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Visual Calculation Through Shape Grammar In Architecture

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Abstract - *Design is often perceived to be subjective, an inventive flash based entirely on one's intuition and free creative expression. To develop such intuition is often considered a big hurdle for an architecture student during initial years of graduation. Shape grammar which is a system of rewriting shape rules through mathematical computations can be considered as solution, as well as aid to the design students. In this research we have analyzed that Design process can be explained through a very objective approach rather than through subjective factors 'creative inspiration', the 'inventive flash', or 'individual genius' Shape grammars equip user with algebraic and graphic methods which are explanatory and/ or generative in use. Shape grammars allows intervention at multiple steps which helps in bringing subjectivity in the design process and helps in achieving a design which is truly unique and not a standardized module. Shape grammars allow us to overcome the organic nature of creativity and give design students and educators a way to make learning visible and concrete.*

Key Words shape grammar, visual calculation in design, formal methods, nonstandard shape algebras

1.INTRODUCTION

Although design education has been discussed widely as the traditional studio method, in which Students develop their design projects under the advice of an experienced architect-instructor, is still the prevalent system. The studio method has been described as a reflective conversation between a student and his coach. Computer-aided design in architectural courses has also had an influence on teaching and most schools are still searching for appropriate ways of balancing design activities between paper and computer. The traditional studio method does not provide the novice student with the tools and methods he or she needs to develop a design that is based not only on functional issues, but also on formal ones. On the other hand architectural education introduced as pure art, without regard to users and their needs, is also criticized.

This research introduces the shape grammar formalism as a generative system for the development of designs. Shape grammar one of the earliest algorithmic systems for creating and understanding designs directly through computations with shapes, rather than indirectly through computations with text or symbols.

2. SHAPE GRAMMAR

Shape grammars were introduced by Stiny and Gips in 1972. It is a set of shape rules applied in a step-by-step way to generate a set, or language, of designs. It gives designer the ability to show their design process and design rules by shapes rather than text. Shape grammar is spatial, rather than textual or symbolic, algorithmic. Shape grammar is a set of rules applied on initial shape to generate designs. The rules are designed to transform the initial shapes, so the user may decide which rule can be used to achieve the desired outcome. Since the designed shape may consist of different shapes, and there could be different rules for different shapes.

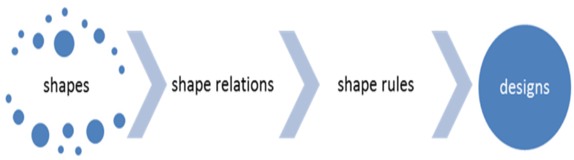


Fig-1: Stages in shape grammar design

Steps showed in Figure 1. are generally followed in the given temporal order, but the user has full control over each step and can make adjustment at any time as desired.

A shape is composed of a finite collection of labeled or unlabeled points, lines, planes, areas, or solids. A rule in shape grammars can be written in the form A→B,

where A and B are shapes.When this rule A→ B is applied, an instance of shape A is replaced with shape B.

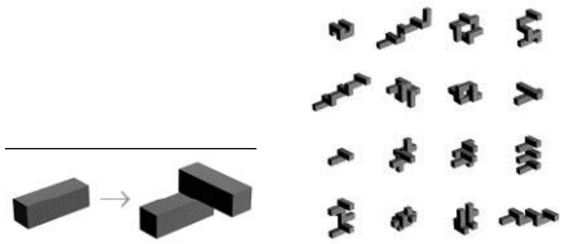


Fig-2: with the use of addition rule different possible designs created by the grammar

Figure 2. exemplifies a shape grammar based on a vocabulary (composed of a single oblong) and one simple addition rule. Despite the simplicity of this grammar it can generate a number of different designs within a language.

Shape grammar generates designs on an orthogonal grid. The initial shape is a square (I). The rule (R) specifies a possible shape replacement operation, joining two shapes: a pattern, a square, and its replacement, the same square with the addition of a translated copy arranged.

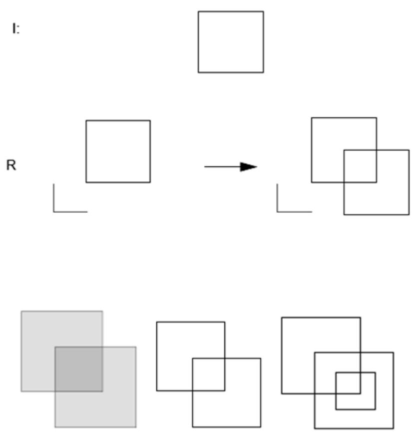


Fig-3: transformation in shapes by using simple shape grammar

Applying the rule to the initial shape yields a shape containing three squares, two the same size as the initial shape and one half the size, emerging from the two. Applying the rule to the smallest square yields squares of three sizes: two the size as the initial square, two half that size, and one a quarter.

The fundamental unit of a basic shape grammar is a shape. In order to allow the reflection transformation in a basic shape grammar, we need to add a label to each shape object . The spatial relation between the labels of two shapes specifies the spatial relation between the two shapes unambiguously. These rules determine the geometric orientation of the newly generated shape objects.

3. SHAPES

The term shape is commonly used to refer to the form of an object or its external boundary (outline, external surface), as opposed to other properties such as color, texture, material composition. Shape is the arrangement of basic elements in space. Shapes have a position, orientation, size in a coordinate system.

basic elements

space	points	lines	planes	volumes
0D	√			
1D	√	√		
2D	√	√	√	
3D	√	√	√	√

Fig-4: Arrangement of basic elements in the space

4. SHAPE RELATION

Spatial relations arise whenever there are two or more shapes in the space. With the advancement in the field of Geometry which involves spatial relationships (position, shape and size), substantial values can be derived helping man to think and find out the value of image produced and how to combine two or three-dimensional shapes to create new ones in the environment

Three kinds of shape relations are:

Overlapping - Those shapes that share a common part are said to overlap.

Embedding - If two shapes have common parts and at least one of these shapes has no part that is not a part of the other, then this shape is said to be embedded within the other.

Discrete shapes - Planes with no shared boundaries are discrete. However shapes that share a common boundary but have no part in common are also discrete.

4.1 Bullion operation on shapes:

Within the defined shape algebras, we can add and subtract shapes of the same kind of basic elements.

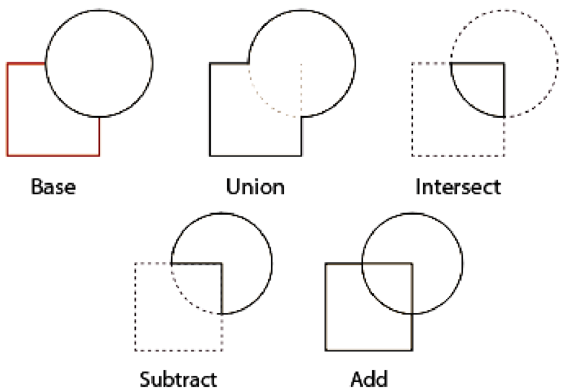


Fig-5: Boolean operations on shapes

4.2 Euclidean transformations on shapes:

Euclidean transformations that are used in shape grammars are translation, scaling, rotating and reflecting along with their combinations.

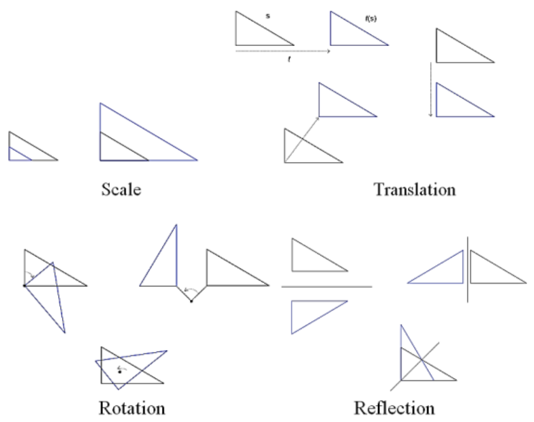


Fig-6: 2D transformation of shapes

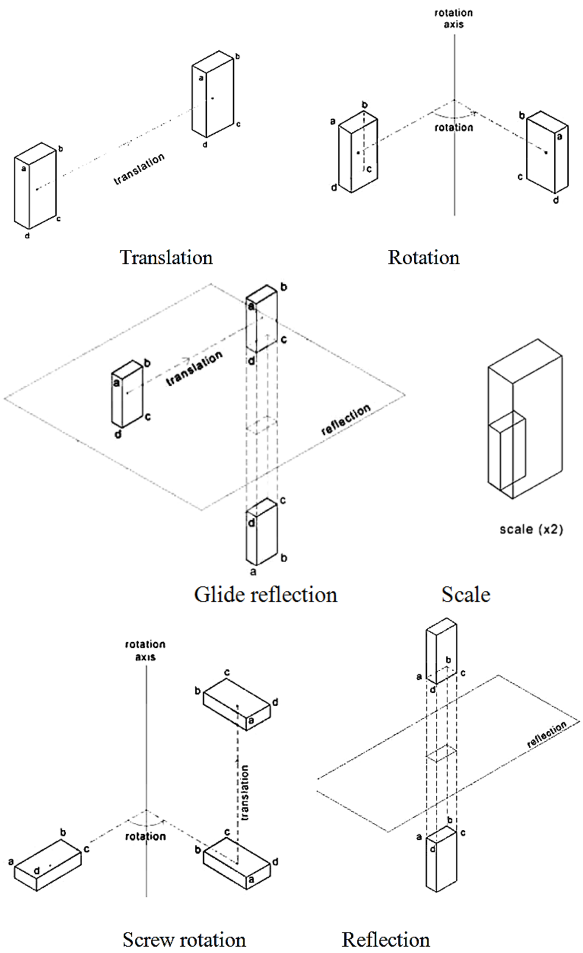


Fig-7: 3D transformation of shapes

5. SHAPES RULES

A rule in shape grammars can be written in the form A→B where A and B are shapes. When this rule A→B is applied, an instance of shape A is replaced with shape B. Creativity in rule-based design lies in the creation of the rules. Rules can be modified and expanded at every stage of a design process allowing the designer to make explicit his/her design knowledge in a structured framework. The designer controls form-generation by explicitly defining the criteria for new designs that fit a given context.

A rule applies to a Design whenever there is a transformation that makes the left-side A, a part of the Design.

To apply the rule first subtract the transformation t of the left-side A from the Design and then add the same transformation t of the right-side B to the Design.

The result of applying the rule is a New Design:

New Design = [Design - t (A)] + t (B)

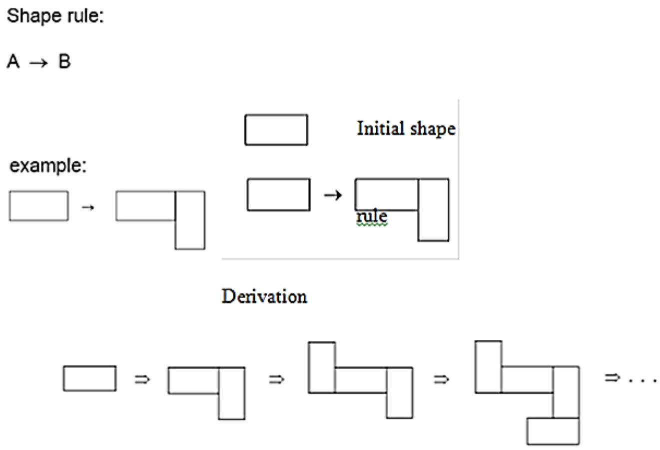
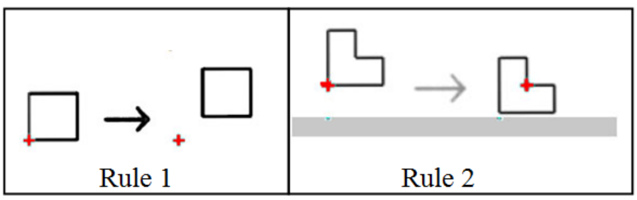


Fig-8: Applying shape rules

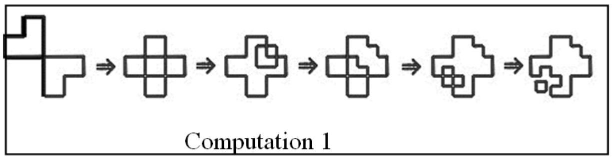
Final shape will depend on what rules are used, and when and how. This can vary for different rules and in fact it changes every time any rule is tried.

For example, if we consider two rule

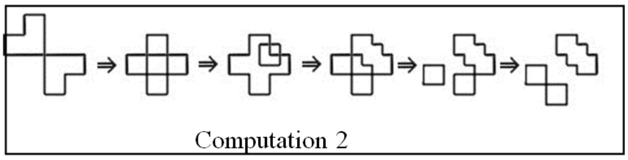
- First rule shifts a square halfway along diagonal axis of square
- Second rule shifts a L-shape along diagonal axis.



Using above grammar we can do the design computation. From second step on rules can be applied either to emergent L-shape or square. So the user has the opportunity to use which rule to apply and on which shape it has to be applied.



Below is another computation of the shape grammar. The computation is identical for first three steps then after it diverges and follows a different path to produce a different design.



We can use rules to change shapes without being consistent about what we see. This doesn't sound like calculating, but it is. And it's what you need to design, so that you can change your mind about what you see and do as you go on.

6. SHAPE GRAMMAR APPLICATION IN ARCHITECTURE AND ARTS

The history of shape grammar applications in architecture and the arts for the two complementary purposes of synthesis and analysis.

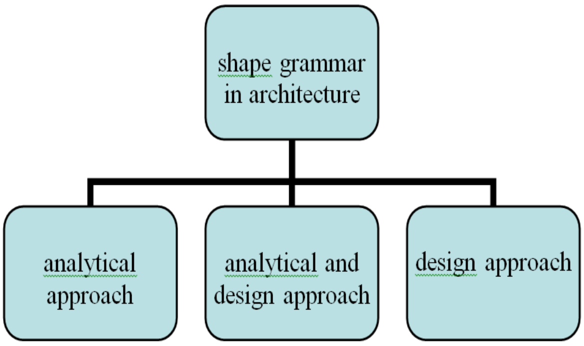


Fig-9: Shape grammar in Architecture and Art

6.1 Original design

Stiny and Gips do not explore or explain the genesis of the original grammars they give in their early works. A specific approach for creating original grammars from scratch was first proposed in 1980 by Stiny in his paper, "Kindergarten grammars: designing with Froebel's building gifts. Stiny examines the kindergarten method of Frederick Froebel and its analogy in the studio method of designing, and then proposes a constructive alternative to these mostly intuitive methods. A five stage program is given for creating new design languages: a vocabulary of shapes, spatial relations, shape rules, initial shape, shape grammars. Stiny uses Froebel's building blocks in the many simple and elegant shape grammars and designs created with this approach. These shape grammars are the first defined in a three-dimensional space, laying the groundwork for three-dimensional architectural grammars to come.

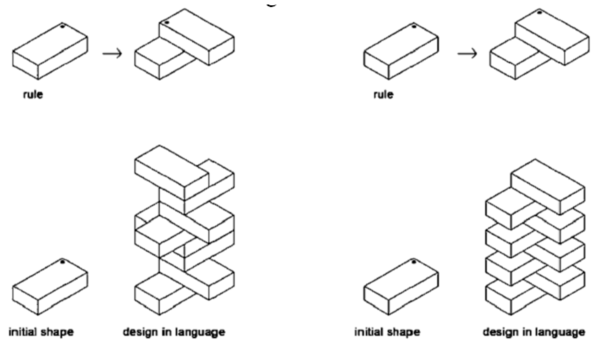


Fig-10: Kindergarten grammars, Stiny (1980)

Stiny's kindergarten program for creating original grammars lay dormant for several years while analytic applications of shape grammars grew quickly (see below). In papers beginning in 1992, Knight took up Stiny's program in an expanded approach for creating shape grammars as well as color grammars in three dimensions. Colors in a color grammar are used as indices for attributes of shapes such as material, function, functional elements, or colors themselves. Knight put this program into practice in graduate architecture courses taught at UCLA and MIT. Some student projects from these courses are documented. Computer programs implementing Knight's program have been developed and used by students at MIT in recent years. Concurrent with Knight's work was work by Radford, Woodbury, and others with simple, user defined and computer-implemented grammars.

6.2 Analysis

The first two decades of shape grammar applications focused almost exclusively on analysis. Through this work, shape grammars became an established paradigm in design theory, CAD, and related fields. The first analytic exercise with shape grammars was given by Stiny in his 1977 paper, "Ice-ray: a note on the generation of Chinese lattice designs" With five simple rules, the grammar captures the compositional conventions of lattice designs, generates existing lattice designs and an infinite number of new, hypothetical designs in the same style.

The one of analytic application of shape grammars, the Palladian grammar by Stiny and Mitchell from 1978, initiated work on more ambitious and complex shape grammars for architectural styles that continues today. Included in this work are shape grammars for the architecture of Giuseppe Terragni, Frank Lloyd Wright, Glenn Murcutt, Christopher Wren, and Irving Gill, for the vernacular styles of Japanese tearooms, bungalows of Buffalo, Queen Anne houses, and Taiwanese traditional houses, and for the landscape architecture of Mughal gardens. The Wright grammar is notable for being the first three-dimensional architectural grammar--motivated in part by Stiny's earlier work on kindergarten grammars and the alleged influence of Froebel on Wright's architecture.

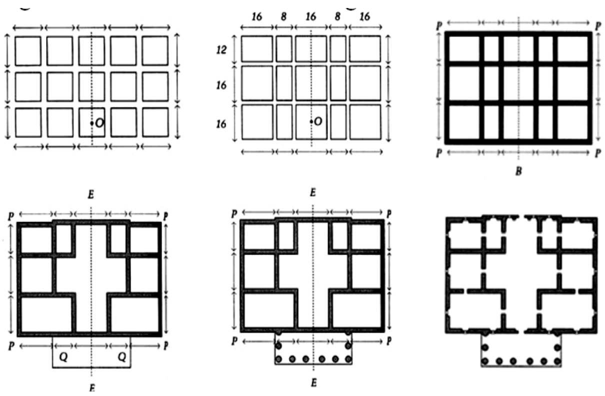


Fig-11:. the Palladian Grammar (Stiny& Mitchell 1978) Analysis/original design

In 1981, Knight proposed a method for developing new languages of designs on the basis of existing ones. Languages are created by transforming the spatial relations underlying grammars for existing languages. In other words, a known style is first analyzed by inferring a grammar for it, the rules of the grammar are transformed, and then the transformed rules become the basis for a new grammar and style. Knight's model had a dual purpose. It could be used to characterize the historical evolution of known styles into succeeding ones. It could also be used to innovate new styles on the basis of given ones.

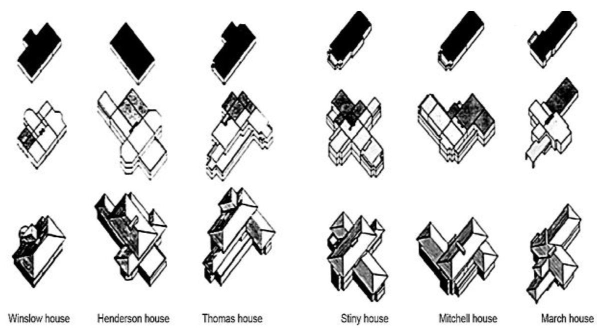


Fig-12: F L Wright Prairie House Grammar (Konig&Eizenberg 1981)

In a 1990 paper, Flemming proposed a model similar to Knight's for teaching architectural composition. General architectural languages based on vernacular or "high-style" traditions are introduced to students. These languages include wall architecture, mass architecture, panel architecture, layered architecture, structure/infill architecture, and skin architecture. Grammars underlying these architectures are also presented. Students use the grammars to learn about the languages, then modify them to generate their own new languages. Thus, Flemming's strategy is both analytic and synthetic or creative. Others have adopted similar teaching strategies. Julie Eizenberg, an award winning architect and coauthor of the Wright grammar, has introduced shape grammars in her studio teaching at UCLA, Harvard, MIT, Yale, and elsewhere in and

analysis →transformation →synthesis process.

7. APPLICATION IN ARCHITECTURE EDUCATION AND PRACTICE

Shape grammars are more than twenty-five years old, but their potential in education and practice is still far from being realized. Shape grammar theory is now far in advance of practical applications. Why? What can be done to narrow this gap?

The number of design (architecture, arts, engineering) schools that include shape computation or shape grammars as part of their curriculum has grown steadily as graduates of shape grammar programs find teaching positions worldwide and establish their own shape grammar courses. Introducing shape grammar in pedagogy needs the appropriate teaching strategy. The answers have to be find out that "Should the teaching of shape grammars be theory-based or practically-based?" In other words, should shape grammars be taught through their mathematical and philosophical foundations, should they be taught through concrete, practical applications or through some combination the two?

One critical problem in authoring an original grammar is how to develop a grammar that meets the goals and constraints of a particular project. Most work on shape grammar implementations has involved straight lines or planar surfaces. Yet almost all objects in life, even artificial objects, have curves and curved surfaces. Introducing shape grammars to the students with different levels and kinds of experience and abilities may require different teaching strategies.. Another question that arises from practical uses of grammars is how to find or generate subsets of a language that satisfy particular criteria.

New analytic/synthetic grammars must be structured in some designed way in order to be practicable. Most traditional analytic grammars are not structured in this way and thus are not practicable.

8. TEACHING PROPOSAL FOR ARCHITECTURE STUDENTS

With the help of shape grammar introducing new ways of thinking as well as introducing students to the new pattern of architectural education. The 1st year design studio is seen as the students' entry level to architecture, sometimes described as the architectural kindergarten, where students form their first ideas about design and architecture that will distinguish their design ideologies. For teaching purposes, computer implementations may not be as effective as by-hand applications of grammars. By-hand applications of rules require careful thinking about how rules work. In the long term, this results in a better understanding of grammars and better quality design work. Computer implementations provide only two-dimensional representations of generated designs. Three-dimensional grammars can generate complex designs that are difficult to comprehend without a physical, 3D model. A two-dimensional representation of a three-dimensional object, no matter how sophisticated, cannot compete with the object itself.

Students usually begin with abstract actions. Starting at the early abstract experimentation stage with simple design assignments that are mostly about abstract or artistic explorations of shape composition, form generation, color and texture, etc. Goal driven composition at the Mid-Stage introduces some limitations to the design exercises in order to teach students to design in response to a defined purpose. More complex design requirements are introduced during the final stage of Experiencing architecture in a complete (yet simple) architectural project But the closer look at the novice students' thinking behavior and the expected learning outcomes reveals that the complexity plan in itself is not enough, there are other factors that should be altogether responsible for defining themes to control the selection of each stages' exercises. For example, the target thinking type at each stage should be defined, knowing that the architectural education aims to develop a bipolar thinking skill for students. Teaching them to control, combine and alternate between rational and imaginative thinking types in order to produce logical yet artistic designs.

One fact of the beginning studio is that novice students are more absorbent for new knowledge and experiences in their early design experimentation than other advanced students. Once they have seen something done in a certain way, or done it themselves, this experience tends to reinforce the idea in their fresh minds and may block other alternatives. Therefore, instead of teaching students to see things in a definite way, the proposed exercise intends to train their eyes on flexibility where there is no correct answer and all possibilities are open.

9. THE WORKSHOP

The conducted experiment was organized on the basis of shape grammar experimentation through physical manipulation of building blocks. This design education proposal was tested with a group of students, who gained theoretical knowledge and practical design experience. Architectural theory was introduced through discussion and experimentation of the shape grammar exercises.

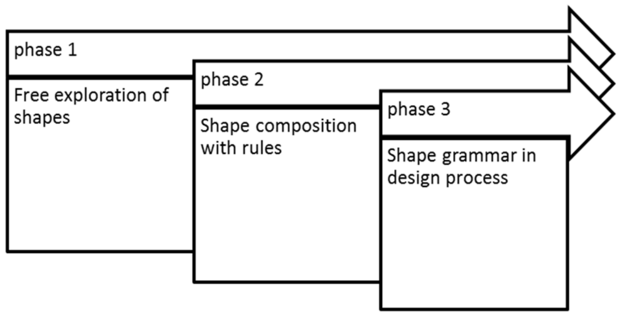


Fig-13: design studio exercises were organized in 3 different phases

Phase 1: Free exploration of shapes

The experiment began with a quick lecture about shapes and how do we see it from a 1D to 3D perception, accompanied with examples from architectural masterpieces with basic geometric forms. started by identifying the composition's basic elements (vocabulary) then the way they all connect. Examples like "the ice-ray grammar were shown to demonstrate the simplicity of the vocabulary behind complex patterns like the Chinese Ice Lattice designs.

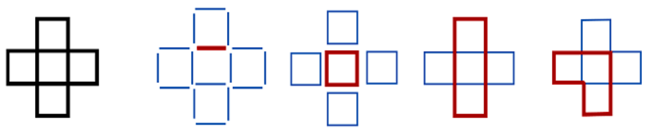


Fig-14: An example on Ambiguity that shows how to perceive the basic elements of one shape in different way

Afterward students were challenged with indirect and more complex ways of conceiving shapes as possible projections of multi-dimensional elements.

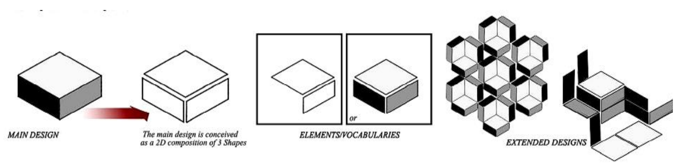


Fig-15: Part of the tutorials example that shows the process of vocabulary extraction and design modification

At this point, students became aware that something different lies behind every simple layout of a shape. Students were then given the experiment which is more like a creativity test. They were grouped in groups of three; each group was given one of the 2D shapes. They were then asked to draw at least 4 different readings for the shape and its basic elements with at least one 3D interpretation of which. To extend and modify the existing design they have to extract its basic elements and work with basic geometric operations to create their new designs.

Fig-16: shapes given for the workshop

After the exercise, each group was asked to present their final ideas. Although lots of them were not aware about their own design's quality.

Fig-17: some of the design built on the basis of direct interpretation of basic elements

Such process not only motivated the students' ability to see and make respectively, it also developed flexibility in design, an analytical awareness as well as confidence to take design decisions. This became a good start point for the next level workshop where students will be learning to design in response to shape rules. One question that arises out from these observations is whether the accomplishment of students is momentary- only for the time of the experiment- or will it last and affect their design behavior in future projects.

Phase 2: Shape composition with rules

After the first exercise of shape exploration students were now moved to next level where they will be learning to design with shape grammar. The exercise begins with the introduction of shape grammar theory. The students were guided, which rule to apply, where to apply the rule and how to apply. Grammars are experimented conceptually through the physical manipulation of thermocol blocks.

Fig-18: design built by the group 1 by applying rules

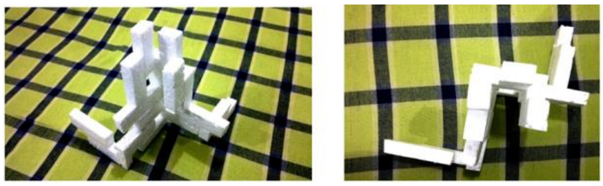


Fig-19: design built by group 2 by applying rules

Fig-20: design built by group 3 by applying rules

Phase 3: shape grammar applied in design process

After this conceptual rule exercise students were ready to design at their own. They were given building blocks and developed their own design solution for a house. The blocks were pre-cut and painted in different colors that defined their functions. A hypothetical location was given with definition of orientation (North Arrow) on the baseplate, which also had composition guidelines, allowing dynamic arrangements to be tested.

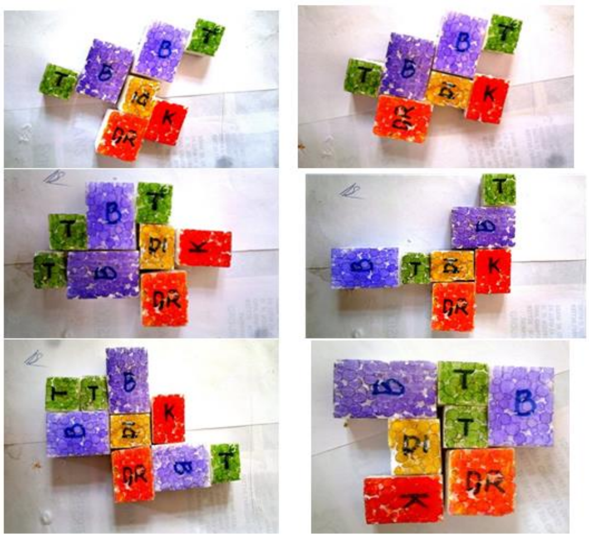


Fig-21: design made by the arrangement of building blocks

Although students applied structured rules to their design compositions, the solutions were innovative and diverse. The results showed that the process produced interesting, viable and creative designs and the richness of the students' work demonstrated that the application of rigid rules does not interfere in the creative process. The students' learning curve was extremely fast. They assimilated the rules and enjoyed the design manipulation, which gave them more security in reaching viable solutions. The experiment showed that such innovative ways of developing a design project can give studio teachers new insights in architectural education. Care must be taken to avoid addictions to specific methods and treat design problems in isolation.

10. CONCLUSIONS

Shape grammars lays guiding rules for "science of design" and for a "theory of architectural composition". It can be developed into an innovative and scientific approach of understanding design process. Design process can be explained through a very objective approach rather than through subjective factors like 'creative inspiration', the 'inventive flash', or 'individual genius'. Questions like "Where do designs come from" or "how to design" can now be answered via this shape grammars approach. This approach is also relevant for teaching composition and visual correlations such as proportion and symmetry. Analysis and synthesis application of shape grammar

The concept of "Make Learning Visible", which states that teaching alone in isolation, is not enough for effective learning. If the learning can be quantified from time to time then steps can be taken by educator to increase the effectiveness of teachings. Shape grammars allow us to overcome the organic nature of creativity and give design students and educators a way to make learning visible and concrete.

The focus of such approach was to help the students in understanding design as a systematic and structured process . "Perception of space" is another dimension of design which can be explored during such activity and can be analyzed keeping in mind the acumen of the students and the objective of the activity. Due to simplicity of the rules design process become easy but such approach should be treated in isolation for each project and should be worked out on project to project basis.

REFERENCES

[1] Stiny G. (1980). Kindergarten grammars: designing with Froebel's building gifts, Environmental and Planning B, 1980, volume 7, pages 409-462

[2] Koning, H. & Eizenberg, J. (1981). The language of the prairie: Frank Lloyd Wright's Prairie houses, environment and planning B, vol 8, pp. 295-323

[3] Flemming U, 1987, "More than the sum of parts: the grammar of Queen Anne Houses" Envimnen'l and Planning 8; Planning and Desrgn, 1987. volume 14, 323-350

[4] Krishnamurti R, 1981, "The construction of shapes" Environment and Planning B: Planning and Design 8:5-40

[5] Stiny G, 1982, "Spatial relations and grammars" Environment and Planning B 9 113–114 Google Scholar Abstract

[6] Tapia M A, 1999, "A visual implementation of a shape grammar system" Environment and Planning B:, volume 26, pp.59 – 73.

[7] Knight T (1999) Shape grammars in education and practice: history and prospects

[8] Stiny,G. (1976) "Two exercises in formal composition" Environment and Planning B 3, 187–210

[9] Knight, T.W. (1998b) Shape Grammars, Planning and Design, American Indian Rock Art, Vol 22

[10] Krishnamurti R, 1980, "The arithmetic of shapes" Environment and Planning B: Planning and Design, 7:463-484

[11] Varghese, P., George A.,(2012) "Vision and visual system as a backdrop for design" Abacus, vol-6 no-2

[12] George A, (2006) "Interactive learning for higher education in architecture" Journal of The Indian Institute of Architects, Vol. 71, Issue 03

[13] Stiny G, 1977 "Ice ray: A note on the generation of Chinese lattice designs" Environment and Planning B 4 89–98

[14] Stiny G, 1980 "An introduction to shape and shape grammars" Environment and Planning B 7 343–351

[15] Knight Terry, April 1999 "Applications in Architectural Design, and Education and Practice" Report for the NSF/MIT Workshop on Shape Computation

[16] Almeher Khurshid, FEBRUARY 2002 "A Figurative Study of Louis Kahn's Capitol Complex at Dhaka: Analysis through Shape and Shape Grammars Theory"

[17] Manuscript Elsevier Applied computing jun2013.doc (D20840667)

[18] Şahika Özdemirdeğişiklik.docx (D17443289)

[19] http://www.shapegrammar.org/education.pdf

[20] http://blog.nus.edu.sg/zitong/files/2008/09/shape-grammar.pdf

[21] http://www.mit.edu/~tknight/IJDC/page_history_analysis.htm

[22] http://www4.ncsu.edu/~daham/DerekHam/styles.html

[23] https://www.cl.cam.ac.uk/events/tangibleinterfaces/TUIworkshop-Jennings.pdf

[24] http://www.geocities.ws/ksameher/images/master_thesis. pdf

BIOGRAPHIES

Asst. professor at Dr.K. N. Modi university , Niwai, Rajasthan. Having expertise in healthcare planning and designing. Intrest in teaching learning process, education technologies and new paradigm of Architecture Education.