Paper Models for Science Dissemination and the Study of Drawing

Alessio Bortot, Annalisa Metus

Abstract

This contribution concentrates on a peculiar category of analogical models made of (movable) paper already present in scientific treatises from the 13th century onwards. If the first animated pages, capable of showing three-dimensional models, initially supported various fields of knowledge (gnomonic, perspective, astronomy, cryptography, the art of memory, anatomy, etc.), from the 18th century they became objects of entertainment, more markedly recreational, however for an adult public until the late 19th century. Paper models that could be folded to form volumes mainly concerned areas of knowledge related to geometry and gnomonic, as if to denounce how the written word and drawing were insufficient for the description of complex entities in space.
One of the movable techniques, the pop-up, was the subject of a workshop, partly inspired by the experiences of Origamic Architecture. The didactic experience will be described using two approaches: first emphasising the importance of being able to obtain a not entirely predictable model through cutting and folding operations and, secondly, describing the subsequent representation of the same model through the methods of drawing and surveying. The experience indirectly created links with the subject of design, ideally moving from the abstract form made of paper to its materialisation in the construction field.

Keywords: movable books, descriptive geometry, folding; cutting, paper engineering.

Introduction

The relationship between model and drawing, as well as that between drawing and survey, has accompanied the evolution of representation methods both in the domain of abstraction and in building practices. Since antiquity, the study of surfaces and their related curves –consider, for example, Apollonius' cone– has required first of all the use of a physical model and only later its representation through drawing. This contribution aims to offer some observations on the use of analogical models aimed not so much at the figuration of a work to be constructed, but as in the case of the Apollonio's cone, at materialising abstract models to subsequently observe their 'behaviour'. Massimo Scolari observes how: "the model seems to reverse its theoretical sequence and pass, with respect to drawing, from generated to generating. If it is true that the model brings to light the image of the building fantasised, conceived and turned over in memory, it is also true that it is only from this that the drawings of its fantastic elevations and sections seem to branch out" [Scolari 2003, p. 138]. According to some authors, the evolution of representation methods over time is partly linked to the observation of physical models, sculptural elements used to communicate a mental image of an object (architectural or otherwise) preferable to other media for its immediacy, but also for economic reasons (consider, for example, the cost in ancient times of drawing tools such as parchment). The analogue model has not only fulfilled the function of a scaled-down clone of something unrealised, but has often embodied an

underlying idea of design: "architectural scale models have been employed as mechanisms of thought, used not only to design future buildings, but also as models for understanding and testing concepts of invisible things in general. In other words, scale models were used to define what was considered absolute truth or, typically, the work of the divine" [Smith 2004, p. 3].

Movable books as tools for scientific and artistic dissemination

What we prefaced is well represented by the so-called movable books –fascinating works for their modernity– that have enriched scientific literature in various fields since the Middle Ages. The term 'movable books' encompasses, in its generality, a series of subcategories of literary works characterised by specific techniques and delicate mechanisms, sometimes combined with each other: paper or parchment elements capable of rotating on themselves, folding, lifting and animating themselves to gain the third dimension. Those among scholars [Crupi 2016; Connolly 2009; Wilkins 1997] who have dealt with these peculiar literary objects recognise in the *Chronica Majora* (1240) by the benedictine monk Matthew Paris (about 1200-1259) one of the earliest and most refined witnesses. Starting from the city of London and passing through major European cities, the book suggests routes to the two Christian pilgrimage destinations, Jerusalem and Rome. The dynamism of the narration is guaranteed thanks to folded parchment flaps capable, when necessary, of expanding the space of the sheet, guaranteeing the description of the traveller's routes. A further invention is linked to the temporal dimension, this time using rotating concentric disks (*volvelles*) as a technique for calculating Easter: "Matthew transformed the Paschal Table at fol. v of MS 26 into an ingenious thirteenth-century 'computer' by attaching the large circular table of lunar cycles, epact [1] and other computational data, taken from another sheet of parchment, to the page by means of a metal pin, so that it could be rotated" [Lewis 1987, p. 11]. In the centuries that followed, this system of concentric wheels for calendar use would become a combinatorial model supporting other knowledge, for example astronomy, which in ancient times was not dissociated from astrology. These are dynamic cosmological representations to describe, for example, combinations of astronomical events, as in the case of the sumptuous *Astronomicum Caesareum* produced by Petrus Apianus (1495-1552) in 1540. Close in content and historical period is the *Dess Menschen Circkel* by the physician and alchemist Leonhard Thurneysser (1531-1595), a paper astrolabe that is part of the eight-volume work *Archidoxa* (1575), [Crupi 2019, pp. 30-32]. The peculiarity of this text, conceived in such a way as to allow the reader to calculate his or her horoscope or predict nefarious events, is the possibility of making the configuration of the concentric disks three-dimensional: a paper mechanism, consisting of a wire that acts as a tension rod, allows the structure to be lifted, effectively converting it into a *maquette* (fig. 1).

Fig. 1. Thurneysser 1575, fol. 641.

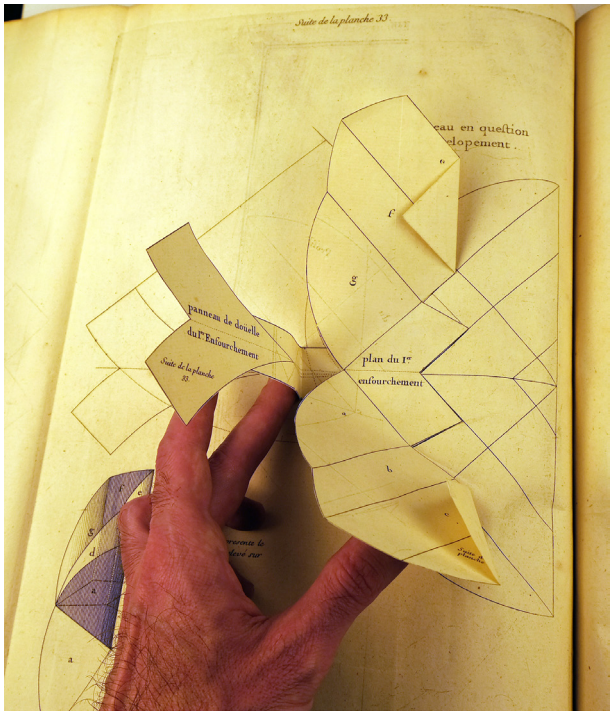
Fig. 2. Billingsley 1570, fol. 314.

The more usual two-dimensional applications of concentric disks rotating thanks to a pivot found useful uses in the art of memory starting from the medieval period thanks to Ramon Llull (1232-1316): concentric disks, visible for example in his *Ars compendiosa inveniendi veritatem seu ars magna et maior* (1274), subdivided into text boxes allowed the creation of logical associations of concepts to achieve knowledge. In the Renaissance, as the art of warfare and cryptography evolved, similar mechanisms allowed for the encryption of messages, which could be deciphered by combining wheels with letters, symbols or other letters [2]. Folded fragments of parchment were not only used to enlarge the surface of the page, as in the case of the *Chronica Majora*, but also to reveal hidden elements overlapping one another: through a sort of paper autopsy, Andreas van Wesel (1514-1564) in his *De humani corporis fabrica libri septem* [Van Wesel 1543] unveils the organs of the human body to the reader.

Moreover, the flap technique was also used to move from the two-dimensional space of the page to the representation of entities in space in the form of paper models: in an English edition of Euclid's *Elements of Geometry* (1570), the printer John Day decided to turn over the faces of some polyhedrons in the form of paper elements that, once folded, could show the model of the solid: the aim was obviously to make the study of Euclidean geometry more popular and comprehensible (fig. 2). A further area in which folded elements were used to reconstruct paper volumes, leaning on the pages, is the treatise on stereotomy, as can be seen for example in *planche 33 bis* of the *Traité de la coupe des pierres* [De la Rue 1728] by Jean Baptiste de la Rue (1697-1743). In the treatise, characterised by rather clear textual explanations as well as refined illustrations in orthogonal projection, perspective and cavalier axonometry, the author states that he considers these graphic-representative methods insufficient to show the morphological complexity of certain stone blocks and therefore resorts to the use of flaps. In the explanatory text of *planche 33 bis*, De la Rue declares to be against the approximation of the intrados surfaces of hemispherical vaults by means of cones, because in many cases: "the length of the surface […] is not sufficiently elongated" [De la Rue 1728, p. 61], as demonstrated by the folded paper flake in the said table that bears the caption "Proof of the error of the model shown through its development" [De la Rue 1728, p. 61] [3] (fig. 3).

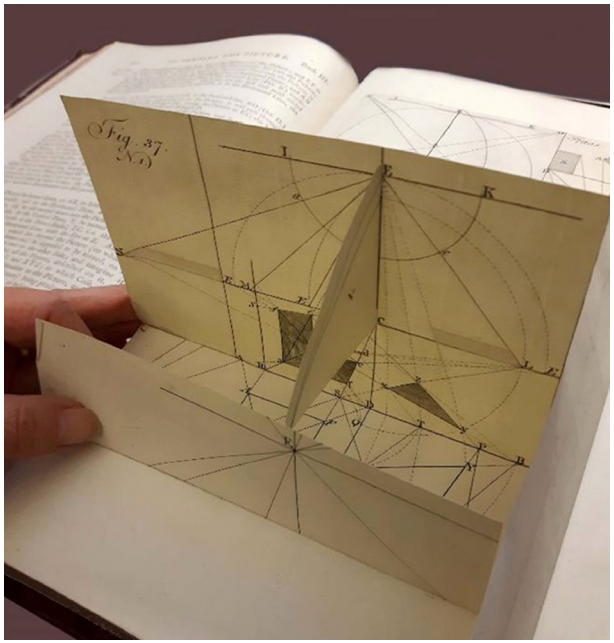
Extensive use of flaps can be found in treatises on the subject of perspective, generally employed to fix the observer's point of view by means of a liftable paper element from which the reader can verify the coherence between what the eye sees, and the image constructed according to geometrical methods. Cristina Candito [Candito 2018] reminded us some famous examples of this practice, such as the *Traité des pratiques géométrales et perspectives…* by Abraham Bosse (1611-1676) [Bosse 1665] or *A compleat treatise on Perspective…* by Thomas Malton (1726-1801) [Malton 1775] (fig. 4). The paper models in the latter's work are not only intended to demonstrate the correspondence between *perspectiva naturalis* and *artificialis*, but also to explain the reasons for the method of perspective through its spatial genesis and thus, through the overturning of geometrical entities, the construction

Fig. 3. De la Rue 1728, planche 33 bis.



of the image alluding to the third dimension of objects on the drawing sheet. "The result is a real device, similar to the mechanical instruments that, in the allegorical repertoire as in experimental practice, became one of the symbols of the scientific revolution that characterised the social and cultural history of the modern able to reproduce a model of the natural phenomenon, observable and operable as in a craftsman's workshop" [Zoerle 2017, p. 94], states Stefano Zoerle analysing the flaps in Salomon de Caus's (1576-1626) treatise on perspective [De Caus 1611].
It is only in the 18th century that the movables for popular or entertainment purposes appeared and the ones for children are produced in the first half of the 19th century, in parallel with the development of children's literature. In the years in which peep shows were fashionable, in the form of voluminous constructions used as popular and street attractions, dioramas –scenes developing in depth like a small theatre– and panoramic representations of landscapes or architectural works became widespread: the purpose in this case was not didactic but rather popularising, as a tourist guide or a view album might have. Jean-Pierre Brès, with *Livre joujou avec figures mobiles* (1831), is the first to have the idea of transforming illustration for narrative purposes: an asterisk inserted in the text indicates when to act out the transformation of the page, changing, for instance, the panorama seen through a window or the subject of a painting on canvas. In 1860, the firm Dean and Son in London created the first automatic three-dimensional books (pop-ups); in the same years fading images appeared, i.e. two images that intersect each other, decomposed and printed on a special paper.

Fig. 4. De la Rue 1728, planche 33 bis.

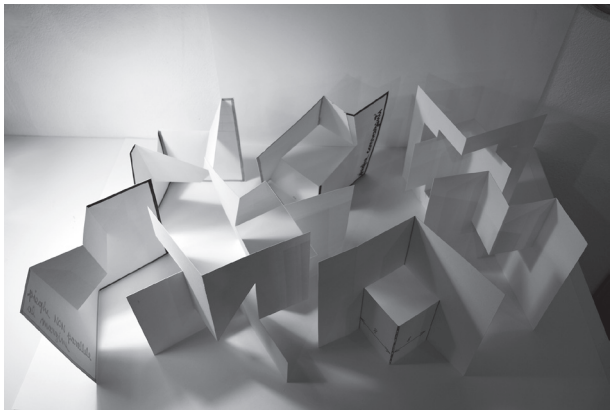


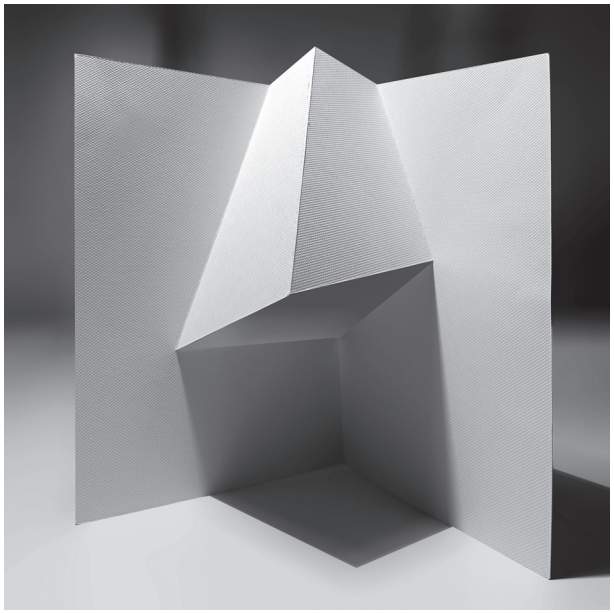
Cutting and folding in paper models

Beyond the techniques and the great number of movables applications in scientific treatises, what seems to be emerging is the need to confront a physical model in the path of knowledge. Today, in the field of didactics and popularisation, the possibilities of abstraction and narration on multiple levels, offered by a skilful and creative application of paper engineering, are in continuous development and are experiencing a parallel fortune with the diffusion of digital animations. Potentialities of these tools are evident if we think of how digital models and applications of augmented reality can offer unprecedented resources precisely for the study of ancient treatises by digital pop-ups [4]. However, we believed that these technologies should complement analogue models, especially in the context of architecture and engineering schools, where 'seeing with the hands' remains an indispensable practice for learning building practices.
In the process of realisation using a movable, it is necessary to reduce the object, which must be simplified according to the limitations of the chosen technique. Schematically speaking, we can identify two methods for placing an object in traction on a page and building it three-dimensional: exploiting the lever in the centre of the page and arranging the load-bearing sides at an angle (*V-fold* technique) or positioning the load-bearing sides parallel to the central fold (parallel fold). The choice of technique influences the positioning of the object on the page, the behaviour of the object in the time of the page opening, the consumption of the page surface and –in its most basic applications– the sacrifice of one of the three dimensions. Some applications of paper engineering in the field of architecture

Fig. 5. Pop-up made during the workshop through cuts and folds technique.

Fig. 6. Pop-up made during the workshop through cuts and folds.





were experimented by us in a workshop dedicated to the relationship between model and drawing [5].
A first round of exercises focused on the figure of the cube, precisely to highlight how the choice of technique (V-fold or parallel fold) influences every other decision concerning the pop-up in the economy of a page of constant dimensions. A second application was explored in a more creative context abstractly related to the study and conception of form through the cutting and folding of the sheet, among other things reflecting two of those operations of composition identified by Franco Purini [Purini 2010] [6]. These models, constructed by freely tracing some cut and fold lines on a single piece of cardboard subsequently folded in two, once opened at 90° reveal shapes that are not easily predictable, defined by generically inclined planes able of stimulating the imagination in abstract space (figs. 5, 6). The exercise is inspired by the technique known as Origamic Architecture (OA), which is often used today in so-called pop-up books, referring to the experiments conducted in the 1980s by a Japanese professor of architecture, Masahiro Chatani (1934-2008) (fig. 7).
The creative process involves a few simple steps: some straight lines are drawn on the rectangular sheet, possibly in different colours for greater clarity, to represent the traces of the cutting planes, the convex and concave folds, which are then marked with a tracing tip. The unpredictability of the shapes, once the sheet was opened to 90°, was of

Fig. 7. Akihiro Higarashi, pop-up model of the Golden Mile Complex in Singapore.

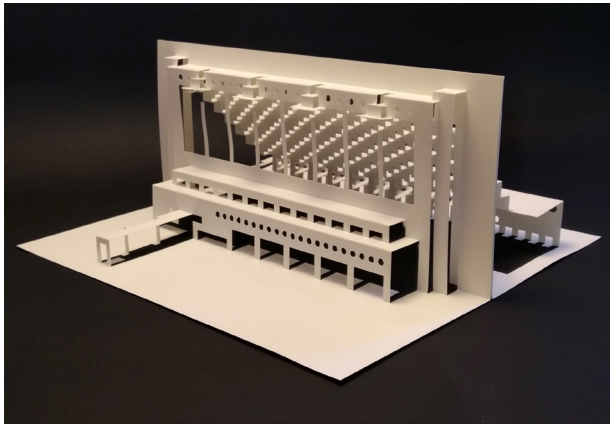
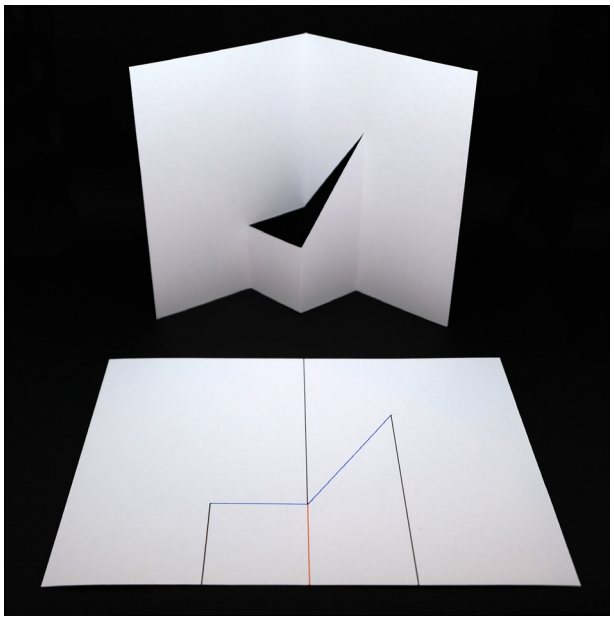
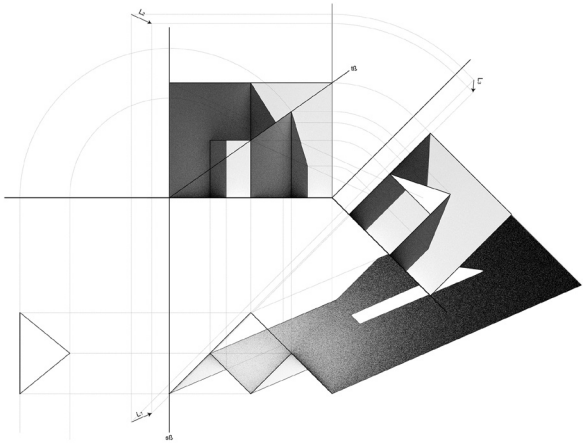


Fig. 8. Pop-up made during the course. The colored libne of the drawing identify cuts and concave and convex folds.

Fig. 9. Orthogonal projection drawing of the previous model after its survey.



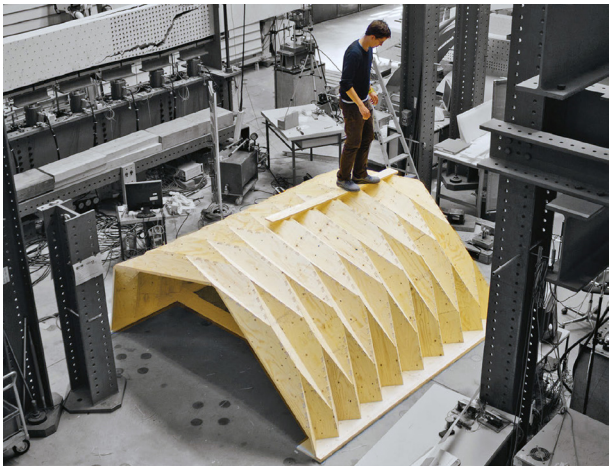


great importance within the seminar, it was then asked to the student to survey and then represent the model on paper in Monge's method with the relevant overturns to obtain the true shape of the faces belonging to inclined planes and, finally, to draw it in isometric axonometry. In a subsequent step, having assigned a light source with a centre at infinity, it was asked to represent in orthogonal projection the shadows through the intersection with secant and tangent light planes (figs. 8, 9).
From the model to the drawing then, that is, having a paper maquette constructed geometrically, trying to imagine it but without foreseeing it in detail, letting the three-dimensional form generate itself in space thanks to the tension generated by folds and cuts. These spontaneous forms, through survey and drawing, then underwent a process of engineering, inviting the student to imagine them as a concept for a design object [7], a building element (fig. 10), an urban furniture, and so on.

Conclusions

Paul Jackson states: "the transformation of a single flat sheet of paper into a three-dimensional structure without the

Fig. 10. An example of an Origamic Architecture prototype made at the ETH Zurich [Weinand 2017, p. 208].



addition (or loss) of material is a contemporary form of 'paper alchemy' that never ceases to fascinate and impress the public" [Jackson 2014, p. 8]. An attempt has been made to highlight how analogue paper models have been a privileged tool for transmitting knowledge since ancient times, enclosed in treatises that, like treasure chests of science, once opened immerse the reader in another space. Moreover, pop-up, conceived in abstractly geometric shapes, have proved to be effective teaching tools for the development of spatial imagination through simple cutting and folding operations. Finally, we could say that the analogical models described here, despite their diversity, represent an idea rather than an object, or possibly a process, the one that from the conception of form leads to its realisation through the tools of drawing, in this case generated rather than generator.

Notes

[1] The epatta of the year is the number of days to be added to the date of the last new moon of the previous year to complete the solar year.

[2] Among many possible examples, consider the treatise by Giovan Battista Della Porta (1535-1615) [Della Porta 1563].

[3] To deepen the representative strategies in De la Rue's treatise see Bortot, Lopez 2020.

[4] On this topic, see e.g. Bortot 2020; Bruschi, Grimaldi 2019.

[5] The workshop From model to design. The cut and fold in paper structures, edited by Annalisa Metus and Alessio Bortot, took place within the Drawing and Surveying workshop of the degree course in Architecture in Gorizia (23 October 2023).

[6] On the subject of cutting and folding in architectural composition, see also Zanni 2010.

[7] On the use of paper models, obtained by folds and cuts, as a source of inspiration in the field of design, see for example: Razani 1993; in the field of architecture and engineering: Weinand, 2017.

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