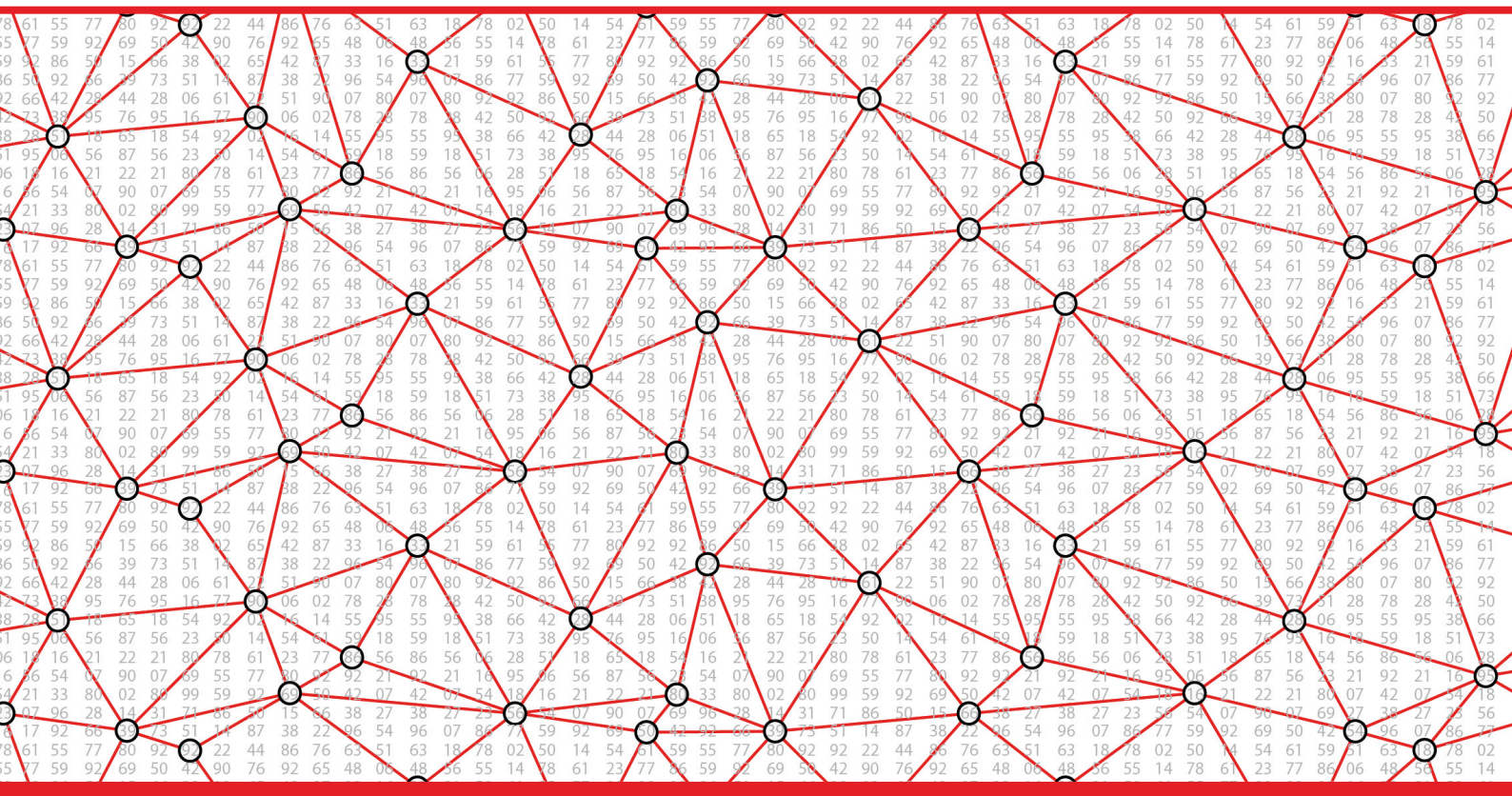
REPRESENTATION CHALLENGES

Augmented Reality and Artificial Intelligence in Cultural Heritage and Innovative Design Domain

edited by

Andrea Giordano
Michele Russo
Roberta Spallone



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Physical and Digital Pop–Ups. An AR Application in the Treatises on Stereotomy

Alessio Bortot

Abstract

This paper focuses on the relationship between stereotomic traces and building construction techniques. Starting from the first essential drawings representing stone cutting methods in full scale – which are still visible in some Gothic cathedrals in France and Spain – it will be analyzed the evolution of stone cutting drawings to the most recent examples in 19th–century treatises. In particular, it will be examined the progress in terms of representation according to different centuries concentrating on the development of theory and practice. It will be therefore given a short overview of the most important Renaissance essayists dealing with changes in representation methods according to the codification of assumptions related to descriptive geometry. In the last part it will be proposed the involvement of augmented reality techniques in order to visualize and study Louis Monduit's treatise on stereotomy through the use of digital pop–ups.

Keywords
stereotomy, Louis Monduit, 3D modeling, descriptive geometry, augmented reality.

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Evolution of The *Trait* in the History of Stereotomy

The research carried out in this paper has led me to study several stereotomic drawings in order to understand the reasons why these 'blueprints' are connected to the concrete practice of construction. The first stereotomic traces are engravings on the floor (less often on the wall) in some European and Middle Eastern Gothic cathedrals. In this regard Calvo–Lopez states "tracings were prepared exactly below the element under construction in order to control the placement of *voussoirs*. Generally speaking, in the Gothic period they were executed on scaffoldings placed under vaults, at springer level, while in the Early Modern period, they were laid directly on the floor" [Calvo–López 2020, p. 127]. The large–scale drawings – which seem to transform the buildings where they are located in a sort of 'stone treatise' – were used to solve specific problems and allow the formal compliance of the piece under construction. In other words, these first stereotomic developments were not intended as a representation of an abstract problem and didn't want to spread construction skills as well. In fact we should remember that in the Middle Ages stonecutters used to belong to guilds that usually concealed every building skill. As a matter of fact, stereotomy was a type of practical knowledge which used to be conveyed orally by the foreman to his stonecutters only in the construction site. In addition, it should be taken into consideration that writing and drawing materials were very expensive at the time. For instance, parchments were much more used in case of public presentations to clients than in standard communication [Erlande–Brandenburg 1993, p. 79]. In this period the most important graphic document is the well–known notebook *Livre de portraiture* by Villard de Honnencourt (... – XIII century). Even if this latter can't be really considered a treatise on stereotomy, anyway gives us a meaningful example of representation in the field of construction site machines, building techniques and use of proportions in the Gothic period. According to Sakarovitch, it is quite interesting to notice that in the carnet by de Honnencour one can find some elements which are represented in double projection despite a lack of awareness in terms of a projective correspondence in the two views [Sakarovitch 1998, p. 41].
We know that stereotomy literature thrived in the Renaissance period basically due to *Le premier tome de l'architecture* (1567) by Philibert de l'Orme (1514-1570) [1]. In this treatise the illustrations show how the medieval secrets – traditionally kept by the guilds – were finally unveiled. The stone cutting techniques spread at the same time as the role of the 'architect' flourished – intended in the modern meaning. From being a 'mechanical art' architecture was gradually turning into a 'liberal art'. What's more, these historical dynamics pointed out the separation between the architect and the foreman (the *maître–maçon*), between the designer and the builder. The authentic expressive medium of the building work is the trait: the technique allowing to trace the layout of the stone structures in order each ashlar to be properly cut. For what concerns this topic, Robin Evans (1944-1993) asserts that the trait is something that is in between two different roles: artisans on one side and architects on the other. Although it isn't part of any of them, it exists as an independent reference such as geometry [Evans 1995, p. 205]. In this period treatises are didactic tools, but also ways to show the skills of the authors, often very critical of the stereotomic solutions developed by their own predecessors or peers. In the treatise by de L'Orme virtuous artifacts arise along with complex illustrations. One of the best examples is the renowned *Trompe d'Anet* – a case mentioned a few centuries later by Viollet–le–Duc (1814-1879) as an "artifice that has nothing to do with the rigorous art of the builder, made to amuse curious spirits with unnecessary problems" [Viollet–le–Duc 1854-1868, book IX, p. 314]. The drawings of this structure (one in pseudo axonometric projection to show the object in a three–dimensional space and some others in pseudo orthogonal projection) aren't able to solve the problem except for a reader who is also an expert in construction site practices. Something similar occurs to other *planches* where geometric operations (similar to 'surface unwrapping') are applied to each ashlar row in order to obtain the corresponding *épures*. In Renaissance treatises it is likely to find a certain need for three–dimensional representations. Thanks to the codification of the perspective laws, in this period these models – which in the Middle Ages were kept secret in the constructor's mind only – acquire education purposes as well.

Several treatises on stereotomy were published in the Enlightenment. This way, cutting solution were codified as well as graphic strategies developed to explain the techniques of division into ashlars. In the huge production of scientific books on this topic it is essential to mention at least the ones by Amedée–François Frézier (1682-1773) [2] and Jean Baptiste de la Rue (1697-1743) [3]. Both are illustrated with high–quality figures using orthogonal projections, axonometric and perspective views of arches, vaults, trompes and staircases. For the first time in the history of treatises on stereotomy some parts dealing with the explanation of general geometrical problems (e.g. conic sections, intersection among shapes, etc.) are included too. This addition is quite important because it reveals a different approach to the relationship between form and structure which can define the superiority of geometry in the field of this construction technique. Other descriptive strategies used by de La Rue suggest the need for a 'stereoscopic' approach which gives the opportunity to go beyond the two–dimensional limits characterizing paper surface such as the use of pop–ups. In fact, his Planche XXXIII describes – both graphically and through pieces of paper which are glued to the page – the mistake made by de La Rue's colleagues in the solution related to the corner segment of a spherical vault. In this sort of stereotomic 'origami' the reader can concretely realize the error by de la Rue's predecessors which is explained developing the faces of the block of stone. More in general, we can affirm that the use of this technique comes from the necessity to control very complex formal configurations such as spherical vaults or trompes.
In scientific literature the tradition connected to the use of pop–ups or movable books dates back to the medieval period [4]. Another example in this field concerns the use of removable paper elements (flaps) or the aforementioned pop–ups in treatises of gnomonics and perspective. Finally, movable books on optics, gnomonics and stereotomy became significant tools when simulating the projective and geometric processes applied to these disciplines, in order to support the representation of elements in space. What's more, three–dimensional paper models used to be designed in order to visualize the cutting flat surfaces of stone blocks in space in order to find the shape of the single faces and define the skin containing the volume.

Louis Monduit's Treatise: a Case Study

I chose the treatise by Louis Monduit as a case study to carry out an experiment on augmented reality. His book was published in a historical period in which stone cutting construction technique was about to be substituted by new methods and materials which were soon the turning point in terms of development in the field of architecture in the 20th century. Stereotomic techniques were therefore strengthened and optimized due to experimentations and publications on the same subject over the centuries. The treatise by Monduit doesn't show any innovation related to cutting solutions, since the case studies included belong to a tradition which dates back to the Renaissance period. Beyond, some features are particularly useful in this research such as the clear projective coherence of the drawings and the general structure that serve specific didactic purposes. This volume opens with a glossary of technical terms in the field of stereotomy and projective geometry. Monduit supplies some definitions referring to the measurement systems and concepts related to planar geometry. Then he draws his attention to the examination of the main proportional ratio, the study of solids, polyhedra (with their development) and a short (but precise) explanation of concepts related to descriptive and projective geometry. A special consideration is dedicated to the method of orthogonal projections which is explained first in three–dimensional space and then on plane. This first section is followed by the study of intersection among solids (cylinders, cones and spheres) – represented in cavalier drawing. This specific part is clearly influenced by the well–established method which was codified by Gaspar Monge (1746-1818) – professor at the École normal supérieure of Paris since 1794. At the end Monduit explains the tracing of the épures and the technical design of the project. Both are useful to develop every ashlar properly.

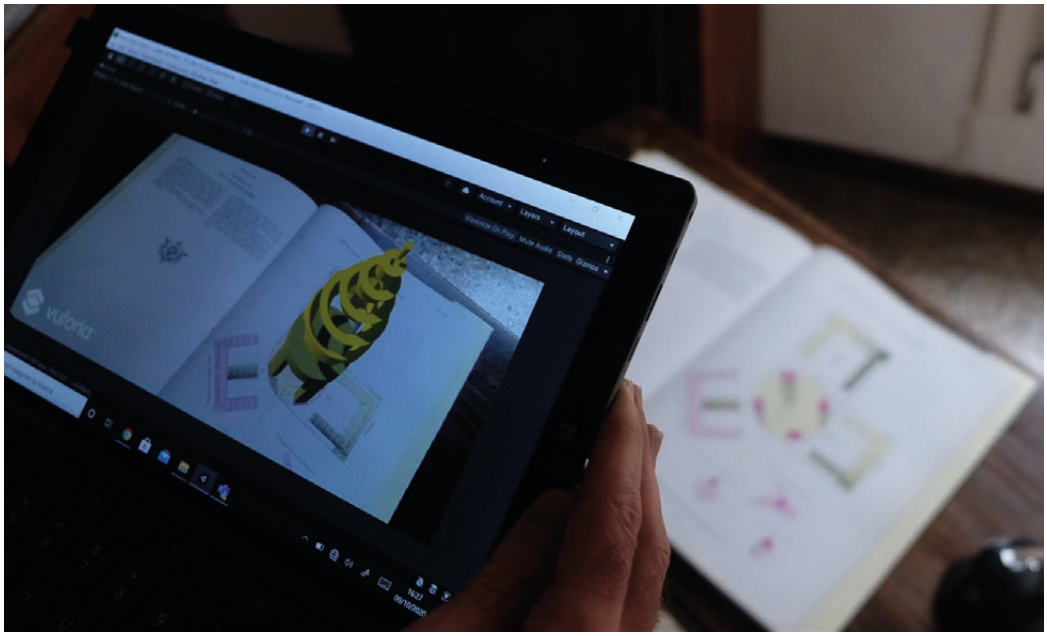

Fig. 1. Exploded view of the 3d model obtained from the digital reconstruction of Planche 46 of Monduit's treatise.

I decided to use digital tools for AR in order to reinterpret the need for three–dimensionality expressed by the historical treatises on stereotomy. The first phase of the work has involved the construction and research on the digital model of the case studies proposed by Louis Monduit. The 3D models were furthermore imported to a Unity software equipped with Vofuria Engine plug–in. As soon as every table in the treatise was set as a target recognizable by the mobile device to display the corresponding model, I defined ambient lights and materials to ensure a successful visualization. The following step involved the organization of contents in the form of an app for tablets and smartphones designed to study the treatise through its digitalization and the definition of models with different semantic values. The different information can be found on the screen overlapped to the real book framed by the device. A first menu entitled 'geometry and shape' allows us to see the digital model divided into blocks, the essential geometric entities representing the cutting planes of the ashlars and the opportunity to observe the model through an exploded view drawing (fig. 1).
For what concerns this device it will be possible to read the Monduit's text through the use of a parallel window in the interface which explains every geometrical phase in the defi-

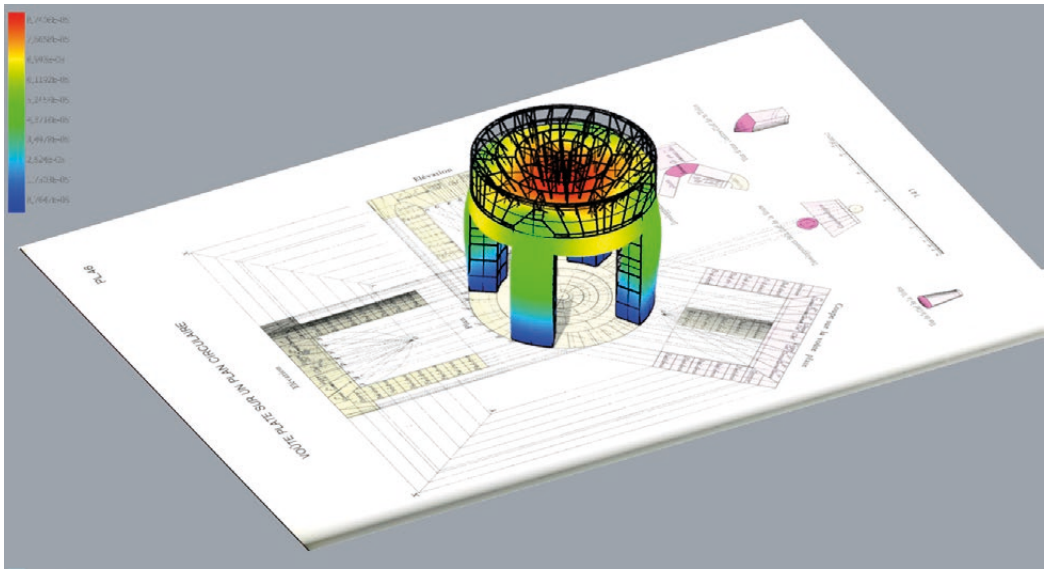

Fig. 2. False color Fem analysis of the 3D model obtained Planche 46 of Monduit's treatise.

nition of various traits. Placing the mobile device in front of the book it will be possible to refer to a database of georeferencing associated with every single case study. This database will gather the existing architectures which were carried out and theoretically described by Monduit in order to obtain an extensible catalogue of stereotomic structures with a description of their own historical and artistic features. Anyway, starting from the important relationship between form and structure in the analysis of stereotomic buildings, I decided to add the opportunity to see a structural model in this app showing the strain of the elements through the use of a false color Fem analysis (fig. 2).

Conclusion

This experiment has shown that the augmented reality can be considered an important tool in the enhancement, analysis and dissemination of cultural heritage through the creation of digital pop–ups. Stereotomy can be considered an excellent field to experiment these kinds of technologies and highlight the closer relationship between geometry and structure while interpreting ancient and complex treatises. In addition, we can state that the use of these technologies must be combined with an in–depth critical development of contents as well. Otherwise the risk is to appear as simple tools of entertainment, instead of sources of knowledge.

Notes

[1] De l'Orme Philibert (1567). *Le premier tome de l'architecture*. Paris: Federic Morel.

[2] Frézier Amedée–François (1737-1739). *La théorie et la pratique de la coupe des pierres et des bois pour la construction des voûtes et autres parties des bâtiments civils & militaires, ou Traité de stéréotomie, à l'usage de l'architecture*. Paris: Guerin.

[3] De la Rue Jean Baptiste (1728). *Traité de la coupe des pierres, où par une méthode facile et abrégée, l'on peut aisément se perfectionner en cette science*. Paris: Charles–Antoines Jombert.

[4] To analyzed this topic, please, see for e.g.: Candito Cristina (2018). Drawings and Models in English Perspective Treatises of the XVII and XVIII Centuries. In Cocchiarella Luigi (ed.). *ICGG 2018–Proceedings of the 18th International Conference on Geometry and Graphics*. Milan: Springer, pp. 1882-1894.

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