painted or plastic illusory spaces that remind us that designing methods aim to add dimensions to the human sphere, creating new dynamism, not only in the physical one but also in the creation of material images and allegories. Descriptive geometry and disciplines of representation provide, in the many phases of project and according to several methodologies, the scientific and artistic tools for practical resolutions of geometric and constructive problems. Industrial design, interior design and building industries are really sensitive to the development of tools and processes that encounter the market need of low-cost and fast-track conceptual/fabrication tools.

The possession of a design tool, carefully selected to provide a balanced system to be able to operate in continuity in the various phases and appropriate to the goals to be achieved has always been a fundamental step in order to carry out projects and describe existing architectures quickly and accurately, and this for reasons intrinsic to the representative process (Gaiani, 2006). According to this concept, the book reviews emerging tools and processes that are changing the understanding of architectural heritage as well documented in the *Handbook of Research on Emerging Digital Tools for Architectural Surveying, Modeling, and Representation* by Stefano Brusaporci (Brusaporci, 2015). Digital tools are opening broad scenarios for new investigations as disseminated during the last international meetings of the U.I.D.-Unione Italiana per il Disegno in Rome, Matera, Parma and Turin.

The book is also dedicated to universal challenges as designing efficient forms in terms of static and aesthetic performance, building according to geometry, generating harmonious construction process, and understanding cultural heritage. This multidisciplinary approach presents selected researches and projects that are related to science and art of representation and visual arts, following the universal truth that the world is enriched through distinct cultures and traditions. Progressive researches are generating new branches of consolidated fields of studies like visual computing, cultural heritage and digital documentation, generative design and manufacturing.

## **ORGANIZATION OF THE BOOK**

The book is organized into two sections and thirty-six chapters. Section 1 (chapters 1-18) describes the geometric, visual and projective tools for design and assessment of space including disciplines like descriptive geometry, computer vision, perspective tools for design, architectural perspective, anamorphosis, oblique projection, parametric design, BIM, digital heritage. Section 2 (chapter 19-36) reviews the geometric tools for building, construction process and generation of shape including disciplines like pattern based design, geometry based ornament, geometry of composition, geometric construction, shape grammar, pattern language, folding-unfolding, generation of complex shapes, 3D modelling.

A brief description of each of the chapters follows:

Chapter 1 identifies the existing challenges in the computer based visualization of the architectural heritage and investigate on its relationship with other disciplines. Digital tools are used indifferently and simultaneously in dissimilar research fields, and a clear definition of the ontologies, principles and procedures for advanced surveying, modeling, and visualization could allow the interdisciplinary collaboration.

Chapter 2 depicts the increasing emergence of digital practice in architecture. It is an essay that delves deeper into computational research in relation to several pivotal design experiences. After decades of improvements, computational thinking has led the design process to the post-parametric material instance: digital simulations and virtual optimization need to be translated into physical object hood.

Chapter 3 sets the framework on mathematical algorithm and nonlinear theories used in order to study the establishment and development of traditional settlements. The study investigates the fractal pattern of housing in Masouleh village, Iran. By referring to the fractal dimension calculated with box counting method, different type of information are collected and this attempt is helping decision makers, planners, architects and designers, especially in new housing developments.

Chapter 4 points out about the recent advances in acquisition technologies such as LiDAR, range cameras and photogrammetry that put point clouds in the forefront of several fields with applications in Computer Graphics, Vision and Machine Learning. The chapter focuses on how these fields can be combined in new and innovative ways, so that professionals can optimally exploit the advantages that these improved technologies can offer.

Chapter 5 presents survey methodologies based on spherical panoramas produced by image stitching techniques. It is an interactive survey system to generating 3D models of architectural structures and urban scenes. Photogrammetric fundamentals are applied using two different approaches to obtain the 3D model: by using texture-mapping techniques in the way of creating the virtual models; and by using parametric visual programming process.

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Chapter 6 rewards with a valuable insight the more intimate aspects of the geometric reason for the Imperial Roman architecture and its ornamental patterns. It establishes the need for modern tools of understanding and the most progressive historic researches are offering extraordinary graphic suggestions for why elemental geometry was used in and how its meaning may be interpreted.

Chapter 7 illustrates the use of BIM tools for the reconstruction of lost nineteenth-century architectural heritage. Thanks to the properties of BIM to enter information related to each element constituting a building, every part of the model will be accompanied by information on the degree of reliability and references adopted for its creation. In this way, each family of elements could more easily and knowingly be reused for other similar projects.

Chapter 8 analyses the elements of architectural heritage in the Maestrazgo de Montesa, a Spanish region in the north western part of the province of Castellón. The methodology used three main sources of information: historical documentation, manual data collection and 3D scanner and photogrammetry. Starting from the data processing, it is possible to share such architectural knowledge with visual impairments people through tactile models.

Chapter 9 reviews the advantage of digital surveying to investigate the complexity of religious Baroque buildings while studying the church of Santa Maria dell'Odigitria in Acireale (Sicily). The three-dimensional space of a computer instead becomes the core of the unveiling process, the place where the scholar has the opportunity to interact, to question on the geometric and spatial qualities of the object.

Chapter 10 describes the use of the synthetic method through digital generative algorithms in the study of geometry. In particular, the paper describes the construction of a ruled surface given three skew lines in the mathematical representation method. Constructing algorithms for generating and controlling the geometric shape allows having a greater control on both the final form and on the generative process of form itself.

Chapter 11 presents digital representation technologies that can enhance the didactic activities in architectural training. A positive trajectory which includes the use of virtual reality, augmented reality and parametric modelling, as well as freehand drawing and the production of physical models both by automating the unfolding process and by digital fabrication processes of 3D printing and laser cutting.

Chapter 12 is talking about design visualization that seems to be matter of the contemporary era while talking about projection mostly pushes our feelings back to the past, despite even advanced digital visualizations are projection-based, or better, they are projective visualizations. These projective visualizations are not only mere supports to show design results but, mainly, they are irreplaceable thinking-and-operational tools for design development. Given their semantic wideness, these visualizations work as customized tools in the various branches of design.

Chapter 13 focuses on solving the problem to obtain oblique perspectives (or axonometric views) from a three-dimensional model, because it's a common lack in most CAD programs, since they only can produce orthogonal projections and linear perspectives from the model. This inconvenient drives to the fact that employment of this type of representations has been drastically reduced despite their importance in the design representation.

Chapter 14 introduces readers to the investigation of a controversial treatise entitled *Architectura Civil Recta y Obliqua* written, in the late XVII century, by Juan Caramuel de Lobkowitz; it is often mentioned by historians in relation with the debate around the Bernini's Vatican colonnade project in Rome. The book has been subject of a renewed interest in the recent past and, in the chapter, a systematic study that efficiently reviews the treatise is presented.

Chapter 15 presents the case of the *biais passé*, which was both a clear illustration of a special warped ruled surface but also an example of how constructors dealt with the problem of building a skew arch, solving structural and practical stone cutting demands. The representation of the *biais passé* in Théodore Olivier's model achieved a perfect correspondence to its *épure* according to Monge's Descriptive Geometry.

Chapter 16, dealing with illusion and reality, through the application of perspective-based design tools, describes the most important anamorphical representation in Italy and the architectural space that is hosting this masterpiece: the anamorphosis, a distorted projection and perspective painted by the French scholar Jean-François Nicéron at the Trinità de Monti in Rome.

Chapter 17 focuses on the architectural perspective known as Quadratura: an illusory architecture is painted and the perspective projection creates the illusion of spatial depth on a flat or curved surface. This study developed an accurate survey and a digital 3D-reconstruction of the Palazzo Vizzani perspective, painted in Bologna by Antonio Galli Bibiena, through the graphic description of its projective system.

Chapter 18 concluding the Section 1, highlights the principles of projective-geometric design of illusory spaces illustrating the methodologies for the relief-perspective architectures which featured the architectural spaces during the sixteenth and the seventeenth century. The chapter analyses the relief-perspectives of Borromini and Bitonti and their partnership in the design of the perspectival tabernacle in Bologna and of the perspectival gallery for the Spada palace in Rome.

Chapter 19 opens the Section 2, and questions whether creativity is only applicable to the formal attributes of the repetitive pattern in parametric design; and also aims to examine how parametric design can undertake a repetitive pattern to simultaneously achieve remarkable creativity in its formal and perceptual issues. The chapter proposes an approach that enable designers to visualize the interaction between the organizational qualities and the perceptual ones of the composition.

Chapter 20 analyzes how a set of basic volumetric transformations can generate complex spatial outcomes. Using platonic solids as base volumes, different ideas are explored, applying generalized extrusions, mesh schemes of subdivision and multiplication of the object's faces, and a set of tools to create high-genus meshes. The goal of this process is to create a set of illustrated steps to activate architectural inquiry and to generate innovative design solutions.

Chapter 21 documents all initiatives taken in order to determine the geometric ratio in Islamic architecture passing over the exotic aura and looking for a formula able to explain how spatial, ornamental and constructive compositions remained constant along time. Emilio Camps Cazorla was one of the first Spanish theorists in searching that geometrical ratio which he called "Caliphal module" and that the study reviews through a series of graphical analysis.

Chapter 22 describes the Islamic Stereotomy in Cairo and the extraordinary Cairene domes. The art of stonecutting requires geometric knowledge which, although it starts with the professional practice at the workshop associated to the job, reaches extraordinary complexity and abstraction levels. In Islam, the passion for geometry finds in the masonry art a field where it can be developed without limits through the geometric tools of descriptive geometry.

Chapter 23 describes the geometry and the construction of vaulted and decorative systems called 'muqarnas', one of the most typical elements of Islamic architecture. This way of 'vaulting spaces', with a system of regular staircase-elements that break down the surface covering it with simple geometrical figures, derives from different generative geometries, and from building techniques and used materials. Drawing is the unique media to describe their remarkable complexity.

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Chapter 24 reintroduces Stereotomy within the field of “research by design”: the discipline, in fact, can be used as a means of re-composition of the design, project and execution phases. Particular attention is given to the prototyping workflow according also to historic treatises: seven stone prototypes, developed during recent years as a result of the attempt to combine multiple instances into a synthetic architectural object, are presented.

Chapter 25 makes new contributions to Borromini work and formulate new hypotheses regarding his construction practice in the building of the Dome of San Carlino alle Quattro Fontane in Rome. The comparison of the geometric construction of survey data and the design data develops the understanding of the original design idea, highlighting not only the designer’s *modus progettandi*, but also matches, modifications or changes that featured the constructive challenge.

Chapter 26 proposes mathematical models of the vault of Borromini’s San Carlino alle Quattro Fontane based on parametric curves and surfaces, including the shape of the vault and rules for its tessellation with crosses and octagonal coffers. Several models were tested measuring their distance from the 3D point cloud that was surveyed. The data analysis validates the hypothesis of construction procedures by checking symmetries of coffers shape, scale and position.

Chapter 27 starts from some considerations on the inter-scalar figurative relations which bind all the parts and details, within a work of architecture. The research investigated the portals by Francesco Borromini and the door cornices at Palazzo Falconieri in Rome. The comparison between the original drawings and the construction of the portal of the Orazio Falconieri apartment gave remarkable insights about Borromini mindful design and the built solutions.

Chapter 28 contains a geometric analysis of the architectural work of Rafael Moneo, winner of the Pritzker Architecture Prize in 1996. The result of the investigation is that the geometric component underlying his works has its roots in Platonic thought and that for Moneo, architectural ideas have an ontological nature, transcending the imperfection inherent in nature and approaching the perfection of Platonic order.

Chapter 29 reviews the teaching results from over ten workshops, with ‘Unfolding and Folding’ methodologies, developed in Chile, Argentina and Brazil to build up design projects that allow the spatial and material properties of architectural folded compositions to be investigated. The chapter proposes that design tools be updated through Parametric Design (2D generative patterns), 3D origami software and Digital Fabrication machines (CNC and Cutting Laser).

Chapter 30 investigates the connections between Visual Computing, which is oriented towards the representation of complex surfaces, and Geometrical Design Tools, which source from the movement created through dance, itself understood to be the art and technique of composing forms in space. In this area, a driving role has been taken by the Synthetic Method that analyzes surfaces as “geometric places”, collective points in space that share the same properties.

Chapter 31 introduces a methodology for free form architecture engineering starting from a physical model of an arbitrary shape to a construction-aware detailed project. Free form architecture involves many problems of a geometric, structural and construction nature. The development of powerful tools such as parametric and algorithmic design software is allowing great freedom for shape design and remarkable control in managing large amounts of data.

Chapter 32 offers some insights on the incredible design opportunities offered by new computational instruments, as well as highlighting circumstances in which the act of ‘modeling’ takes over the ‘design.’ Parametric modeling allows to understand geometry and manipulate shapes in dynamic, articulated and yet intuitive ways.

Chapter 33 explains the use of geometrical algorithms to fix computing problems during the creative process when designing a product, resolving the continuous comparison between the digital and the real models. The need to compare the two models is due to the designer's need to construct full-scale prototypes.

Chapter 34 points out the parametric morphogenesis into architectural design, meant as the process of form creation, of the Gherkin skyscraper in London by Norman Foster. The geometric study addresses its shape characterization as the result of a synergy between environmental, structural and functional issues.

Chapter 35 presents a research on algorithmic approaches to formulate effective strategies for sustainable urban projects, guided by Transit Oriented Development (TOD) principles. TOD is an urban development model that considers geometric principles and measurable parameters for designing sustainable cities. The chapter focuses on the use of computational tools to provide quick and dynamic assessment while planning and discussing interventions in urban areas.

Chapter 36 concludes the Section 2 and the book, presenting the principles for the architectural modelling of an olive to estimate morphology and radiation relationship. The research integrates the study of trees with the science of representation, in order to investigate the relationship between morphology and light interception in a tree, starting from the case study of an olive, modeled without using any automation in survey.

This book is part of a wide project to create a base of knowledge and a repository for researches and applications related to the Second Industrial Revolution introduced by digital design media; as in the words of William J. Mitchell and Malcolm McCullough, a designer's view point is taken throughout: devices and techniques are introduced as a means of pursuing serious design intentions rather than as illustrations of the principles of computer science and technology (Mitchell & McCullough, 1995). The aim to combine knowledge about geometry, representation and descriptive geometry with emerging tools for cad, generation and visualization of shapes and spaces and new technologies applications is giving the opportunity to develop also a source about digital heritage and its multidisciplinary fields of applications. The book addresses a multidisciplinary target and research challenges, as requested from market and industrial/institutional bodies, encompassing the specialist audience, academics and scholars, and the end-users, students, practitioners and company employees. The effort is to encounter the strong interest about publications that starting from the solid roots of fundamentals and demonstrate how emerging processes and digital tools are innovating the fields of design and educational practices.

Concluding this preface it's important to acknowledge the 60 scholars from 31 Universities and 10 different countries which generously joined the research project and also created a solid framework of people who wish to innovate the applications of descriptive geometry and visual computing encouraging young people to get advantage from this knowledge. They shared their Art where art is a concept related to skills and ability coming from study and practice; a smart attitude, known since Greek philosophy as *Tekhné*, that can be developed through research and study.

Visual computing and geometric tools for design are arts embodying a wide knowledge coming from mathematics, optics, perspective, technology, computer graphics and other sciences that let the artist to be not only a talented artisan but also a *literatus*, a *polymathes* and *polytechnes* (Clair, 2015). Analyzing the practical thinking of visionary men like Antoni Gaudi it is possible to develop new disciplinary references for descriptive geometry whereas, in the laboratory of Gaudi, as well as in the contemporary designer studio, the ability to draw in space enables to use drawing as the descriptive geometry technique to bring together expertise and fabrication issues (Amoruso, 2013).

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A practical philosophy, as the heretical Reason professed by Leonardo da Vinci, that after the intuition of knowledge takes action into the know-how practice. And, if for Leonardo each cognitive process starts with a feeling, whereas “love wins everything”, then the need to use geometry and its analytical tools to understand the human universe is born from the irresistible charm and beauty of his inventions, of art and science.

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