Graphic Imprints, Grids and Diagrams in Architecture

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Abstract. This text aims to reflect on the imprint that procedures, strategies and graphic instruments may have on design, and as a consequence, to what extent they influence the language of architecture.

Our essay explores the influence of grids and diagrams upon the course of architectural practice. In addition to the possibilities inherent in the *analytical* diagrams popularized by Rowe, we examine the *generative* role that diagrams can play, teasing out the potential structures of order latent in the exploratory stages of the design process. The critical role played by generative diagrams is most abundant in the design strategies of projects from the Renaissance onward, when drawing became the primary tool for conceiving and representing architecture. But the design and construction of pre-Renaissance buildings can also provide clear, if less explicit evidence of generative diagrams: evidence conveyed by the tracery of mediaeval masons, the placement and proportions of cathedrals laid out directly as templates on site; or the architecture of antiquity, with its alignments and optical corrections of walls and peristyles. The prescribed repetition of an array of aligned columns in a dimensional grid or the 'rational magic' of the happy Hippodamian layout are, perhaps, among the brightest moments of architectural reason. We also try to define *transformative diagrams* characteristic of some contemporary architectural practices with topological implications.

Keywords: Grids · Generative diagrams · Transformative diagrams

1 Introduction

The idea of order is integral to any creative act. Works of art are therefore inconceivable without considering a structure that follows an internal logic, a logic that provides it both order and meaning. Be it a musical score, a pictorial composition, a work of sculpture, or merely a good story, all must establish an order – a *logos* – that sponsors the creative work, and attempts to make it intelligible to others.

An author is a demiurge – an inventor of *logos* – who orders the elements of his discipline to artistically shape his creative work. In addition to the technical issues of architectural craft, the ability to engender a work that captures and conveys meaning distinguishes creative work from mere construction.

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2 Order

With architecture, the necessity for order is, if possible, even greater than the other arts. In addition to its creative nature, architecture is born from necessity (Milizia 1826); it cannot solely serve a purely expressive purpose: it must also be subject to its utilitarian nature. Buildings cannot be formless structures, lacking order: it would render them unintelligible to their inhabitants. In his 1923 manifesto, *Vers une Architecture*, Le Corbusier stated not only the need for order in the discipline but also the intellectual pleasure that its comprehension could produce in humans: "The regulating line brings forth the sensory mathematics that produces a beneficent perception of order" (Le Corbusier 2007, p. 137).

Beyond its utilitarian obligations, architecture is further constrained by a quality intrinsic to its identity: its scale. Its very size ensures that architecture is bound more fully by gravity, distinguishing it from all other artistic endeavours – even sculpture – due to limits imposed by the resistance of materials. Geometries achieved in a work of sculpture may be unfeasible with larger scale of architecture. Gravity and scale determine much of the physical limits for constructional geometries, and implies a logical, prior sub-set of order for all feasible architectures.

Until the advent of Newtonian mechanics, and subsequent advances in quantifying the strength of materials, builders relied heavily upon structural symmetry for guidance to the structural behaviour of buildings. That is one of the reasons for architecture's typological tradition. Regularly spaced, modular units – of both material elements and the spacing between them – generate three-dimensional grids. These in turn produce rhythmic patterns that make tangible the order upon which they are based. The modular arrangement of beams and columns simultaneously provides for the structural resolution of architecture, systematically channelling forces and loads safely to the ground.

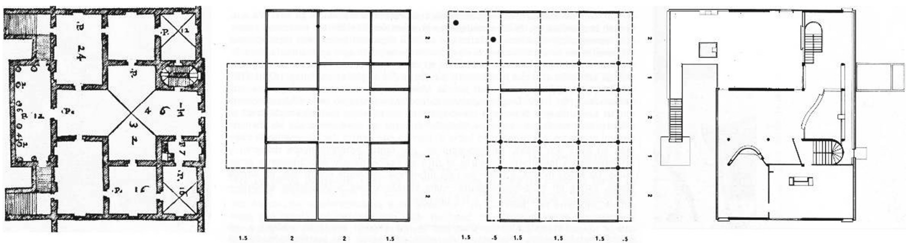

Fig. 1. Le Corbusier (Villa Stein, 1927) and Palladio (Villa Malcontenta, 1550). Comparative analysis of the floor plans and the analytical diagrams of both villas (diagrams first published by Collin Rowe in "The Mathematics of the Ideal Villa: Palladio and Le Corbusier Compared", Architectural Review, 101, Mar. 1947).

Modular tectonics, with its accompanying spatial rhythms, has traditionally helped to define architectural order and make it intelligible. Christopher Alexander has articulated and analysed this sense of order throughout his lifetime, research that rests significantly on the practice of *patterns* (Alexander 2006). Patterns constitute ways of organizing matter in space, and provide an ordered whole that renders it recognizable. For Alexander, it is due to these meaningful arrangements that we come to understand architecture, and beyond that, existence itself. As Mark García (2009, p. 12) has pointed out, Alexander's first approach to patterns in his early *A Pattern Language* extended his influence into other fields ranging from sociology, design and urbanism (Alexander 1977).

Patterns – in the form of grids – were similarly used by Wittkower and Rowe for the analysis of the architecture, revealing their unifying role in the establishment of spatial orders. These were identified graphically through the superimposition of simplified grids over the plans of these buildings (Fig. 1), thus side-stepping the architectural stylistic qualities of each period.

Observing the plan diagrams traced by Rowe (1976) for Villa Stein and Villa Malcontenta, not only do they plainly reveal his comparative analysis, we also recognize how diagrammatic representation can free architecture of its timely or stylistic limitations. These works are pared to their essence, so that nothing further can be removed without eradicating the kernel of the design. This gives evidence of the role of diagrams in relation to plans and to architecture: they are the utmost synthetical notation of a given architectural design. As Carazo and Galván have noted (2017), for this reason alone, diagrams are a vital tool for teaching purposes.

3 Order Systems

For myriad reasons, grids have always been used in architecture (de Molina 2005). In the first place, grids *embody* order. As such, they can also *engender* it. As Ching's *Architecture: Form, Space, & Order* (1979) demonstrates, the organization of architectural space is linked throughout history by what he calls spatial organization systems, and which we refer to as *order systems*. An order system is an *a priori* arrangement of the elements of a composition, one that pre-figures matter while establishing an organization of the material boundaries defining architectural space.

At the same time, ordering systems do not pre-determine design. They provide structure, yet remain open and flexible, a combination of qualities that makes them immensely useful for the design process in architecture. There are unlimited possibilities to produce different architectural designs that arise from otherwise similar linear orders, transcending traditions or styles. Thus, if we compare varied examples of architecture over time with diverse chronology, aesthetics, uses, constructive and structural systems, we can observe striking consistencies. The Egyptian temple complex at Karnak, the Parthenon of Athens, the Basilica Julia, Salisbury Cathedral, the Barcelona pavilion or the Yokohama port terminal: all are examples engendered by the same organizational system. All follow a predominantly linear order – even if most also support a supplementary orthogonal arrangement – wherein matter is ordered along a main axis that can even become a continuous winding gesture. Such is the case with FOA's Yokohama project, which, despite otherwise eschewing the conventions of orthogonality, threads its various flows along an intrinsically linear thrust.

The use of grids as a powerful spatial tool need not be the result of a graphical scheme. Millennia before Alberti first argued for scale drawings as a necessary prelude to the act of building, grids were employed as the initial conceptual framework of 'design', arrayed across the surface of the earth, to literally 'stake out' the project site. For instance, Egyptian surveyors fashioned ropes with 12 evenly-spaced knots, allowing them to a portable yet precise tool to lay out right angles erected on site (Balmer and Swisher 2019, p. 13). Arranged to form a three-sided figure with $3 \times 4 \times 5$ proportions, Egyptians made use of the special properties of the Pythagorean triangle long before it was given such a name. This practice indicates both: a working knowledge of geometry, and the utility that such an easy and effective geometric tool has proven to be in relation to the setting-out of construction sites ever since.

We know relatively little about graphic representation in antiquity, as the survival of drawings on papyrus or paper are exceedingly rare. There are, however, examples of ancient sculptures in which building plans are represented, suggesting the knowledge and practice of graphic representation based on orthographic projection. Such is the case of the headless statue of Gudea (Fig. 2), as Franco Taboada (2017) has noted.

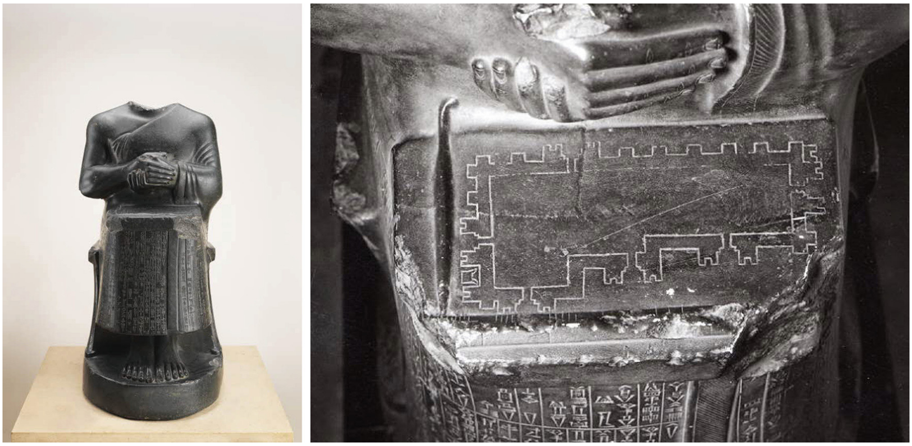

Fig. 2. Headless sitting statue of Gudea (prince of Lagash), Mesopotmia, 2120 B.C.E (Louvre). (Source, presentation by Franco Taboada UID Conference in 2017). A floorplan is inscribed on a tablet resting on Gudea's lap, a drawing which implies that horizontal sections were known and already in use to represent architecture.

Pompeian frescoes show a knowledge of a rather precise form of perspective in Ancient Rome (though some rules of its construction vary from those first developed centuries later in Florence). Vitruvius' seminal text on architectural theory mentions the term *scenographia,* stating the lines of the side façade are convergent in a point, which some have interpreted as the use of these kind of representations by architects. He also speaks of floorplans and elevations as well as the use of compasses and rulers architects needed to draw them (Vitruvius 1995). In fact, it is known that Vitruvius' original text was accompanied by drawings but, unfortunately, these were lost in the course of time (Rodriguez 1995).

However, despite the most likely professional use of architectural drawing in ancient times, what it is now clear is that architectural representation has been based on projections since the Renaissance, when many of the graphic representation systems of architecture were precisely established, not only perspective. In his letter to Pope Leo

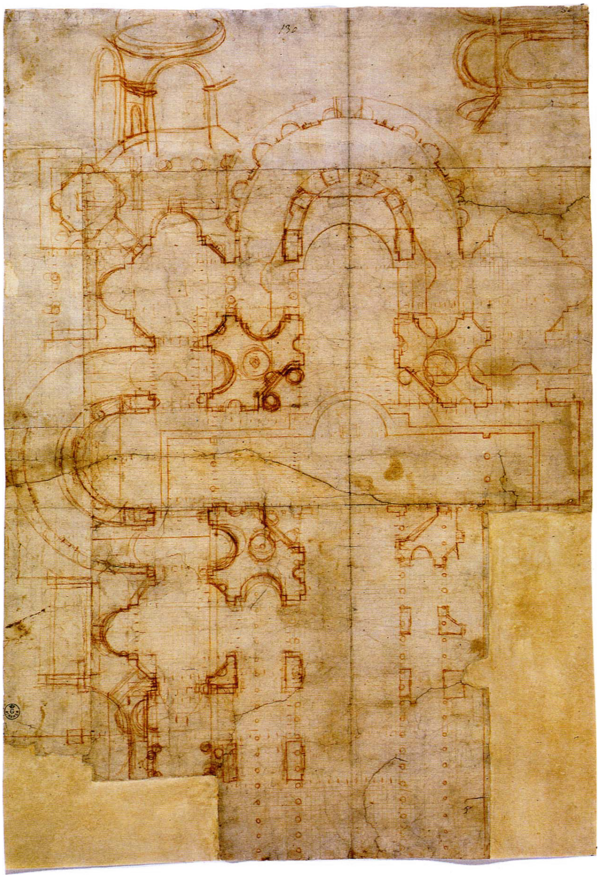

Fig. 3. Bramante. Partial plan of St. Peter's Basilica, Rome, c.1506. (Source: Borsi, F., *Bramante*, Electa, Milan, p. 75, 1989). Bramante's design, drawn over the plan of the earlier Paleochristian basilica, conveys the influence of Imperial Roman vaulted architecture. Bramante's drawing conveys the striking change of scale from Old St. Peter's.

X, dated 1519 (Hart, Hicks, 2006), Raphael's use of the three most characteristic types of orthographic projection in architectural drawing – sections, floors and elevations – was already stated. This system of representation was an attempt to dissect architecture into plans at scale. The unmistakeable influence of Alberti can be traced here, as he already distinguished between the use of the two types of projections suitable for painters or architects, respectively, in his *Re Aedificatoria* (Alberti 1991, p. 95). This intimate relationship between architects and drawings has remained so throughout the centuries.

Once plans could be drawn to represent the design (and anticipate its laying out on site), geometric constructions used to precisely depict architecture in scale naturally led to the use of grids. In Bramante's plan for St. Peter's Basilica (Fig. 3), ancillary construction lines generating a grid can be interpreted as an *appoggiatura* for the drawing itself. Their capacity to embody a certain order can be easily understood, considering the setting of alignments, rhythms and spacing defined by them.

From a strictly compositional point of view, grids are systems of relations between their three constituent elements: lines, nodes and interstices. Lines establish alignments, predominant directions in space, orientation and axiality; in other words, lines define the anisotropic quality of any architectural space. Nodes, the points that are highlighted at the intersection of the grid lines, are given a special status of hierarchical singularity within the grid. Interstices, the spaces in between the lines, are the void areas that engender architectural space itself. Typically, lines and nodes are the geometrical locations where the architectural limits or the structure are placed, while the interstices constitute the architectural space defined by them. The set of relations that the grid defines are equally granted to the elements arranged from them.

4 Grids and Diagrams

Grids and diagrams are, to begin with, abstract notations of architecture. They continue to maintain a certain relationship with cast projections, but they involve a step beyond any form of figuration. That is to say: the basic relation of analogy between matter and space, on the one hand, and the graphic representation with regard to its projective nature, on the other.

Although any type of drawing is a mere shadow on the plane with respect to the richness of architectural space, a section, a floorplan or an elevation are, nevertheless, quite precise and descriptive representations of architecture. Yet, these plans convey relevant architectural information that very significantly cannot be directly inferred through experiencing built architecture. In fact, the findings we can gather from a visit to a building on site and through the observation of its plans is complementary; a critical assessment of an architectural design needs attention to both different realities although based on a same referent (Allepuz 2019).

Grids -considered as schematic and generic order systems-, and diagrams -basically, particularization of grids- make architectural shorthand possible. These graphical notations have the ability to define the basic hierarchy and scale of the different parts with respect to the whole, as well as the topological relations of connectivity of the entire morphological structure. Nevertheless, true architectural diagrams must preserve measurable relationships inherent to scale drawing to represent the geometric essence in a work of architecture. In this sense, we can consider them as synthetic representations of a specific architectural order rather than of architecture itself.

Probably, the first architect who was aware of this synthetic quality of diagrams was Durand (2000 [1805]). He devised this type of graphic notation to free his design method from any particularization associated to historical styles. In doing so, he managed to overcome the limitations of the style and syntax of his time, allowing further development and deepening of its use. Today, Durand's system is generally dismissed as formulaic, based on rigid geometries but this is because we see it with the eyes of our time. Its method, far from being traditional, was quite innovative in its time. He should be attributed the invention of this explicit graphic notation not only in regard to analytical aspects but, above all, as a generative graphic device capable of anticipating and prefiguring architecture.

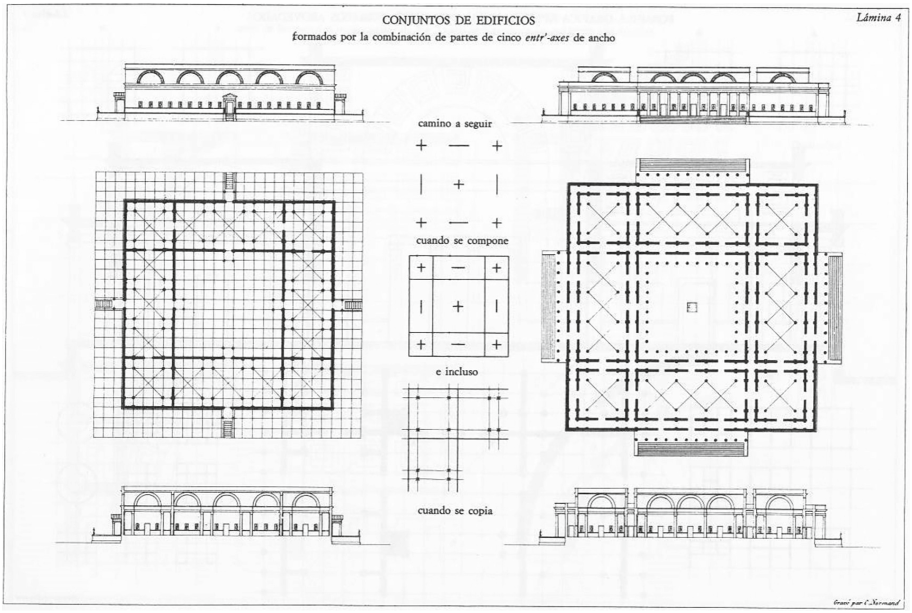

Fig. 4. J.P.N. Durand. Building ensemble. (Source: Cours d'Architecture, Ed. 1821). Note how a same diagram is able to generate two different projects shedding evidence of the generative character of Durand's proposed design methodology.

As it can be seen in Fig. 4, two different design proposals share a same diagram (Madrazo 1994, p. 19). This alone shows the potential of diagrams to generate form in addition to their intrinsic analytical possibilities, regardless of the architectural epoch or the kind of architecture to analyse (Figs. 1 and 5). In Fig. 5, we can observe how diagrams need not be exclusively based on plans but may also be drawn in axonometric projections.

Modernist architecture was also inspired by grids since the dismembering of skeleton and skin in architecture was determined by the International Style through the concentration of vertical loads in columns –*pilotis*–. Even Neoplasticist architecture was inspired by a conspicuous orthogonal plot – although the spacing of the grid is rarely regular. Wright made extensive use of grids, producing some of the subtlest examples of rich geometries in the exploitation of these order systems. Think, for instance, in the design of the Hanna house-Honeycomb (Fig. 6). Even late modernists like Kahn and Breuer continued to make extensive use of them.

One of the most significant examples for the use of diagrams among the early proponents of Modernism was Louis Sullivan. Detailed evidence of his design process illustrates how operational graphic notations can be geared to shape architectural form. Equally significant, Sullivan's system of generative diagramming provided him the means of introducing complexity and harnessing irregularity through them in the design (Sullivan 1990) (Fig. 7).

The incomparable fluidity and richness of Sullivan's ornament is clearly derived from geometric constructions, grids and diagrams, progressively evolving through increasing

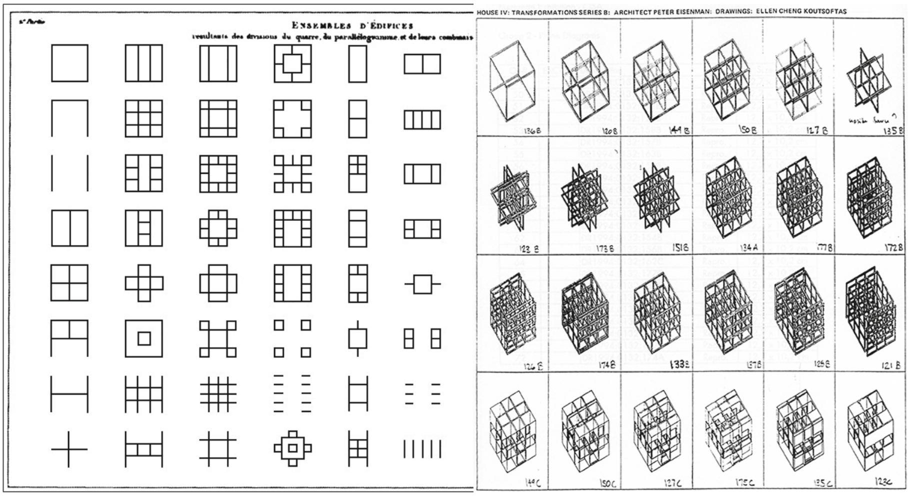

Fig. 5. Left: J.P.N. Durand «Ensembles d'edifices resultants des divisions du quarré…» (diagrams of buildings based on a square plan), (Source: Précis, Ed.1802). Right: Eisenman. Analytical series of axonometric diagrams for House IV, 1971 (courtesy Eisenman Architects). Note the idea of variations developed over a same scheme on both plates. While Durand is proposing a series of possible plan diagrams based on the square, Eisenman is doing the same within a cube which; most of the design process is, however, based on the 9 square grid.

levels of organic complexity, and guiding his design process forward. Without a doubt, Sullivan's generative system of geometric production played a pivotal role in the development of Wright's prolific dominion of form: Serving for several years in his capacity as chief draughtsman to Sullivan, Wright referred to his great mentor as *Lieber Meister* throughout his lifetime. Whereas Sullivan's inspiration for his grammar of ornament is *figuratively* organic, Wright's claim for an organic architecture of his own can be understood as an abstraction of Sullivan's procedures applied to the architectural form, as well as to his geometrized ornamental repertoire.

This generative and evolutionary procedures developed by Sullivan should also be considered in relation to D'Arcy Thompson's *On Growth and Form* (1945). First published in 1917, Thompson's work hinges on a rich array of diagrams produced to explain evolution through the graphical evidence of anatomical transformations. However, Sullivan's approach is a certain blending of geometricism and the use of nature's forms as a source of inspiration. Thompson's *topological or transformative diagrams*, on the other hand, are a graphic depiction of geometric transformations that species have undergone throughout the course of evolution shaping them to make them fitter for survival. To be precise, they are more homeomorphic transformations on a topological space as the changes depicted do indeed deform their anatomies (Fig. 8) through processes of continuity.

What is most remarkable about Thompson's explorations is that a simple distorted Cartesian grid can serve as a guide to follow, interpolate and even to predict these kinds of transformations (Fig. 8). The importance here is the way in which he manages to

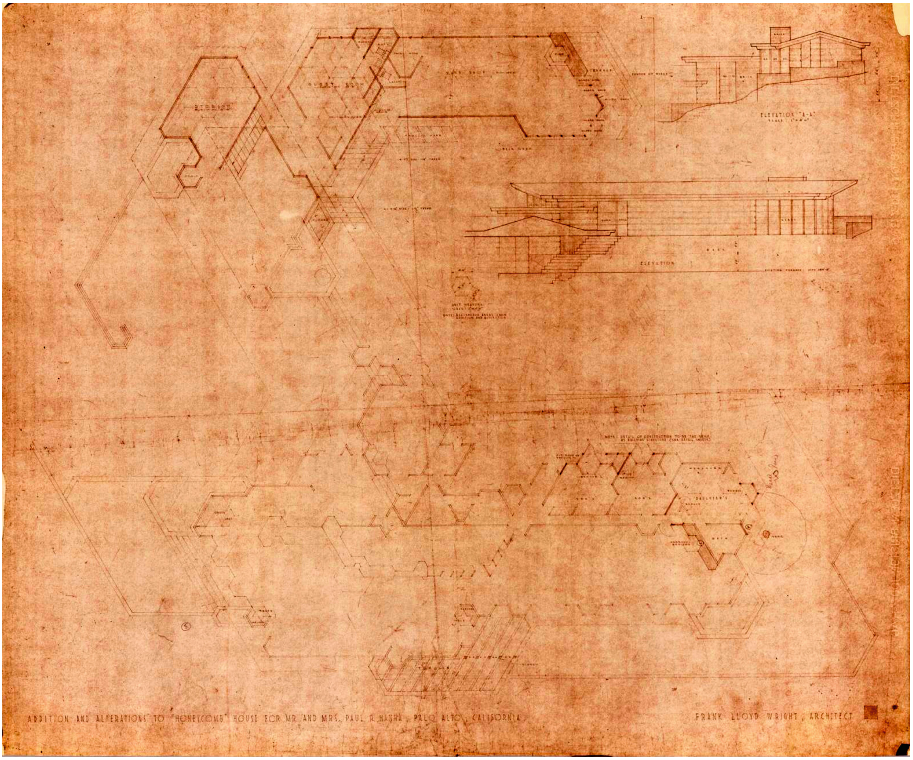

Fig. 6. Frank Lloyd Wright. Addition and alterations to Honeycomb House, 1936. (Source: Hanna House Collection. Stanford Libraries) Process drawing of Wright's Hanna Residence, showing the generative influence of its hexagonal grid.

superimpose the cartesian grid over a given anatomy (geometrically defined through drawing projections), just as Bramante's scheme for St. Peter (Fig. 3) is drawn over the plan of the earlier Paleo Christian basilica. The coexistence of two different realities, the cartesian grid and the anatomic depiction in the case of Thompson, or the existing and the proposed basilicas in the case of Bramante, is the only reason for an enhanced reading of potential relationships. It is through this superimposition that Thompson is able not only to graphically verify the validity of biological evolution but, moreover, to predict intermediate evolutionary stages by interpolation to suggest *missing evolutionary links*.

The difference between geometric isomorphisms and topological homeomorphisms rely on the fact that the first keep the proportions of the parts to the whole (symmetry, rotation, translation or homothecy), whereas the latter imply an alteration of these proportions. That is the reason for the common image of the topological space understood as an *elastic* space. These types of transformations can be any kind provided they are continuous, thus, no gluing or breaking of the forms are allowed. Greg Lynn has pointed out that Thompson's deformations of the neutral Cartesian grid superimposed over the anatomies "suggest an alternative to the static morphological transformations of autonomous architectural types" (cit. Carpo 2013, p. 37). In fact, this same procedure

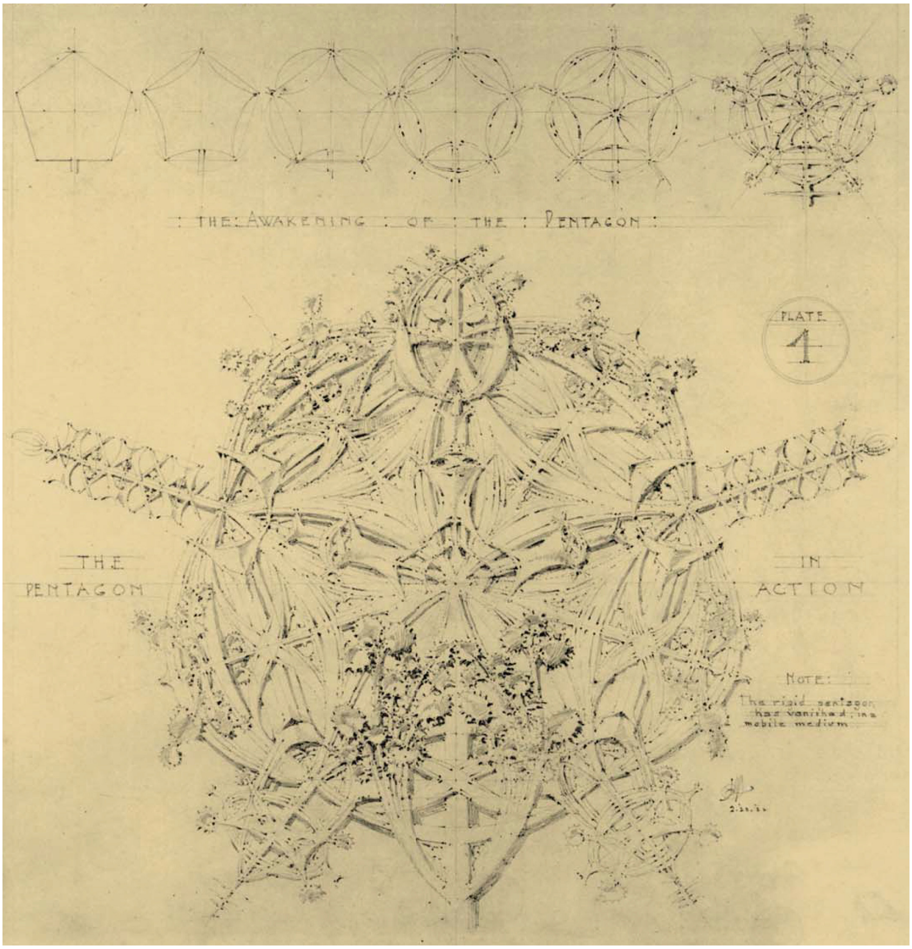

Fig. 7. Louis Sullivan. A pentagonal ornamental arrangement. (Source: A System of Architectural Ornament, 1924, plate 4). Inspired by his observations of geometries found in natural forms, Sullivan's treatise on ornament demonstrates the iterative process of transforming simple geometric shapes towards the full flowering of complexities.

has underwritten algorithms within graphical software, including Photoshop, to attain irregular transformations of a given form.

It is only in the past recent decades, when irregularity has become a hallmark of recent contemporary architecture, when we find a more disruptive strategy in the use of diagrams which can be mirrored in Thompson's procedures. Without any doubt, Eisenman should be credited for the most innovative approach in the use of diagrams and their generative potential (Marcos 2011). Much of his production in the last decades is inspired by this new generative diagrammatic approach; he has written much about his own work and its relation to diagrams (Eisenman 1999).

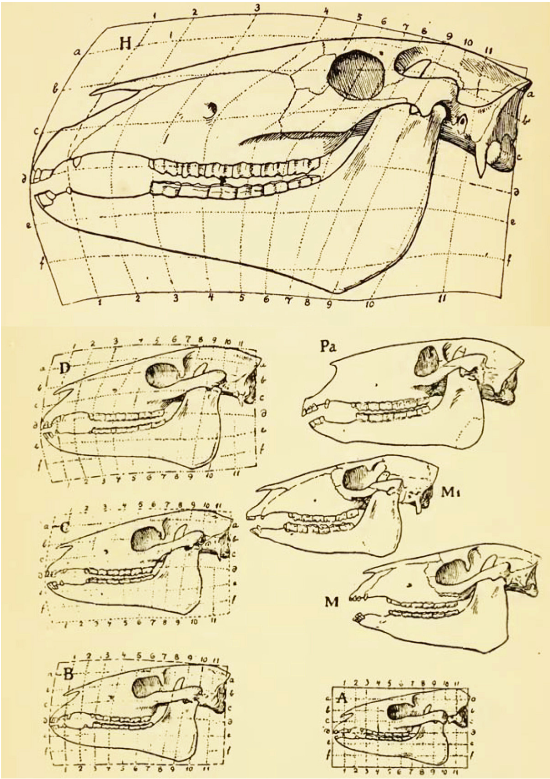

Fig. 8. D'Arcy W. Thompson, 1945, pp. 1078–1079. Evolution of the skulls of different animals through the superimposition of a coordinate system from A (Hyracotherium, Eocene) to H (Horse, Quaternary), and interpolations of imaginary types (B,C,D). The latter to be compared with real extinct species such as M (Mesohippus, Oligocene), Mi (Miohippus), Pa (Parahippus) (Source: On Growth and Form).

Meshed geometries and software have promoted the use of such supple geometries and homeomorphisms. In fact, the diagrammatic strategies followed by Eisenman since the mid '90s could be, in most cases, considered as topological transformations (Figs. 9, 10). It should be noted that, without the previous analytical use of diagrams that Eisenman commenced in 1963 for his dissertation, under the supervision of Colin Rowe (Eisenman 2006), together with the extensive use of this kind of graphic notations for his houses in the '70s, this deep transformation in the use of diagrams might not have been accomplished. His project for the *virtual house* (Fig. 9) is an extraordinary example of the use of *transformative* or *topological diagrams* in architecture.

Such generative and transformative capacities of diagrams to become a potential architecture hinted within them is certainly one of the most extraordinary possibilities of diagrams considered as a design strategy. As Allen has stated, "a diagram is not a thing in itself, but a description of potential relationships among elements, not only an

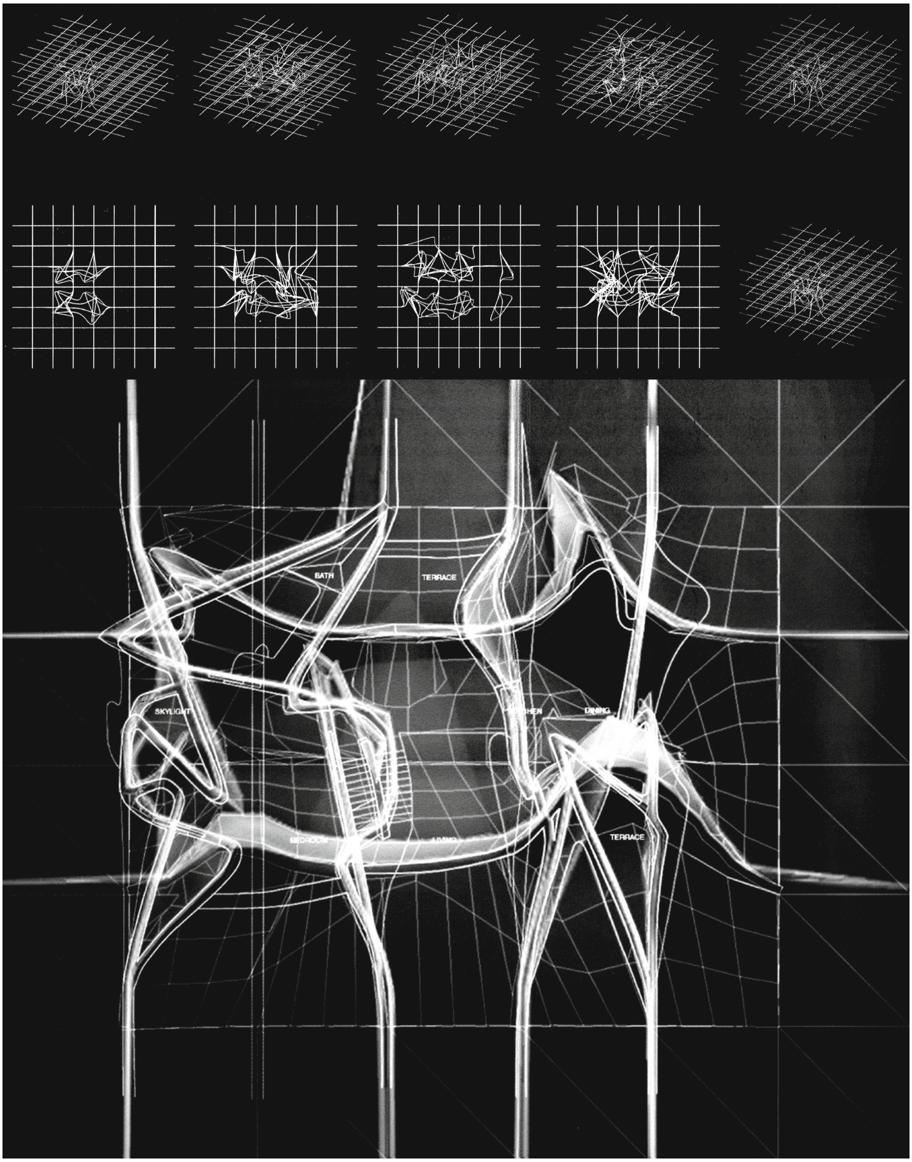

Fig. 9. Peter Eisenman. The Virtual House, ANY competition 1997 (use of generative diagrams). "Use of the notion of the virtual in architecture risks literally materializing the immaterial. Therefore, one needs to address the productive making, or the condition of the virtual within architecture, in order to allow architecture to question traditional ideas of form and space." (courtesy Eisenman Architects).

abstract model of the way things behave in the world but a map of possible worlds" (Allen 1998, p. 16).

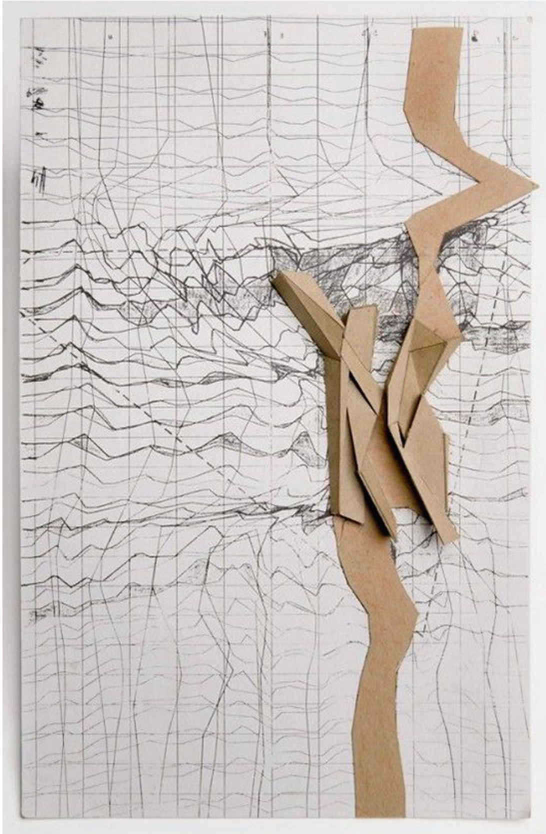

Fig. 10. Peter Eisenman. Study models for L'Huei Library, Geneva, 1997 (use of generative diagrams and physical model extracted from them). Note the different grids and diagrams superimposed -including an alien diagram to site or program which works as an external agent, almost a Deus ex machina (Eisenman 2007, p. 59)-, all of which collaborate in obtaining the final result (courtesy Eisenman Architects).

Nevertheless, most interesting to this research is Vidler's consideration of Eisenman's work as a "late-modern critical and ironic investigation of the Modernist legacy" while attributing the diagrams to be "a device to both recall and supersede its formal canons" (Vidler 2012, p. 55). To a certain extent, this sentence may well serve as a closing statement with regard to the ambivalent analytical and generative potential of diagrams.

5 Conclusions

This research attempts to reveal why diagrams can still be regarded as useful tools in contemporary architectural design as much as they were in disciplinary practice in the past.

The synthetic potential of diagrams to embody architectural order together with the topological relationships between architectural space and the physical limits that build it up make of diagrams a powerful design tool.

Accordingly, they are suitable for professional practice as well as for teaching purposes; they are a graphic compositional resource that students should be familiar with, especially in their first courses.

Surprisingly, the utility of contemporary generative design diagrams is not based on regularity as it was in the past when Durand inaugurated their use. That is another reason for their contemporaneity.

Grids and, consequently diagrams too, do not necessarily have to be regular and arise from the repetition of simple rhythms, nor do the lines that conform them have to be straight.

Early modern and modernist architects have made use of grids and diagrams alike. A possible connection between Sullivan's diagrammatic ornament design methods and Wrights' design practice can be established, but in the case of the latter, it could be also extended to his own architectural *organic* approach, something that needs further research attention.

D'Arcy Thompson devised a diagrammatic method to graphically explain the anatomical evolution of animals making use of *topological diagrams* which allow him to represent morphological transformations.

D'Arcy Thompson's graphic conception of diagrams can be considered *transformative* rather than *analytical* or *generative*. This potential has been embedded in design software and is being used in digitally disruptive contemporary architecture.

If we observe some of Eisenman's projects from the '90s onwards, it can be observed how the intrinsic directionality of the grids -despite its irregular interstices- allows to structure an architecture that arises from the potential of order embodied in these versatile graphic instruments that we can regard architectural diagrams as.

Throughout his long professional practice, Eisenman can be credited as one of the pioneers in the use of the three types of diagrams we have tried to differentiate in this research: *analytical*, *generative* and *transformative*.

To summarize, generative diagrams are neither drawings nor graphic schemes, they are abstract machines for architectural ideation. They possess an ambiguous status in between being and becoming, mediating in a certain way amid form and matter. They prefigure what the design could be but with a degree of openness that makes of them a supple and powerful mechanism to unfold multiple paths in the design process.

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