The Didactic Aspect of Ars Combinatoria in Architectural Design

Employing syntactic (“space syntax”) formulations to communicate architectural design to students of Architecture.

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This paper presents educative aspects of visualization techniques based on an idea by B. Hillier to illustrate architectural forms with the space syntax theory. It explores and renders the technique of transformation and implementation of syntactic analysis in order to convey to students of Architecture spatial concepts and to differentiate spatial arrangements that present understandably similarities and differences. The technique is applied to plans of well-known examples from the history of Architecture and illustrates to a sufficient extent the theoretical interpretations taught in the architectural design studio.

Keywords: architectural configuration, design strategy, design analysis, shape evaluation

INTRODUCTION

In the studio courses of architectural design in National Technical University of Athens, we start by studying examples of architecture from a wide variety of buildings through history. Our purpose is to explore the ideas in architecture that transcend time and place. By using comparative methods, we are trying to investigate how architects in different epochs and diverse cultures struggled with similar or divergent spatial concepts. Because of the wide range of architectural sources in the course, it is important to carefully note the specifics of these examples so the students can understand the conceptual relations we draw between them. In this effort we use various transformational techniques that convert the architectural plans into diagrams that share a common characteristic denominator. Permanent pursuit of the teaching of architectural design is the formation of a coherent process of producing diagrams that will translate in the same way architectural plans by creating a common base of comparison. Very often various diagrammatic techniques lead to oversimplification and misleading ideas that should be avoided when explaining the roots of architectural solutions. This paper investigates a transformational technique that we employ to convey to our students spatial concepts and to differentiate spatial provisions showcasing in a comprehensible way similarities and differences. The technique is based on an idea found in Bill Hillier’s book “Space Is The Machine”. Hillier’s idea is to introduce the architectural plan first as a shape. “[...] It is clear that any shape can be rep-
resented as a regularly constructed mesh of cellular elements, or tessellation, provided we can scale the mesh as finely as we need. This can then be treated as a graph, and thus expressed as a pattern of universal graph distances. [...]” (Hillier 2007 p.80)

Hence Bill Hillier applies the syntactic analysis he introduced together with Julienne Hanson (Hillier, B. & Hanson, J., 1984) calculating “[...] the mean depth of each cell from all others, and express the results in a distribution of dot densities for the square elements in which the higher densities, or darker colors, stand for greater integration - that is, less depth - graded through to lightest colors for the least integration, or greatest depth.” (Hillier 2007 p.81).

Initially we found out in discussions with students during the course of the Architectural design that elucidated geometrical shape examples presented by Hillier in “Space is the machine” had an enormous acceptance by students.

**METHODOLOGY**

To investigate further B. Hillier’s ideas I developed software in the AutoLisp programming language, within the AutoCAD environment that allowed me to try out various configuration patterns in order to study the impact they had on students of architecture. Initially, the research began based on Hillier’s idea that any shape could be represented as a regularly mesh of cellular elements, or mosaics, that he called “tesselation”, provided we can weigh the mesh with the precision we need. During the first phase of the software development, the examples found in Hillier (2007) were repeated, indicating the central position of the structural analysis of the shapes, defining the normal shapes as configurations. The research, moreover, had the ordered task of trying to explain to young students differences between the shapes that trained architects understand almost self-evidently. In this context even trivial remarks, like centrality in a square shape comparing to a circular one, could be illuminated by Hillier’s example in a sense that the examples are illustrated marking the centre of a circle with the “highest integration, and that integration reduces evenly in concentric rings around the centre. In a perfect circle, all edge locations will have an identical degree of integration [...]”. In contrary in a square shape “[...] the pattern of integration not only runs from centre to edge, but also from the centre of the edge to the corners. The square form is thus more complex than the circular form in a simple, but critical way.” (Hillier 2007 p.81).

The introduction of an overlying shape that determined the calibration of the system quickly gained the interest of research by identifying different states of the shapes. This again after Hillier (2007:p90): “buildings are not pure shapes, in the geometric sense of free-standing forms in a uniform context, but oriented shapes, in the sense that they are oriented to and away from the ground on which they stand. If we take this simple fact into account in analyzing building façades as shapes then we easily find some very suggestive results. This can be demonstrated by simply standing shapes on a line, which we will call the ‘earthline’.”

![Figure 1](image)

Indeed, by studying Hillier’s examples, they established their importance for students to understand basic concepts taught in architectural design. For example, the square shaped building anchored to the ground reduces the original eight symmetries to a simple bilateral symmetry which is generally the understanding of an actual building in which someone distinguish the left-right symmetry but not the up and down one. (There are no recorded examples illustrating the up-down symmetry). Also the general impression we have for the shapes of the buildings. A breadth and long building is perceived as a building anchored to ground in opposition to a tall one that relates to the horizon and these ideas surprisingly disclosed to students in a particularly vivid way. Of par-
Particular interest was experimentation with the understanding of shapes and the regulating line which has the obvious property of drastically differentiating the distribution of the calibration in the shapes. For example, the 20X24 cells rectangle as shown in figure 2 since the introducing of the four regulating lines on its edges inverses the calibration values and exhibit as more integrated areas the edges instead of the center of the shape.

Figure 2
A 18X24 Rectangular Tessellation open and bounded with 4 regulating lines.

Figure 3
Barcelona Pavilion, designed by Mies van der Rohe. Tessellation analysis with out (above) and with regulating shapes.

Figure 4
Tesselation analysis of alternative Spatial arrangement (2 sofas in a rectangular room)(cell grid : 20 cm)

Extensive experiments with transformation of architectural plans in tesselation configurations enabled us to conclude the importance of the analysis once the technique of introducing the adjustment shapes to calibrate the distribution of integration values. Of primary importance in the calibration of differentiation of integration values was the decision to introduce the regulation shapes only as “calibration actuators”. Large-sized shapes joined with multiple cells gain de facto the higher integration values. At the same time, they raise the relative position of integration value of all the cells with which they are directly adjacent. Upon completion of the integration values calculation for each cell, the “calibration actuators” are removed from the list and the values are sorted by including only smaller cells. These transformations then illuminate the combinatorial aspect of architectural configuration exemplifying the assessment of well-known architectural plans (like the Barcelona Pavilion shown in fig 3) and identifying similarities between architect’s theoretical beliefs. In Barcelona Pavilion, designed by Mies van der Rohe, a 636 cell tesselation configuration by introducing a standard one meter grid, insertion of walls and pool shapes as regulating shapes gives a calibration that better describes the spatial qualities of the building. Unfortunately the pavilion was to be bare, with no exhibits, leaving only the structure accompanying a single sculpture and specially-designed furniture, thus it is pointless to investigate the functional aspects of the space. Nevertheless the open space in front of the central swimming pool appears better integrated with the right-over entrance, the entry hall is well integrated while the rest-room and the small pool are discreetly isolated. The technique allows a plethora of information regarding the architectural configuration to be exploded, introducing a differentiated pedagogical model to assist the teaching of architectural design.

COMPARATIVE ANALYSES
The transformational research using tesselations then passed into small layouts of domestic spaces. Thus we produced mappings of the syntactic values of different spatial arrangements producing visuals that enable students to differentiate similar spatial arrangements. In these spatial arrangements a set of basic elements, the shapes of the furniture of the room are combined with a tessellation of square grid
to represent the transition area in the room plan. Illustrating the integration value of different configuration (see fig 4) we were able to illuminate traditional theoretical notions that we were using in the studio during architectural education. Exploring key notions of these discussions that focus on the distribution of movement on a domestic layout, identifying non-discursive architectural ideas like symmetry-asymmetry, crowded-empty, bounded-unbounded etc.

After various discussions with students illustrating the properties of geometrical shapes we developed the idea a little further, and closer to everyday studio experience. We started describing by tiles of squares of a size 60 cm x 60 cm to get as close to a space occupied by a free standing man, the tiles had no overlaps and no gaps and at the beginning were simple configurations of functional layouts capturing important aspects of how they fit into everyday living patterns. We analyzed with the method of tesselation as described above many well-known buildings of modern architecture. Mostly houses where there was evidence of the placement of furniture by architects where the furniture marked the use of the premises. The main reason for the above option is the engagement of the furniture in the tesselation analysis defined as regulating shapes. In fact, the 60x60 cm grid defines the motion in the house and the presence of furniture constitutes the function within individual rooms. One of the houses analyzed is the famous Robinson House in Williamstown, Massachusetts designed by Marcel Breuer in 1947 (see fig 5). The house covered an immense expanse of land and features a design which interacted with the landscape which surrounds it. As the plan shows, the house features the binuclear design which Breuer became famous for. The bi-nuclear house encompasses separate wings for the bedrooms and for the living, dining and kitchen areas. These two main parts are separated by an entry hall. The house is single leveled, and the two wings connected by the halls are of two different shapes, a rectangle and a square. The rectangular area is smaller; it contains the garage and bedrooms. The square area contains the living spaces, which include the kitchen and dining area. Inside the living room, a dominant stone fireplace acts as the focal point. All sorts of established studio analysis like Solid-Void, Parti, Symmetry, Hierarchy, Regulating Lines, Center-Perimeter etc were applied with little success on defining a non-disputable argument as the suggested line of analysis. In contrary Tesselation analysis managed to recompile the designer line of thinking. Both the bi-nuclear de-
sign as diagrammatic starting concept and the hierarchy of spaces are vividly exposed in the diagrams. While the house is split into the two main areas, there are levels of enclosure within that. The main integrating core is of course situated in the entry acting as a bridge to public and the private areas of the house. It is surprisingly illuminative that the most of the well integrated areas of the house are those next to the public sitting areas and the living room situated in the bedrooms wing. Kitchen is also well integrated together with the invisible to the main living area access to dining room. If you exclude the northern bedroom, which does not have an exclusive bathroom, thus is connected to the main hallway and through the bathroom, thus gaining higher room integration values, all the other bedrooms are totally isolated, including the maids room that is next to the well integrated kitchen area. It is interesting to note the southwest corner of the living room which is isolated because the architect did not design any infrastructure for use. It’s a big empty space behind the fireplace-facing sofa.

An interesting analysis is accomplished from the comparison of the two types of apartment building built by Le Corbusier in Marseille. The design of Unite d’Habitation in Marseille establishes an innovative approach toward spatial organization to accommodate the living spaces. Le Corbusier designed the residential units to span from each side of the building, as well as having a double height living space reducing the number of required corridors to one every three floors. By narrowing the units and allowing for a double height space, Corbusier is capable of efficiently placing more units in the building and creating an interlocking system of residential volumes. Every three floors two long residencies interlock with opposite functional diagram. One unit with the entry from above has a small footprint dedicated to kitchen and dining and because of the void of double height space that overlooks downstairs has the living space placed within the main bedroom downstairs. The other interlocking unit has the entry downstairs with kitchen/dining and living with the main bedroom upstairs and the double height space that overlooks downstairs onto the living room. This is a challenging layout for all sorts of analytic systems of floor plans. The two types of apartments have shifted the central core of well-integrated cells. In the case of the apartment with the entrance below, the well-integrated area is located on the floor immediately after the climbing staircase and the corridor linking the three bedrooms. In the apartment type whose entrance is up, the central core is closer to the entrance and the dining room. The two oblong bedrooms of the children have different exposure to privacy as well, while the central bedrooms in both types are much less isolated than other classical privacy arrangements such as those of Marcel Breuer that we examined above. What is important, however, is that two apartments that students of architecture in principle regard as equals are completely different as to the degree of privacy they provide for tenants. This difference may be implied by the instrumental analysis launched by Bill Hillier and its development described above.

**DISCUSSION**

Bruce Archer in his article “The Three Rs” establishes that design belongs to a third area of human knowledge “[...] concerned with the making and doing aspects of human activity [...]” distinct from sciences and the humanities” (Archer 1979). He argues for the existence of a different approach to knowledge and of a different manner of knowing, (also in Archer 1979b), which differs from those in the sciences and humanities: “Where Science is the collected body of theoretical knowledge based upon observation, measurement, hypothesis and test, and the Humanities is the collected body of interpretive knowledge based upon contemplation, criticism, evaluation and discourse, the third area is the collected body of practical knowledge based upon sensibility, invention, validation and implementation. Hence, although introducing students to architectural design is a difficult task to be comprehensibly prescribed, researching into its mechanisms and functions provides the opportunity to test methods that enable students to
grasp spatial qualities and finally increases their sensibility in order to develop innovative design thinking. Bill Hillier from another point of view emphatically underlines that in the theory of architecture no idea is more seductive than that architecture is an ars combinatoria "[...] - a combinatorial art: the idea that the whole field of architectural possibility might be made transparent by identifying a set of basic elements and a set of rules for combining them so that the application of one to the other would generate the architectural forms which exist, and open up possibilities that might exist and be consistent with those that do. By showing architectural forms to be a system of transformations in this way, the elements and rules would be held to be a theory of architectural form - the system of invariants that underlie the variety to be found in the real world." (Hillier 2007 p. 216)

In this paper we underscore the shift from mechanistic pedagogy to systematic pedagogy in design studio by introducing a method of explicit transformation of spatial layouts in color-coded images able of conveying the differences discussed in the introductory seminars to architectural design. These transformations illuminate the combinatorial aspect of architectural configuration exemplifying the assessment of well-known architectural plans (like the Barcelona Pavilion shown in fig 4) and identifying similarities between architect’s theoretical beliefs. The technique allows a plethora of information regarding the architectural configuration to be exploded, introducing a differentiated pedagogical model to assist the teaching of architectural design.

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