Teaching Design by Coding in Architecture Undergraduate Education

A Case Study with Islamic Patterns

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Abstract. Computer-aided design has found its role in the undergraduate education of architects, and presently design by coding is also gradually finding further prominence in accord with the increasing demand by students who wish to learn more about this topic. This subject is included in an integrated manner in some studio courses on architecture design in some schools, or it is taught separately in elsewhere. In terms of the separate course on coding, the principal difficulty is that actual applications of the method can rarely be included due to time limitations and the fact that it is conducted separately from the studio course on architecture. However, within the framework of the architectural education, in order to learn about the coding it is necessary to consider it along with the design process, and this versatile thinking can only be achieved by the application of the design. In this study, an elective undergraduate course is considered in the context of design and to yield a versatile thinking strategy while learning the language of visual programming. The course progressed under the theoretical framework of shape grammar from the design stage through to the digital fabrication process, and the experimental studies were carried out on the selected topic of Islamic pattern. A method was proposed to improve the productivity of such courses, and an evaluation of the results is presented.

Keywords: Islamic Patterns, Shape Grammars, Architectural Education, Parametric Design, CAAD.

1 Introduction

The contemporary demand for the inclusion of computer-aided design in courses run in schools of architecture is increasing relentlessly, as a consequence of the fact that students no longer use computer-aided design merely as a representation tool in their design studio projects. The relevant computer-aided design tools have become assimilated into the student's projects in the design stage [1], and this situation changes appreciably the classic design education in the field of architecture. Hence, there are attempts to include novel methods in design education, and efforts are made to determine which of them is the most efficient.

In schools of architecture, computer-aided design is taught in an integrated way in the architecture studio classes, or it is taught as an elective course on this subject, which is included within the architecture curriculum. The main problem encountered in teaching computer-aided design as an elective undergraduate course is that the students are unable to apply their knowledge to actual product design because the architectural design studio is involved in a separate course. It is only possible for students to learn about computer-aided design tools in combination with the particular design by actually applying the methods and also can experience the versatile thinking together with the use of different design tools. Therefore, application-oriented work was considered in the elective undergraduate course taught by this author, with the title “Introduction to Parametric Design”. Here, the intention was to teach the basic visual programming language in the content of the course, in which the theoretical framework of shape grammar was used, and the students were expected to create an Islamic pattern as an application of these principles.

In shape grammars, which enable the creation of innovative designs using computational methods, it is essential that the shapes are used on the basis of a set of defined rules [2] [3]. Different possible emergent design solutions may occur according to the adoption of these rules [4] [5]. These design solutions in shape grammars are generally created using rules such as rotating, reflecting, duplication, scaling, copying, shifting, intersecting and subtracting. If the initial shape is defined as S0 and the application rule is defined as =>, the computation develops as S0 => S1 => S2 => S3 => ... => Sn [6].

Numerous studies have been performed in relation to shape grammars, which are used to create new designs, and also to analyze existing designs, as have been described by Stiny [7], Knight [8], Cagdas [9], Li [10], Duarte [11] and Krstic [12]. Also available are prominent examples [13-15], where shape grammar has been used in architectural education. The use of shape grammar together with encoding in computer is present in the graduate-level course on architectural education [16] or it may be articulated to the design studio in an experimental form [17]. In the present study, which is based on a knowledge of the coding in parametric design, the process followed and the method adopted are discussed in the context of a separate undergraduate architecture elective course. Here, the subject of the application work was Islamic patterns, about which much research [4], [18-22] has been carried out, using the particular advantages brought by the development of the computer technology. As the course progressed, an evaluation was made from the design stage through to the final digital fabrication process.

2 Methodology

The aim of the elective course, "Introduction to Parametric Design" in an architecture undergraduate program, is to teach students how to do basic programming using the visual programming language, which is of increasingly importance in the field. It is, a challenge in its own right to learn the visual programming language in the first place; however, it is considered that the most efficient way to learn it is to create a design product. Hence, during the course, each student is expected to create a design product.

The students, who took this course, had some prior experience with computer-aided design programs such as AutoCAD, Photoshop, and (to some degree) Revit, but not with the use of visual programming language. Accordingly, we commenced the course by teaching 3D modeling in Rhino, and in the following weeks, focused on the basic principles of programming. Subsequently, the production of various scripts was made using Grasshopper (a Rhino plug-in) under the supervision of the instructor. Having understood the visual programming, the students began to produce their own design of an Islamic pattern by means of the principles of shape grammar.

Before starting their design, the students did research on the nature of Islamic patterns using the internet and discovered a variety of such examples, which they examined together with the instructor, who asked them to try to find out how to form the pattern mathematically (rule-based design). Hence, the students had prior knowledge on how to form a pattern by means of shape grammar. Having completed this stage, the students were informed about some detailed studies on Islamic patterns, [18-20] so that they might have some insight into how these fitted into the overall framework of the subject.

During the students production of designs in the course, they were asked to do form-finding [23] studies on specifically Islamic patterns depending on their own set of rules, instead of examining a particular Islamic pattern and reproducing them in a visual programming program with based on rules. Thus, it was provided to be able to discover different forms depending on the rules. This type of method was found suitable to be followed since they define their own rules according to various parameters and shape their forms according to these parameters and create new designs during the production of the form in architectural design.

The students started to produce their Islamic patterns with the use of the basic shapes in Grasshopper. They developed their initial shapes by using such basic geometries as circles and rectangles. Later, they investigated the formation of patterns by defining the different rules regarding the determined initial shape. For example, in the student's work shown in Fig. 1, the initial shape is defined as a triangle formed in a circle, and from which he began to define rules for the production of forms from this initial shape. In this example, the first rule applied to the initial shape is to take a symmetrical mirror, and the second rule is to make an array based on a process of repetition. After this stage was completed, some students were proposed to add a gradual scale with the aid of the closest point component in Grasshopper for creating variations in repetitive patterns.

The instructor suggested that some of the students who started with working in two dimensions could work in three dimensions. For example, Fig. 2 of the student study,

the student identified the initial shape as a hexagon. Then the student identified the points on the corners of this hexagon in grasshopper. She also identified new points on the edges of the hexagon. She then created new lines by combining these points and created new hexagons in the initial shape hexagon. Later, she accepted the whole hexagons, created in the initial shape hexagon, as a module and scaled it. In each hexagon in the initial shape hexagon, she placed this scaled module as considering it the new layer in the third dimension. This process was repeated several times, and as a result the form became a three-dimensional form.
In summary, when we simplify the process by removing the components used as tools for making rules applicable in Grasshopper, we see the rules as divide the initial hexagon into hexagons, scale the unit and place as a layer in third dimension, copy, repeat last two rules (scale and copy) (Fig. 3).

The students, who were trying to reach the third dimension, applied this rising method by stratification. The reason may be the direction of basic commands that they learned (Fig. 4). In the study, the student determined the initial shape as triangle. Then, she created a triangular grid with the repeat of triangles and formed the rotated inner triangles by defining the points in the triangles in this triangular grid. Then, she accepted these formed inner triangles as a collective module, and did copying procedure with array polar. Then, she scaled the whole copied and considered to be a layer in third dimension. She applied the scaling procedure again to the formed new layer and so, added the third layer and in the same way, added the 4th layer. In summary, we see the order of the rules as the repetition of the initial shape (triangle), the rotation of the triangles, copy the unit, placing as a layer in third dimension by scaling and repeat last rule twice.

Simultaneous with the students creating their Islamic pattern, the digital fabrication issue was also undertaken as part of the content of the course. Here, the aim was to make the students prepare their patterns in such a way (as scale and material) that the latter can be produced using the machines present at the school. This is because it is important that the students are able to learn versatile thinking along with an experience of the use of different tools in order to achieve the best results. As Kolarevic [24] has said: "*knowing the production capabilities and availability of particular digitally-driven fabrication equipment enables architects to design specifically for the capabilities of those machines*".

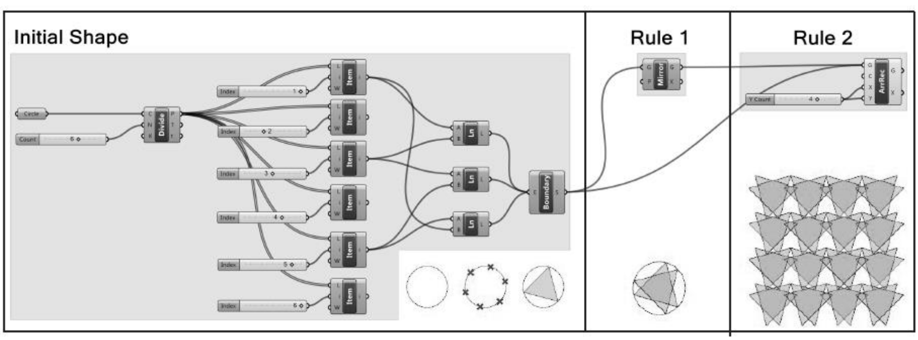

Fig. 1. A student study showing the followed path in the pattern forming stage.

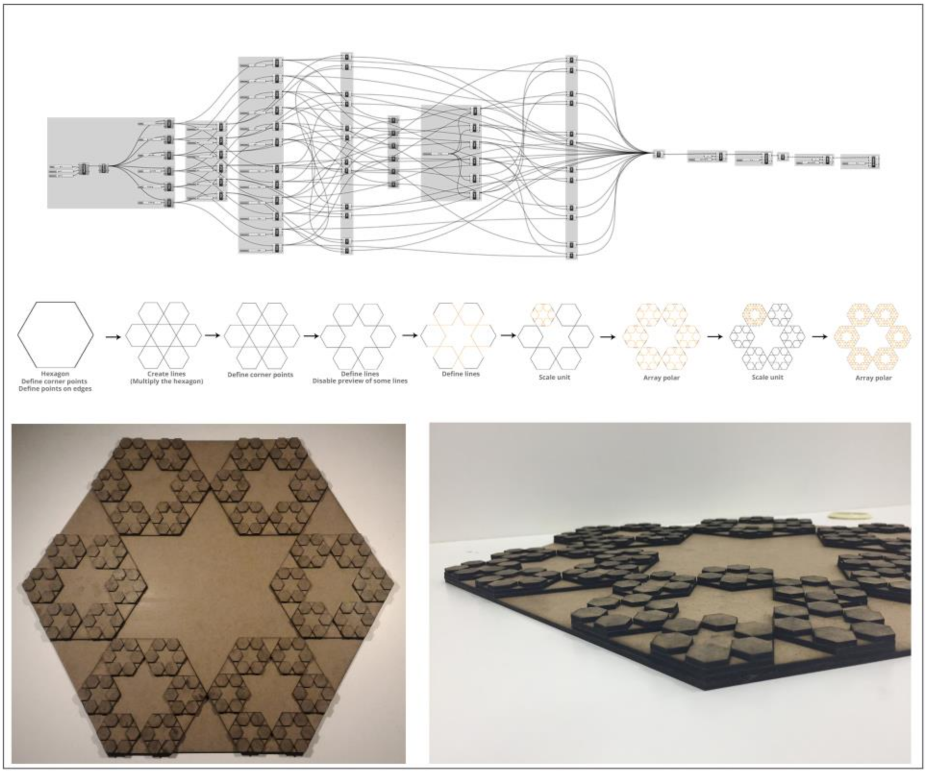

Fig. 2. Student's work of third dimension

Fig. 3. Set of rules used for the pattern creation in the student's work.

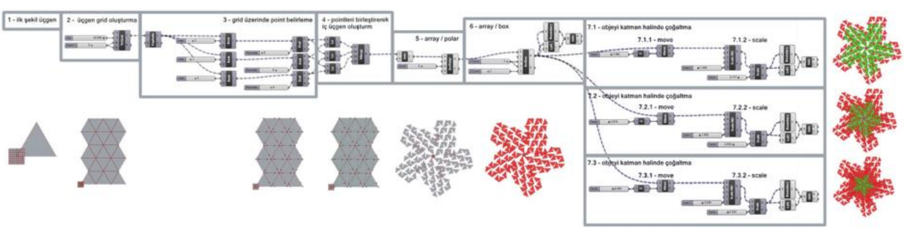

Fig. 4. Student's work of third dimension

3 Results

The use of constructivist pedagogy with well-defined steps, might be one of the answers to an up-to-date problem of designers' reasoning on dataflow programming, because, students tend not to do data flowing on a rule-by-rule basis, when they use the visual programming language program. But, when they start to prepare a definition based on the rules, they begin to create a structure / fiction in their minds. The next rule, that they will define in the visual programming language (by doing visual computation), is based on the form that occurred as the output of a previously defined rule. Consequently, the rules become break points in their definitions, and these break points form the backbone of the students' designs.

The definition of the initial shape (determined by the student) and the rules which are parametric in Grasshopper provide a starting point for emerging forms to be easily differentiated, and the students can quickly and easily produce many alternatives. Accordingly, the students can return to the initial shape or a particular rule in the Grasshopper script and change the value of the related slider to re-define the rule easily, and according to the new rule, can more rapidly produce any other series. As students develop their designs, they have come to the realization that they are especially returning to the breakpoint rules and these rules are actually facilitating the process.

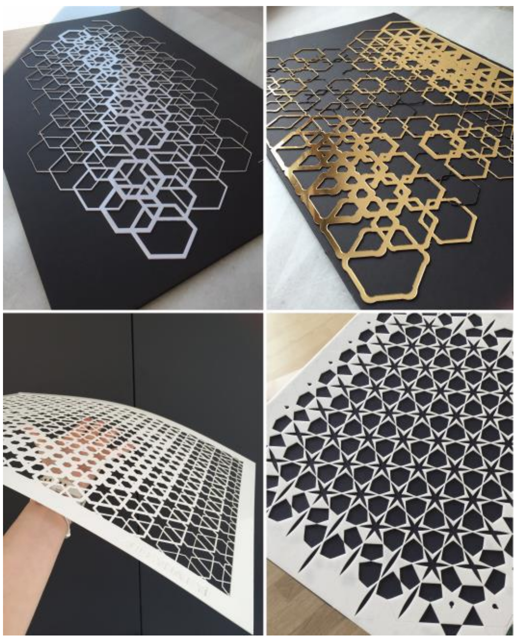

Fig. 5. The models, which were made by using plexiglas material.

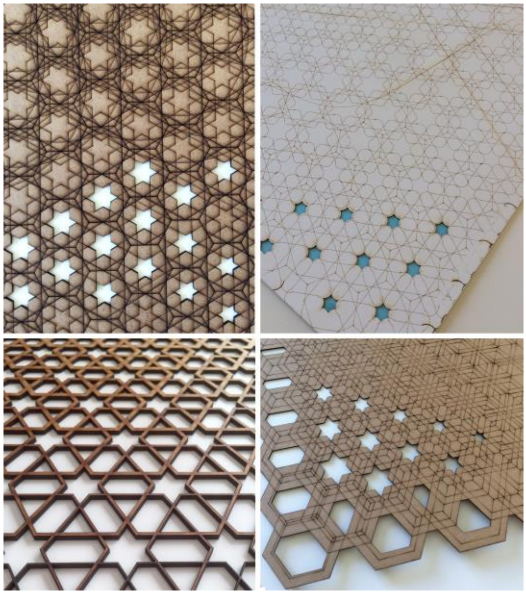

Fig. 6. The models, which were made by using cardboard material and left openings.

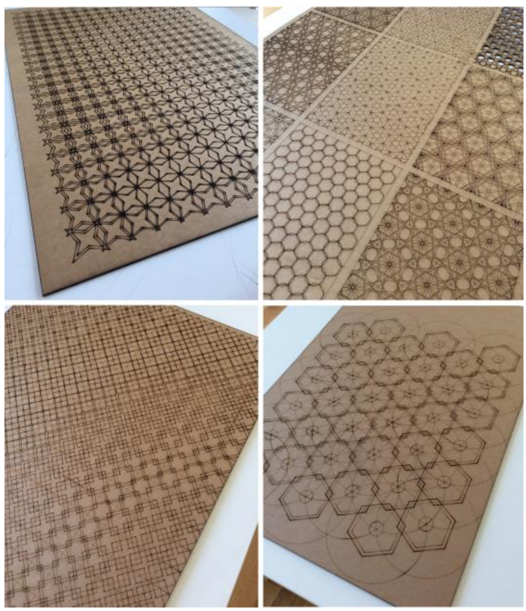

Fig. 7. The models with different geometries, which were made by using cardboard material and produced by doing laser scoring

These series produced belong to the digital sketches, which the students may choose among many alternatives; these sketches also prompt students to explore new ideas. Thus, there is a similarity with the paper-based sketches which are done during the initial process of the project within the framework of classical architectural education. It is also true that in the classical paper-based sketches, the student can arrive at various forms and ideas that cannot be predicted in advance. However, in the parametric design, shape grammar rules are quickly redefined and thus, students can assess the produced alternatives very quickly.

An early experience that students have, in their early years of architecture education, is to create the first digital fabrication of the Islamic patterns that they have made. From the digital fabrication experience, they learn to consider the virtual and the actual models together, and so gain some experience regarding such issues as time management and the selection of materials [25].

At the digital fabrication stage, the students were free to use any material of their choice. Some of them preferred to use plexiglass materials in different thicknesses and colors (Fig. 5), while others decided to leave voids in their created Islamic patterns for openness in the structure. Thus, the students could effectively reveal the contrast of fullness - emptiness (or figure-ground relationship) in their created patterns (Fig. 5 and Fig. 6). Some students preferred to display their products using the laser scoring made on the materials that they used. Thus, those students who opted for digital fabrication, strengthened the representations of their created patterns by expressing different geometries (such as hexagon or circle) with different thickness of lines (Fig. 7).

The instructor cautioned the students in advance about the length of time necessary for laser cutting since they had no prior experience of this technique. This helped them to start the preparation of the digital fabrication stage of their design at a sufficiently long time before the submission deadline, and so they gained experience regarding the time management of the aspect of digital fabrication.

4 Conclusion

In this study, a description is given of an elective course, which has been inaugurated in an architecture degree program and aimed to teach students coding with parametric design. This elective course is taught separately from the architectural design studio, and given the limited amount of time available, it is a great challenge for both the students and their instructor to teach coding efficiently in it. The author teaches this elective course and aims to obtain the most effective results on the basis of learning, together with actual applications. The topic of the application is Islamic pattern, and it was conducted under the theoretical framework of shape grammar.

The design commenced with studies in the virtual environment and proceeded on to the digital fabrication stage. Thus, the students, creating the design with the topic of Islamic pattern, simultaneously learned that it is necessary to act in a coordinated manner, employing the basics of visual programming language, to make a design using the principles of shape grammar and digital fabrication. It is very important that students in the early stages of the architectural education learn that, in the computer-aided design, versatile thinking and the ability to use different tools together are vital. Having become aware of this in the early stages of their course, the students can easily transfer their skills to other projects, which they will design throughout the period of their education.

Computer-aided design has been included in the programs of many architectural education schools. However, different methods should be researched to find the best integration to both education in the studio and in the other courses. Different experimental studies must be carried out to demonstrate which methods are the most effective.

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