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AN ARCHAEOLOGY OF THE PRESENT:
Topo-geometric Properties from the Invention of Geometrical Notation to Non-Standard Variation in Architecture and Design

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ABSTRACT

As digital technologies revolutionise the ways in which buildings are produced there is a growing risk for architecture to become a practice without a theory. Space syntax has contributed to architectural research, through the description of systematic relationships between patterns of use and spatial phenomena. Yet, in the last three decades it has primarily leaned towards a theory of the city[1]. These are studied as the collective products of society that are either self-organising (cities), or operate independently of the agency of their architects (buildings). Yet, from the viewpoint of architecture as a social discipline, there is a need to describe buildings and their relationship to the city not simply as the emergent products of society but also as products of design. This type of study requires theories and tools that describe topo-geometric properties, or the interaction of spatial with geometrical patterns. It also needs to combine historical research with morphological analysis. In this paper I explore the relationship between topology and geometry through three key periods of Western architectural production: first, the classical invention of geometric notations in architectural drawings; second, the shift of emphasis by modern architects to movement and visual information, freeing architecture from constraints of axial geometrical planning; finally, the end of geometric and notational limitations on the variability of forms with the rise of digital technology. Rather than providing a comprehensive account of architectural design, this paper aims to understand the morphological traditions from which contemporary architectural spaces and forms derive. I argue that as much as space has been a silent instrument in architectural discourse, so has geometry been a silent conductor in Hillier and Hanson's theory of spatial configuration. Aside to tools for topo-geometric analysis, we need theoretical accounts of the ideas we 'think with', bringing space syntax and contemporary architecture into the historical and morphological tradition.

KEYWORDS

Geometry, topology, movement, visibility, non-standard variation, algorithmic design

1 Buildings are also studied using space syntax theory and tools but no systemic understanding of buildings exists across a wide range of building types. Further to this, the study of buildings has moved away from the early attempts to build an internal theory of architecture through a clear understanding of the difference between architecture and building. As such, seen from the perspective of architecture, most building studies using space syntax fall into the realm of the normative, recycling old concepts and methods of analysing.

1. INTRODUCTION: THE INVENTION OF ARCHITECTURAL NOTATION

Geometry was always present in architecture but the conscious employment of it goes back to the Renaissance, where through intensive studies of ancient structures and influential patronage, architects, such as Leon Battista Alberti, Sebastiano Serlio and Andrea Palladio established architecture as a discipline separate from artisanal inherited traditions. The purpose was to raise it to an intellectual activity, conversing with learned men, poets, philosophers, and literati. Alberti advises architects to conceive the design in the mind, and revise it many times before building. Once revisions finish nothing should be altered for the better or the worse (1726). Alberti produced the first architectural treatise of the Renaissance, but it was un-illustrated and written in Latin. It was Serlio (1475- c. 1554) who pioneered the use of high quality illustrations to supplement the text, which was written in Italian (1611). Illustrations and the discovery of the press spread the influence of these books in the Western world. While previously architects had to travel in order to study ancient ruins, books brought to them the treasures of antiquity in an illustrated volume. Particularly pocket size books, like Palladio's guide book to the ancient sites of Rome, helped spread classical architecture and paved the road for its revival.

More importantly, it was orthographic projection, the use of techniques to survey existing fragments and generate plans, sections and elevations that led to the design of classical buildings. Until the emergence of digital architecture in the late 20th century, orthographic projection has been a method of representation in drawings and books, a tool for collecting data about buildings and finally a method of design. Raphael described the method of surveying and designing through scaled drawings as follows: *'...you should draw always measuring everything with the scale, and use a line that equals the width of the base of the entire building. From the central point along this line, draw another straight line that makes on either side two right angles; this will be the centre line of the building. From the two extremities of the width line draw two parallel lines, perpendicular with the base line; these two lines should be as tall as the building is to be. Between these two lines, which make the height, you should then measure off the columns, the pilasters, the windows and other ornaments drawn on the front part of the building. And do all this always drawing the lines from every single extremity point of the columns, pilasters, openings, or whatever else, such that these lines are parallel to the lines at the extremities'* (Hart and Hicks, 2009: 186).

Rafael further goes on to describe how the elevation (exterior wall) and the section (interior wall) are derived from the plan. Corresponding parts are joined with parallel lines, which are the conservers of true measure. These lines are considered to be representations of light paths with the source set at infinite distance. *'...the interior wall shows the inside of the building – half, that is, if cut down the middle....In short, with these three orders or styles, it is possible to consider in minute detail all the parts of any building, inside and out'* (ibid.). This method of drawing was essential for the building to be constructed on true measures. But it was also the method that created space. As Robin Evans explains: *'...architectural space would remain, one way or another, limited by and bonded to the pictures that normally gave access to it...projection was an extra ingredient grasping more or less cautiously at the imaginary space behind the three drawings...'*. Evans continues: *'if the side you see is the mirror image of the side you do not see – if, that is, the building is symmetrical about the sectional plane – you see it all through one cut...Vertical, bilateral symmetry is economical within the confines of the technique...A centre line projected through the cavity easily converts into a processional axis. Then the axial route will show up on the principal elevation as a principal entrance, thereby converting the simple, binary equality of left and right sides (a-a) into a tripartite, therefore hierarchical, centralised symmetry (a-b-a)...This is why in most classical architecture design and building are in a near perfect accord'* (1995: 118-119). Another way of saying this is that the building as three-dimensional physical space was an identical scaled copy of the design (Carpo 2007).

2. IDENTITY: ISOMETRIC INVARIANCE BETWEEN DESIGN AND BUILDING

The invention of geometrical notations provided - like an analogue algorithm - instructions for producing a building, as well as for experiencing it from the inside. We can illustrate this by looking at Palladio's Villa Rotonda (figure 1). The most integrated positions in the Rotonda are situated in the circular hall, drawing to themselves pathways and views through the entire building. All systems of spatial relations, such as physical elements, lines of movement and sight obey the same laws of invariance. All registers of symmetry correspond with each other so that when viewers move in the villa, geometry conditions their vision, movement and appreciation of the relationships between the parts and the whole. The transformations of visual fields, expressed by the way in which the angles and radials of visual polygons (isovists) change from space to space are symmetrical along the axes of movement. At the same time, views are symmetrical from symmetrical positions (figure 1). Aligning the geometrical axes with the processional axes, as Raphael advised, has the effect of geometrically controlling the variability of views, so that the whole building can be experienced as a stable image.

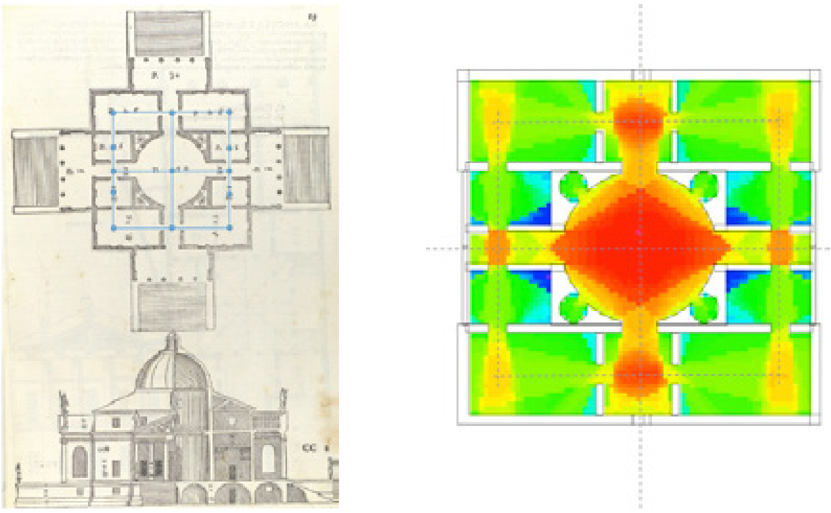

Figure 1 - Villa Rotonda, graph (left) visual integration (right)

Group theory is the branch of mathematics that describes symmetry as the properties that remain invariant under a transformation. In terms of geometry, the Rotonda has six symmetry transformations: reflection on two axes, and rotation on 90, 180, 270 and 360 degrees. In terms of graph structure, the four entrances are symmetrical to each other with respect to the central hall, and the outside, while each of them is asymmetrical in terms of their relationship to the central space; the spaces next to the entrances are symmetrical to each other with respect to each entrance, and so on. Geometrical symmetry and graph symmetry therefore, have the same registers of invariance, creating an isometric correspondence between the building and the design.

Palladio was aware of the difference between built forms and designs, manifested in his exceptional capacity to respond to site and functional problems with elegant solutions (Ackerman 1966). This is evident in his project for a pallazo in Venice in comparison with an ancient house he published in his Four Books, or his *Teatro Olimpico* seen alongside the Roman theatre by Vitruvius (Palladio 1570). Both designs were adjusted to the irregularity of the site conditions. Yet, in *Four Books* Palladio presented an idealised view of architecture, eliminating all adjustments of size and proportions necessary to address the realities of the physical fabric. This marked difference was in effect an outcome of the erudite climate of the period. Architects had to demonstrate to their learned patrons that they practiced architecture as liberal art, concerned with the abstract comparative understanding of architectural types, mathematics and proportions, and not as mechanical art without erudition. The ideal geometries of Palladio in his *Four Books*, demonstrate that he must have followed Alberti's advice to architects, arguing that the design, in essence an informational model, was the product of the author conceived in the mind. The building on the other hand, was an identical copy of this product. In artisanal practices it is the other way around. Artisans and craftsmen 'inherit' 'designs' from existing building practices that survive the test of time and by word of mouth.

If the Renaissance artefact was designed as a microcosm of the universe, and the universe had mathematical origins (Wittkower 1971), the architectural creation had to provide the union between mathematics and the world of the senses. Identity is a special property that defines a symmetry group in mathematics, where a thing can be superimposed upon its image through an isometric relationship of sameness. The classical system of notation established a relationship of identity - or sameness - between geometry and space, or between the design and the building. This type of relationship between the two 'worlds' caused the spatial to emerge from the flat surface. Captured through geometry, the properties of space in architectural theory have since remained an *active* but silent partner.

3. VARIABLY STANDARD: GEOMETRIC CONTROL VS. VARIABLE SPATIAL FORM

Palladio's ideas travelled to the West in the 17th century, giving rise to English and American Palladianism. In the 19th century studies of classical architecture using the generative potential of taxonomy and classification were produced by Jean-Nicolas-Louis Durand (1760-1834) in his *Cours' d' Architecture*, a highly rationalised encyclopedic survey, consisting of formal schemata that are literally empty of any specific content (1805). The approach was rejected by the avant-garde architects in the 20th century, following ideas of organic evolutionary typology, based on studies such as those by D'Arcy Thomson (1860-1948). Yet, as Frampton has recently argued, there were three conflicting paradigms that shaped modernism: the technological, the classical, and the vernacular (or the organic) (2016). The first paradigm was about the impulse to use the technological methods of the period. The second one was a normative standard embodying a rational and international design culture. The vernacular model derived its strength from organically grown built examples and from regional building culture.

The first 'modern' architect before the modern movement was England's John Soane (1753-1857). In Lincoln's Inn Fields, Soane built incrementally a house that challenged the isometric invariance between design and building. The distribution of visual integration captures the grid-like geometry of Durand's system, but the axes of symmetry are broken and the enfilade sequence of rooms, usually arranged in perspectival recession in Classicism, is distorted. The axes of movement correspond neither with geometry nor with the axes of sight (Psarra 2009). Compared to the villa Rotonda, visual fields here not only have more variation in terms of shape, but also greater degrees of transformation along with movement (figure 2).It was Le Corbusier

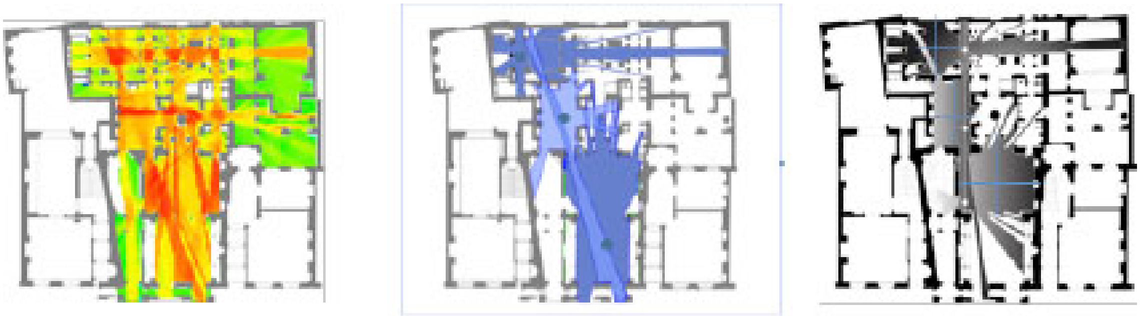

Figure 2 - Soane's Museum; Visual Integration (left); Isovist from points along axial line; Isovists and geometry of room enclosures

who intensively engaged more than any other architect with the organic, modern and classical models. In 1964 he published a site plan of his design of the Venice Hospital in his *Oeuvre*, showing the hospital behind the train station together with a selection of other buildings in Venice (figure 3). The drawing links the project with Palladio's San Giorgio Maggiore, via the Grand Canal dotted by Pallazzi, the Rialto, the Merceria and the Piazza San Marco. Le Corbusier had always aspired to design a public building in Venice comparable in scale and impact to that of Palladio's convent, the grand piazza and the Ospedale Civile. In his *Four Books*, Palladio described the convent as intended for the recreation of the 'houses of the ancients' (ibid.). Thus, the march from the service yard to the embellished front of the city and to San Giorgio

Maggiore in this map expresses Le Corbusier's heroic entrance to the legacy of architecture since Roman times. However, the link with Palladio's convent and church is not simply because Le Corbusier measured himself against the classical architect. It is also because he was aware of the disciplinary roots of architecture with its emphasis on mathematical literacy and geometry. It is in Venice that the first translation of Vitruvius was published, and it is in Venice and the Veneto where Palladio had practiced. Le Corbusier positions the hospital not only in the urban context, but also within the disciplinary tradition of structured architectural knowledge, rooted on classical humanism and against the organic context of Venice.

Figure 3 - Le Corbusier Site Plan of Venice

same time, he had absorbed other influences for the project: first, ideas of organic growth and evolutionary design that were prevalent in the 60s. Second, the urban structure of Venice based on interconnected squares, the separation and intersection of the two networks of movement, that is, canals and pedestrian pathways (Psarra 2011, 2013.) Third, the pin-wheel pattern, a schema that preoccupied him throughout his career. This pattern goes back to the *Villa La Roche* (1925) built for a wealthy client to house his painting collection. This is the house in which Le Corbusier invented the architectural promenade, guiding the visitor through changes of direction along ramps, stairs and raised pathways. In contrast to the axial structuring of movement through similar rooms in classical architecture, he used a twisting course of movement, covering heterogeneous elements. As opposed to geometry shaping human movement, he employed human empirical movement to shape the building.

But it was at the time he was designing the Villa Savoie (1928-1931) that the combination of a simple Platonic volume with a turning path shows up as the first instance of a career long paradigm of designing (figure 4).. At that time he was collaborating with Paul Otlet (1868-1944) on the Mundeneum (1929). Otlet was a significant figure in the history of information society and the networked knowledge base of the future The Mundeneum was intended as a place that would provide access to the world's knowledge. Otlet envisioned a 'city of knowledge' that would serve as a central repository for the world's information. The World City was a utopian vision, which like a universal exhibition would bring together all the leading institutions of the world. It was formed as a giant circulation ramp into a ziggurat-shape to test the spiral idea at a monumental scale. The two schemes, one domestic (Savoie), the other public (Mundeneum) were worked in parallel, combining the simple volumetric form with the pattern of twisting movement.

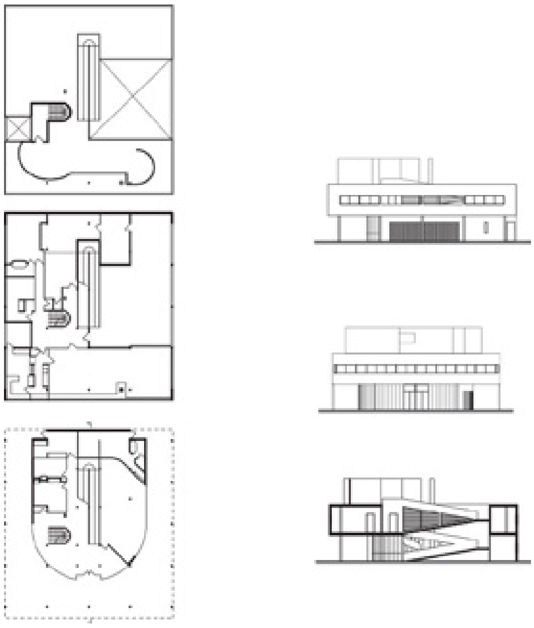

Figure 4 - Le Corbusier, Villa Savoie.

In the design for the Museum of Contemporary Art (1931) Le Corbusier shaped the whole building as a continuously unfolding wall. The museum is entered through an underground passage and is without façade, absorbing the exterior into the interior. A few cuts are made in its surface to allow the visitor to step outside the fixed itinerary and circulate in different ways. In 1936 he used the pinwheel pattern again in the Centre for Contemporary Aesthetics. In 1939 he used the same design theme in his designs for the French Pavilion in San Francisco and the exposition in Liege. The same year marks the Museum of Unlimited Growth in Algeria, in which the future expansion of the museum is based on a spiralling pattern indicated on the ground around the simple box-like form of the building. The rotating path is combined with a central void and four spaces, each on a different side of the volume, defining the pinwheel schema of composition. Le Corbusier used this schema in 23 designs of different scale and social programme, from museums and exhibition spaces to villas, including the monastery of La Tourette (figure 5)[2]. Why was he preoccupied with this schema so consistently and what impact does it make.

2 It turns out that with the exception of the period of the Second World-War, there is no more than a 3-year gap to the start of a new project that involves the spiral-swastika pattern. Total of 23 projects between 1923 and 1965. 1. Villa La Roch-Jeanneret 1923 2. Villa Meyer 1925; 3. Mundaneum 1928; 4. Museum of Contemporary Art 1931; 5. Bata Boutique, 1935;

6. University Campus Rio de Janeiro 1936; 7. Centre of Contemporary Aesthetics 1936; 8. Pavilion des Temps Nouveaux, 1937 9. Museum of Unlimited Growth , 1939; 10.French Pavilion in San Francisco, 1939; 11.Exposition Habitat 45, 1945; 12.Urban Development, Saint-Die, 1946; 13.Exposition Synthese Des Arts, Porte Maillot, 1949; 14.Cultural Centre of Ahmedabad, 1951; 15.Tokyo Museum, 1959; 16.Etude d'urbanisation, Meaux, 1957; 17.Le Couvent de la Tourette, 1950; 18.Museum at Chandigard, 1959; 19.Cultural Centre Chad , 1960; 20.Museum of the Twentieth Century, Eisenbach, 1963; 21.Museum of the Twentieth Century, Nantere, 1965; 22.Musee de lotissement undated; 23.Venice Hospital, Venice, 1965

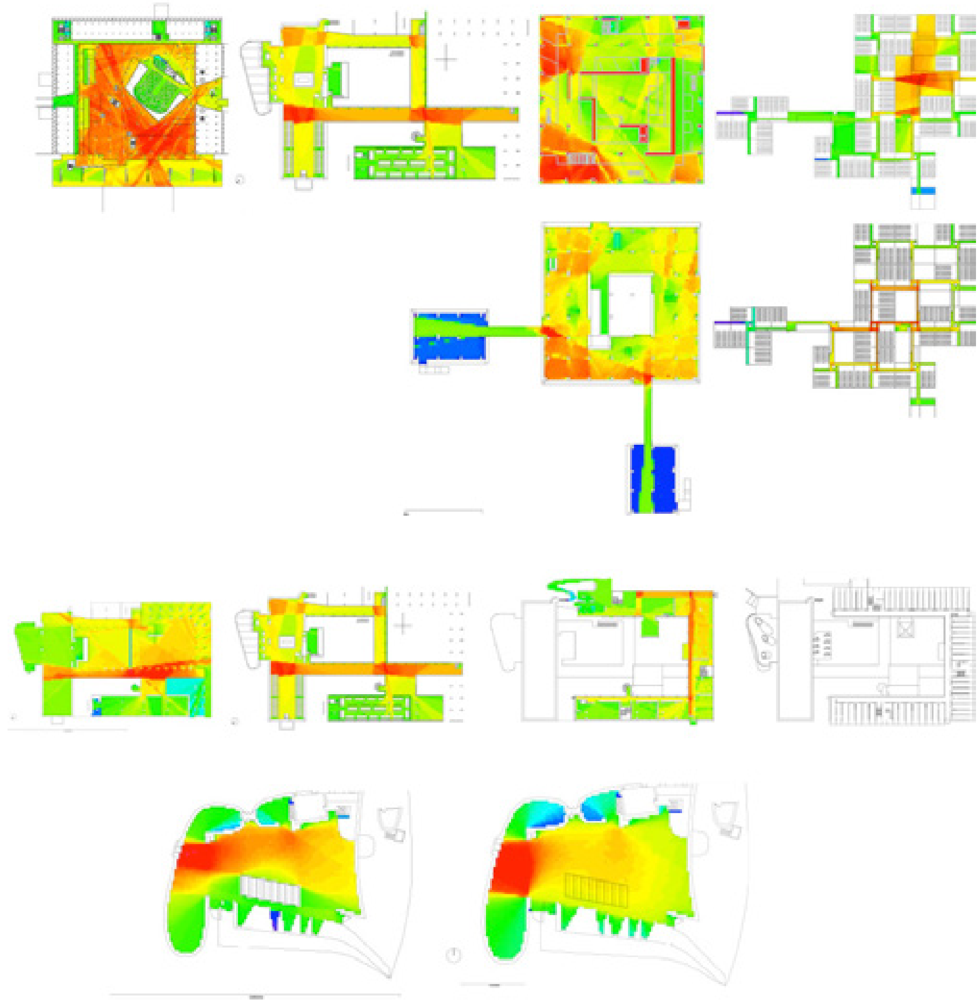

Figure 5 - Le Corbusier's Assembly at Chandigarh (top row left); La Tourette, (first row second left), Tokyo Museum (top row second right); Venice Hospital visibility integration (top row right); Cultural Centre at Ahmedabad, permeability Integration (second row left); Venice Hospital, permeability integration (second row right); La Tourette, ground floor (third row left); La Tourette, first floor (third row second left); La Tourette second floor (third row second right); Chapel at Ronchamp with furniture (bottom row left); Chapel at Ronchamp without furniture (bottom row right).

We can explore answers to this question in three projects, the only ones which were constructed based on the pinwheel scheme: the Tokyo Museum (1959), the Museum of the Cultural Centre at Ahmedabad (1951) and the Chandigard Museum (1959). As with the Rotonda, in the Tokyo Museum there are four such axial connections, linking the central space with the exterior (figure 6).Contrary to the Rotonda, these axial elements travel along the perimeter of the central hall rather than traversing the hall, which is placed at the geometrical centre. In addition, seeing the central hall is different from accessing this space, since there is a break in the classical link between visibility and movement. We see here the clear impact of inserting an object at the centre of a layout and pushing the values of integration to the corners of the space (Hillier 2003). Looking at the graph of the main spaces, we see that there is graph symmetry only with respect to space 1 – at the end of the ramp – which is off the main axis. In the classical model of composition there are usually more spaces that have graph symmetry in relation to other spaces, while at the same time the space with the highest value of integration is at the geometrical axis of the building (figure 1). Compared with the Rotonda, where there is isometric correspondence between geometry and space, the Tokyo Museum is a clear case of invariance between the two kinds of properties.

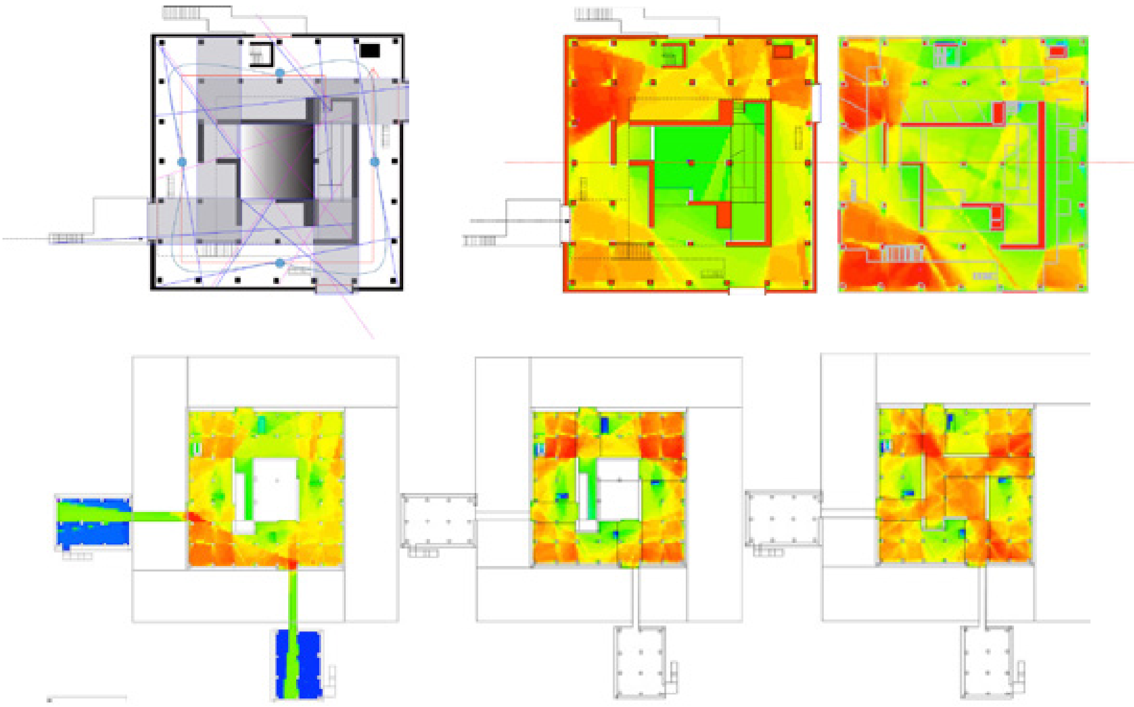

Figure 6 - Tokyo Museum. Axial lines of visibility and permeability (top left); Permeability visual integration (top middle); Visibility visual integration (top right); Cultural Centre at Ahmedabad; Permeability visual integration with pavilions (bottom left); Visibility visual integration (bottom middle); Permeability visual integration (bottom right)

Developed over thirty years of architectural activity the pinwheel pattern became for the Swiss architect a standard independent form, producing different variations on a theme, based on the invariance between geometry and the topological graph of a building[3]. There are three main mechanisms through which invariance between these two systems is generated: first, two-fold or four-fold symmetry in relation to the outer envelope and the central space; secondly, rotational symmetry articulating the relationship between the central space and the adjoining galleries, pathways or openings (the pinwheel plan); thirdly, placing a void at the centre and screening it from the rest of the layout, so as to disassociate the structure of views from the structure of movement.

Le Corbusier dismissed the Beaux-Arts approach to composition, which is appreciated on axis as anachronistic and dogmatic. Yet, he had a clear understanding of the strategies by which the close association of moving and viewing was achieved in classical buildings. He used long axes to organise a plan but in a way, which created variable rules, in the sense that what is invariant in one system is not the same with that which is invariant in the other. The spectator produced by this architecture shifts course with movement while exploring vistas that develop along different directions, but is always in reference to the classical logic of geometrical composition.

Freeing the various systems of properties from each other, or breaking the isometric invariance between geometry and space was a strategy that was widely adopted by modern architects. Many buildings seen in figure 7 use geometry simply as a supporting armature, rather than as a generator of the design. Invariance across systems is nonetheless, present in buildings by 'classical modernists', such as Terragni' Casa del Fascio, Mies' Crown Hall, Tugedthat House and Farnsworth House; Aldo van Eyck's church and Asplund's library in Stockholm. The nordic classicism of Asplund's library (figure 8) is particularly interesting when seen in relation to Palladio's Rotonda (figure 1) and Le Corbusier's Assembly in Chandigarh (figure 8), where a similar U-shaped geometry surrounds a main space with a circular chamber. However, although

3 The scheme of rotational symmetry through the swastika plan finds realisation even in his religious architecture, if for example we look at La Tourette and the three entrances in Ronchamp.

the three projects have a similar *parti*, their spatial systems are entirely different from each other.

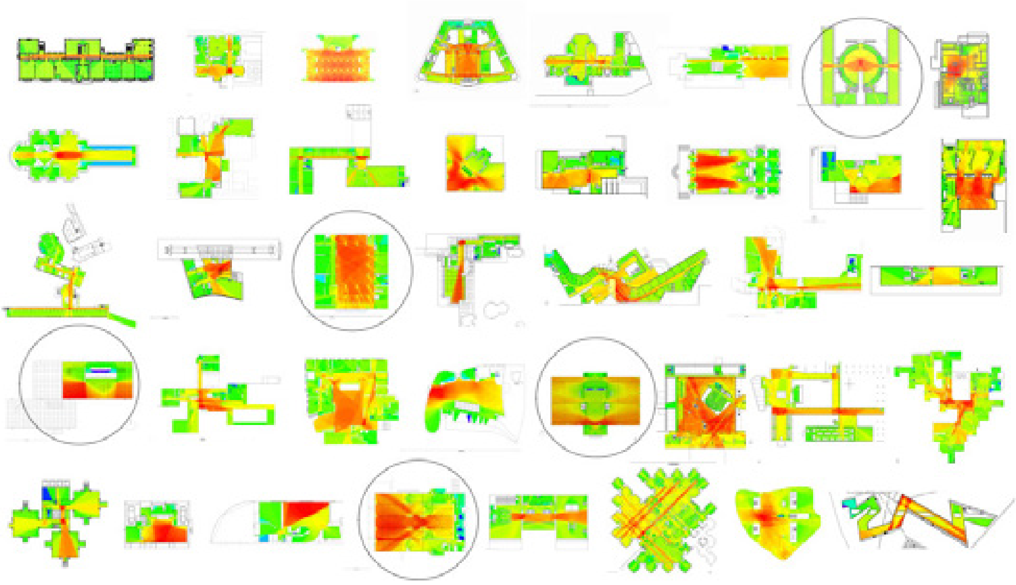

Figure 7 - Visual integration in a collection of 20th century modern buildings; Asplund Library, Stockholm, (top right - in circle); Terragni Casa di Fascio (third row - in circle); Mies van der Rohe Farnsworth House (fourth row left - in circle); Mies van der Rohe Crown Hall (fourth row middle – in circle); Aldo van Eyck's Church (bottom row – in circle)

As with Palladio who influenced modern architecture, the use of geometry and space by these early modern architects affected contemporary architectural practice. A key reference is Mario Botta's domestic architecture, using isometric invariance between geometry and space within the principles of tripartite composition, front and back distinction and the confines of the Platonic solid. Another reference is Rem Koolhaas' Kunsthal as a square volume perforated by two intersections, a road and a pedestrian ramp, and a continuous spiralling circuit of interior space that covers different spaces and programmes[4]. Another clear case is Herzog and De Meuron's De Young Museum in San Francisco (figure 9). The architects have used the corporeal geometry to inform the incorporeal geometries of moving and viewing. The building seems to gather all the elements of a Beaux-Arts Museum: an open courtyard, a tower, a grand staircase, a portico - and reassemble them in a new fashion. The reference of the building to the Baux-Arts is made evident by the analysis. In a manner that is reminiscent of Durand's axial grid-like composition, the pattern of integration picks up the axial lines of the building geometry, but replaces orthogonal geometry with an oblique system of geometrical planning. Contemporary architecture therefore, is still choreographed by the lines of sight and movement of the body.

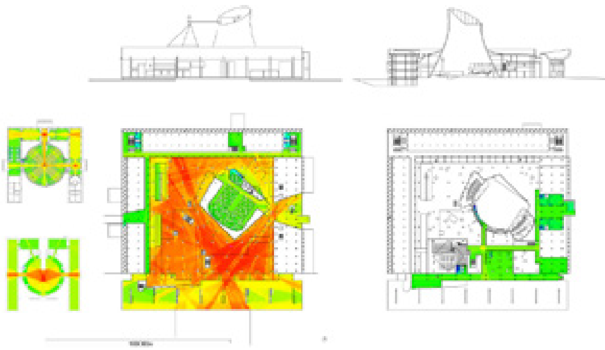

Figure 8 - Asplund's Library and Corbusier's Palace of the Assembly

4 The Kunsthal does not rely on isometric invariance between geometric and topological properties, but uses the idea of the promenade inside an orthogonal geometry.

4. NON STANDARD VARIATION

Traditional drawing was an additive process. The consistency and the essential associative relations between plan, section and elevation, between one element and another, between geometry and space were managed by the designer during the process of design. Raphael's method of orthographic projection guaranteed exactly that. Geometry was the practical, conceptual and intellectual network of associations needed to establish internal coherence. CAD software simply translated this additive logic within the digital realm. This means that even though geometry and space in modern architecture were decoupled, there were by and large no changes in terms of notational tools (plans, elevations and sections) or the strict repertory of orthogonal geometrical forms until the rise of digital technology.

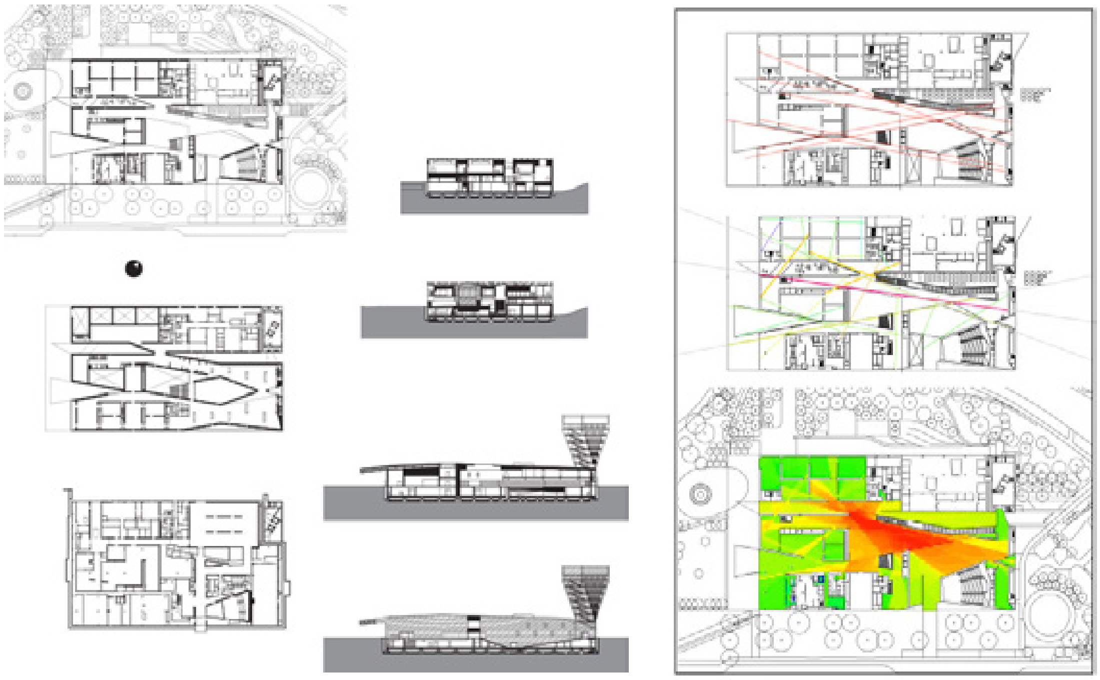

Figure 9 - Herjog and de' Meuron, De Young Museum.

Over the last decades, digital architecture has led to interactive algorithmic models based on associative logic, responding to variations in the design input by manipulating the entire system. '*They have already made it possible to envisage a continuous design and production process where one or more designers can intervene, on a variety of two-dimensional visualisations and three-dimensional representations (pint-outs) of the same object, and where all interventions or revisions can be incorporated into the same master file of the project*' (Carpo, ibid.). For Carpo, '*under the former dominion of geometry what was not measurable was not buildable. Now all that is digitally designed is, by definition and from the start, measured, hence geometrically defined and buildable... today's designers are not working on notations of objects but on interactive avatars of the objects themselves*' (ibid.). Further Deleuze and Cache's description of the 'objectile' defines design as an algorithm rather than as an object, a parametric function which may determine an infinite variety of objects, all different yet all similar as the underlying function is similar to all. Similar to Hillier and Hanson's notion of the genotype in the beady ring settlements, producing endless phenotypical variations of the same model, the objectile can be collaboratively manipulated by designers resulting in a series of non-identical elements. Carpo explains that together with the demise of geometrical notation there is no longer the Albertian author of identical mechanical copies (ibid.).

The invention of the digital not only enabled design to operate directly on three-dimensional coordinates, but also provided a vast repertory of forms freed from constraints imposed by buildable geometry. Yet, although orthogonal geometry, notations and the limitations they impose on formal variability have gone, geometry and its essential link with space are not gone. Even when a building is not aesthetically revealed by spatial exploration, it still embodies relationships of geometry and movement. Design software can produce different formal outputs through inputs that affect the geometry of objects, but the impact of geometry on space outputs is still in the blind spot, still in the shadows of these data, components and node diagrams. It is here where the theory and method of space syntax can contribute, linking geometry and space, generative and analytical approaches to design. Prior to discussing the input of space syntax, it is important to explore what the appropriations of space and geometry discussed here mean for architecture.

5. TOPO-GEOMETRIC PROPERTIES

Tracing morphological paradigms, I explored how geometry influenced the development of architecture as liberal art concerned with conscious design. By foregrounding a geometric world of conceptual intelligibles, geometry in Classicism established an identity relationship between design and building, geometrising spatial structure (which in the three-dimensional world is understood through moving and viewing) as a stable image. By externalising spatial relationships, it made spatial and symbolic messages more pronounced. The technological invention of the structural grid in the twentieth century lifted geometric constraints imposed by load bearing partitions. Freed from geometric limitations, modern architecture established variability in the relationship between geometry and movement.

Yet, in spite of different approaches, the complex relationship between geometry and space facilitated translations from one programme to the other, including from cities to architecture in both periods. Le Corbusier used the pinwheel scheme in public and private commissions, in different sites, programmes and cultural contexts. Many of his museums were incubated in his domestic architecture through the most private commissions. In *Un Maison - Un Palais* (1928), in which he expressed the extension of his ideas from the private house to public buildings and urban spaces, the villas became prototypes for a universal way of living, and the museum a prototype for the city[5]. Influenced by Alberti, Palladio also believed that a building is like a city. His villas and churches were based on his studies of Roman baths, which he interpreted as indoor miniaturized cities, theatrically framing space from the scale of the apse to the house and the landscape. Is it the trans-nationality of these projects, the expansion from the house to the scale of the museum, the hospital and the city as a whole, the intersection of social programmes that are functionally very dissimilar peculiar to Palladio, Le Corbusier and Mies or to the other contemporary architects?

For Beatrice Colomina domesticity has been the real source of modernity in Le Corbusier and Mies' museums (2009). I argue that the roots of modernity reach back into the villas of Palladio in which the pattern of interconnected rooms and their flexible use diffuse the boundaries between the house as a space for private living and the house as art gallery, performance space or theatre. In effect, Le Corbusier's application of the pinwheel plan across different building types and the translation of Venice's spatial structure in the Hospital reveal that these architects invested on generic properties of geometry and space over and above the functional programmes of house, museum, hospital or urban space.

In a building that is like a house, a museum and a city, functional demands imposed by site and social programme are just one filter among others. Without circumventing functional requirements, these architects were concerned with crafting geometry, space and exploring their limits in different frameworks of functionality. The relationship between these programmes and between the building and the city were based on topo-geometric properties that are common to all. By interfacing generic relationships related to urban space and architectural space, these architects extended over and above ontological and functional distinctions between functional building types, architecture and urban contexts. Topo-geometric properties of moving and viewing are shared among cities as multi-authored products of society and architecture as self-conscious product of design. If the former arise as the collective outcome of micro-economic activity and the reproducibility of culture, the latter are the result of conscious intentionality that recognises patterns common to all and translates them through creative invention.

5 Palladio A. (2002), The Four Books of Architecture, Cambridge Mass: The MIT Press.

Describing space as a topological relational field, Hillier's analytic theory has in the last four decades studied buildings and cities in relation to human activity and function. Hillier explains that geometry gets into the topology of the urban network, affecting through the intersections of street lines and the angles of their incidence their spatial structure (1997). However, in spite of extensive application in real projects, the theory of configuration treats architecture and cities solely as empirical objects, based on properties of embodied movement and vision from the ground. It does not take into account how architecture is conceived and produced, including the ways in which generic properties of space and form get into the topology of buildings and streets traversing these two worlds from within and without. If space has been a silent partner in architectural discourse, geometry has been a silent conductor in the theory of spatial configuration. For Hillier, the reason for this deficit is that the relationship between design and use passes not through geometry or form but the realm of space (1996). Yet, with a clear focus on how cities and designs influence one another as revealed by this analysis, the picture is more complex than the clear-cut split into analysis and design, architecture and cities, aesthetic and social practice. The study of topo-geometric properties should make it possible to explore buildings and cities both as the non-authored products of society and the authored products of design.

The examples studied here help reveal a genealogy of ideas around which the concerns of architects converge and the architecture as a discipline is defined. Architecture concerns critical commitment to comparative architectural knowledge on the part of an empirical historical architect, that is, a person endowed with historical consciousness (and an unconscious). Historical consciousness means that the fact that Palladio built before Le Corbusier, and Le Corbusier operated before Rem Koolhaas is as significant as the morphological exploration of their buildings. Comparative knowledge and historical consciousness establish an architect's place in history in relation to the available knowledge of ideas and tools that shape the discipline up to one's present, together with the possibilities and limitations for the future one's historical position enables and withholds.

If innovation and the creative imagination proceed from the intersection of possibility with constraint, the intersection of comparative knowledge and dependence on historical sequence brings us to the question of the imagination. At the beginning of this paper I argued that digital technology might reduce architecture into a practice without a theory. If over the centuries Eucleidian geometry was a platform of mediation through which space/building could be visualised and ideas would be linked to the three-dimensional material world, in computational design mediation between the thought process and the empirical object is abstracted through algorithms and scripting. In the former the cognitive processes that underline design establishing consistency relationships between parts are with the designer. In the latter, the designer produces an interactive digital model responding to variations in the input by manipulating the entire system, enabling to design a process rather than a single object. Lending ideas syncretically to the eye all at once, geometry enabled architects to link form to space, idea to building and intuition to logic.

Computational design can provide the scientific and philosophical exploration of design possibility and virtuality, extending and surpassing the designer's intellect. However, it needs to engage the relationship between geometry and topology rather than simply the mathematically generated styles of software engagement. It also needs to bring the abstract logic of computational design into the realm of principled understanding and the historical sequence of ideas that influence architecture and the imagination. The architectural imagination transgresses functional constraints, social programmes, ontological and historical categories by transferring generic properties across different domains, in ways, which enable one to make innovations and overcome constraints in a work. The principles of space and geometry are not just generic tools, but also the instruments of the critical faculties in architect's imagination. Abstract comparative knowledge and historical consciousness can raise space and geometry from silent instruments to the level of abstract comparative thought, towards a unitary theory of generation and explanation in architecture and the architectural imagination – towards an archaeology of the present.

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