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A shape grammar algorithm and educational software to analyze classic Ottoman mosques

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Abstract:
This work introduce, a shape grammar algorithm and custom-made software that has been accepted as a part of the fulfillment of master of architecture degree thesis in ITU, titled 'A Shape Grammar Algorithm and Educational Software to analyze and understand the composition of Classic Ottoman Mosques'. This software, -a closed system shape grammar example- is distinguished with the possibility that it provides to run the shape grammar algorithm through a Delphi-based system. This study has been held to generate a model to establish a logical framework of an educational expert system, which can be a foundation for future programming exercises of artificial intelligence.

Mosques, which signify the power of the Ottoman Empire during its golden age, have been constructed using the latest technology of its time as well as high-aesthetics, which is still appreciated today. Fast forward to 20th century, especially after 1980's increasing numbers of "new" mosques, attempting to emulate the qualities of mosques built during the Classical Period, fell short on achieving the authentic design principles, because of their disharmonious proportions and shapes. The mentioned software has been designed to guide and enlighten architects who are new to the profession as well as need information on this topic.

This software visualizes the principles on proportioning the mass of Classical Mosques in 3D, and explains the configuration rules of the components in typology. During the design stage, the software introduces all the components of the mosque as building blocks in a defined hierarchy. Therefore by using this software, users can start from the most essential component, the 'dome' and reach to a final product that is composed according to the basic design principles, and correctly configured components.

Keywords: *Shape grammar, classical Ottoman Mosques, proportions of mosque, programming, direct X*

1. Introduction

1.1. Aim and methodology:

The main goal of this study is to generate a model to establish a logical framework of an educational expert system, which can be considered as a starting point for further programming exercises of artificial intelligence. In this context, the side-goals are to have computer interpret the shape grammar, which is generated through the algorithm to enable an infrastructure for shape grammar analysis; using the software as an educational tool and running the software integrated with programming languages and CAD systems. The subject of this software is the Classical Mosque Typology from the Ottoman Era that constitutes a rich and coherent design language. During this study, former examinations about the mosques from the Anatolian Seljuks through Classical Ottoman Era, among with the typology analysis of recently constructed mosques were investigated and they digitized based on shape grammar.

Using the information derived from the former efforts and Şener's (2000) studies on "Shape Grammar Rules on Classical Mosque Architecture", and, this study generated a simplified version of a closed grammar system that can be used for educational purposes. After setting up the algorithm, the steps followed on scripting the software can be listed as follows: Selection of the most appropriate programming language; Definition of the algorithm in the digital environment; Revision of the components according to the programming language; Generation of the elements by the use of a CAD system and finally coding generated elements in the proposed software.

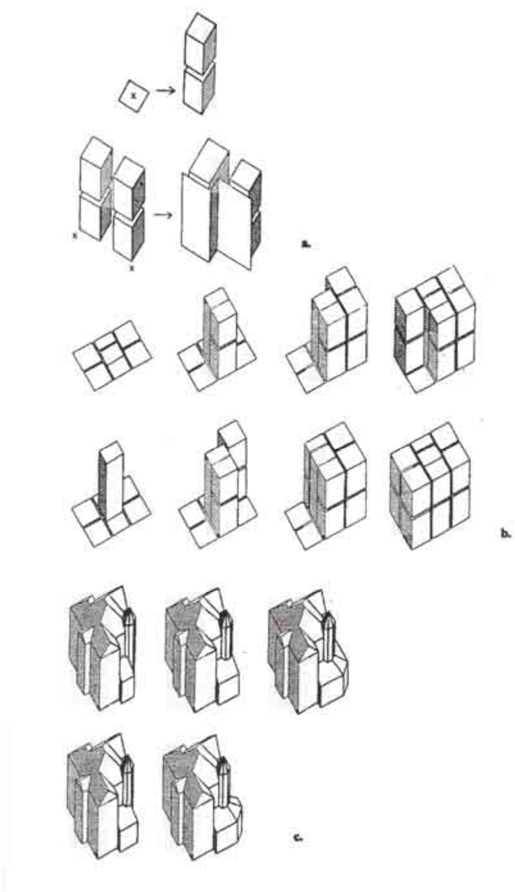

Figure 1. *Queen Anne Houses (Flemming, 1987).*

During the composition of the components, the "parent-child" relation has been examined (Figure 1) and this relation has been transferred to control points, by using Delphi Programming Language. Using 3D objects generated by DXDraw software the user' perception has been facilitated.

1.2. Shape grammar:

Shape Grammar is a rule set which is deployed to form a design language. It could be either descriptive or generative. Each architectural language that belongs to a certain era or an architect has its own compositional principles. These principles are defined with the set of rules and these made up to the grammar of that language. An architectural language can be characterized by a vocabulary and a grammar that has been defined by spatial patterns. This system, which stands on the rules and resolves the syntactic repertoire of architecture, constitutes the language of architecture. One of the most important characteristics of the shape grammar is the possibility and inter-changeability of evaluating these shapes independently. This provides the possibility of defining the generated shapes or forms as the result of the rule set, and furthermore provides the possibility of modifying the pre-defined forms. The manual operations about grammar rules may not only delay the process but also may cause errors. Therefore this computer-based shape grammar algorithm which deploys the defined rule sets has generated to avoid mentioned problems of the preceding generation. Among with the software that is the subject of this paper, to define computers as “shape grammar interpreters”, as they are hardly used as grammar interpreters on shape grammar studies.

1.3. Brief explanation about the development of mosque typology:
Departing from the mentioned definitions, it is essential to give brief information about the design language and the formal components of Classical Ottoman Mosque that is considered as the subject in the definition of the logics, tools and the limits of the introduced software. This will also enable researchers and academicians who want to develop the software to have an accurate assessment of the functions and flexibility of the tools that are used.

In the analysis phase of this study, the formal development of the traditional mosques from Anatolian Seljuk Era up to Classical Ottoman Architecture was examined as case study. With its *covered type plan*, *multi-column structure* and the *proportional hierarchy* of the formal components that consist the major structure, the “Ulu Cami”, of the Anatolian Seljuk’s appears as the pioneering example. The most important element on typology that is inherited from Beyliks period[1] was the intention of connecting the spatial enclosures proportionally to establish a spatial unity. And this was the basis of ‘dome’ the major component of the 16th Century Ottoman Mosque Architecture. The development of the ‘dome’ during this era, has positively affected the progress of the Ottoman Architecture.

The reason why the shape of the dome is highly accepted can be found on the exact overlap of the ‘centralized space’ idea with the structure. The ‘centralized space’ idea, which has being explored during previous periods, reached to its peak during Architect Sinan’s Era. On Ottoman Architecture the main components of the mosque is a cubical body and a spherical roof composed together to achieve a pyramidal shape. The notion of mosque, consisted of four basic features; a main space, an entrance portico adjacent to this main space, a courtyard and a minaret The courtyard functions both as a piece of the mosque and the surrounding neighborhood.

Achieving monumentality has required the development of the structure and this resulted by invention of different typologies that offer different solutions. From a structural point on Turkish-Ottoman architecture view on the dome is the geometrically and structurally leading but not a dominating element, declaring its own identity independent from the rest of the structure. Main reason why dome become the major component is that it establishes the *central space*; it’s compatibility with the earlier *Ulu Cami* plan type, the ability to enable natural daylight and creating an uplifting spatial experience.

After a-300-year experimentation period, dome has turned into the most important architectural feature of Classic Ottoman Mosque is the dome, which has become the main component, to achieve the monumental structure effect. Therefore the main dome and mastering its relationship with the other domes and structural elements lead to a variety of exterior and interior spatial compositions[2].

[1] Beylik is the Turkish word for “principality”.

[2] To reach the desired size of main space secondary elements of half and quarter domes are added among mini-domes and other covering elements. The sophistication of three elements; typology, composition and style appears to be very important on the works of Architect Sinan.

The proportion on Ottoman Architecture is the essence of the structure, achieving beauty, precision and the spirituality both by its form and symbolic means. Structural elements undertook aesthetical functions in the formation and the perception of the spatial enclosure. Especially the curvilinear forms contain a visual continuity that flows from an element to another. On the other hand, there exists a continuous conflict and integration between the second and the third dimension of the forms.

Classical Ottoman Mosques are important as they signify the highest level of achievement in Turkish mosque form. The works produced during this era have influenced later periods by becoming as a prototype. Studying the mosques of Classic Period, understanding the building principles and composition will enable us to understand how and where most of the late examples failed to achieve. The studies on these mosques -from the Classical Era- about examining their formational approaches would be dismantling the formal erosions of the recently built examples, which emulate the former ones.

1.4. Overview on spatial configurations and shape grammar of Ottoman mosques:

The spatial configuration of Ottoman Mosques consists of three groups; joining parts, secondary design components and structural system elements. The first group is the *joining parts* such interior spaces and the complementary spaces. The second group is the *secondary design components* such courtyards and the entrance portico that enfolds the main body of the mosque. The third group is the structural system that plays an important role in the form of the mosque (Figure 2 and 3).

Spatial features and configurational amalgamation of the *joining parts* -the interior spaces and the complementary spaces- mostly dominate the formal appearance of the mosque. The size of the ‘main dome’ determines the dimensions of the *secondary design components* like ‘semi-domes’ and the ‘main pray hall’. The dimensions of the space vary according to the *structural system* selection. In the typology of Traditional Ottoman Mosque, which has been developed depending to structural systems and geometrical schema; some proportional configuration principles were adjusted according to the size of the major dome.

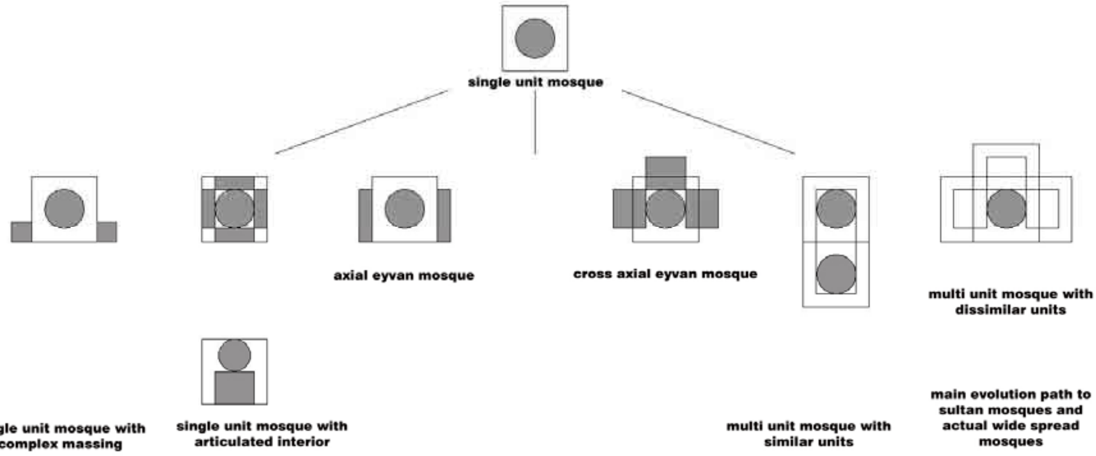

Figure 2. *Typological relations of the components through the evolution of the mosque.*

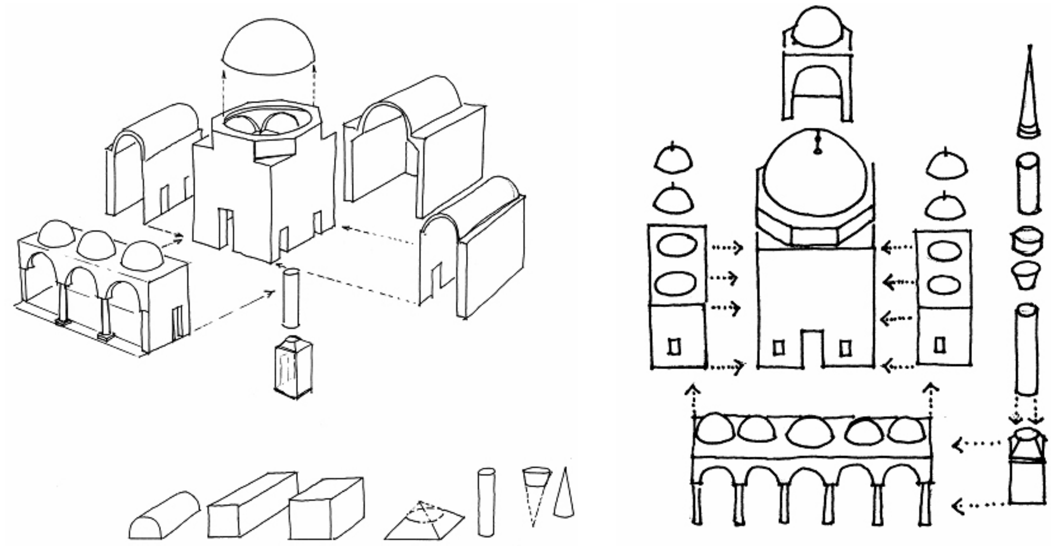

Figure 3 and 4: *Drawings about design components.*

Regarding to prove this hypothesis and to understand the proportional relations, characteristic mosques from the mentioned period has been selected to examine the proportional relations (Aksoy 2001). Departing from these studies, the proportional relations which are also used as the basic rules that constitute the shape grammar can be highlighted as follows:

- The height of the interior space is 1-1.5 times bigger than the diameter of the main dome.
- The width and the depth of the interior space are determined by the structural system selected for the main dome.
- The geometrical features of the selected structural system shape the interior and the interior elements.
- The height of the minaret is 1.5-2 times higher than the main dome height.
- Pieces that are determined by dividing the main dome establish the size of the pieces that form the spatial enclosure.
- Modules have being fixed in order to define mosque typology.
- Egyptian triangles, equilateral triangles or right-angled triangles are used as geometrical proportioning tools.
- The rectangular shape has been composed using equilateral triangles.
- The relationship between height and the other elements in section has been established by the use of equilateral triangles.
- The dome height of the entrance portico is mostly related with an element -like the bottom levels of the frame of main dome or the final point of the pendantive or of the vault, or the center of the semi-dome- from the interior space.
- The rectangular or square shaped plans have the possibility to enlarge the interior space easily by using semi-domes or supplementary components. Therefore in rectangular planned mosques the height proportion increases according to the diameter of the main dome, so that the width and height may enlarges further.
- The height of the interior space is 1.8-2.5 times of the main dome diameter.

- The width is 2- 2.5 times and the height is 2-3 times of the main dome diameter.

It is also observed that the hexagonal plan is capable to expand on the sides. The planar length is generally parallel to the diameter of the main dome, and the width dimensions enlarges maximum to the three times of the main dome diameter. In the hexagonal plan, the general height is 1.5 or 1.8 times of the main dome diameter.

On the other hand the octagonal plan discards the fragmentation of interior space. Furthermore, as the octagonal plan is not capable to expand on the sides, by using the semi-domes and supplementary components, the dimensions of the void remains parallel to the dimensions of the dome. In the octagonal plan the interior height is 1.5 or 1.8 times of the main dome diameter.

After the examinations it is understood that starting from the Anatolian Seljuk Era through the Classical Ottoman Period, not only a strong hierarchy in the formal configuration has been realized, but also a great endeavor has been observed in keeping these proportional relations, and avoiding any possible irregularities on grammar. This essential rule set is also used on configuration of the software, which will be explained in detail. The development of the software, the educative purpose is sought as the main goal, in the means of teaching the traditional configuration and proportions by using the solid grammar.

As the result, departing from the previous analysis on composition (Aksoy 2001) and shape grammar studies (Şener 2000) it is observed that: When spaces are conceived as the separate fragments, then a new shape grammar can be generated with only using the ‘additive rules’. The methodology that has been followed during the process of converting the information into an algorithm can be stated as the initial step of space formation, and moving to roof and other secondary design components is the following step. In this method, after the definition of possible spatial configuration, the configurationally patterns were uploaded to the database of the software (Karaman 2004). Preparing a shape grammar composer for mosques requires the initial definition of the rule sets for software. In order to define the rules of the spatial configuration, the following mosques were used as reference in the development of the software studies.

- Üsküdar Mihrimah Sultan Mosque. 1543-1547
- Zal Mahmut Paşa Mosque, 1572-1580
- Kılıçali Paşa Mosque, 1576-1580
- Süleymaniye Mosque, 1554
- Kadırga Sokollu Mehmet Paşa Mosque, 1569-1571
- Atik Valide Sultan Mosque, 1570-1583
- Rüstem Paşa Mosque, 1559-1562
- Mesih Mehmet Paşa Mosque, 1584-1586
- Nişancı Mehmet Paşa Mosque, 1588

2. Generatıng the software:

2.1. Theoretical background:

Researches of both Stiny (1976, 1980) about ‘formal compositions’ and ‘kindergartens’ and Mittchel’s (1990) are the fundamental source of this study. On the other hand, the methodology that has been used by Koning and Eizenberg (1981) in their shape grammar studies about Frank Lloyd Wright's Prairie Houses -dismantling the basic components from the compositional unity, and implicating the style and configuration-, shed light on the case studies of the research. Furthermore, the shape grammar studies of Çağdaş (1996) both about the 'traditional Turkish House typology' and the 'row houses' were the essential accommodators in the development of the rule sets. On the other hand the study of Agarval and Cagan (1997) about 'coffee machine' was the other input in this study. Not only the studies about shape grammar analysis were the stimulation of this work, but also the educative originated studies like Akın's (1996) -generating a database software for educational use- EDAT Software was the main incentive in the development of this software. Besides the Flemming's (1987) study on Queen Anne Houses, was also points an important impact on this study (Figure 4).

In the light of mentioned researches, the relations between components of a mosque were previously examined by Şener (2000) in his early studies. The preceding studies demonstrate how the formation of the components, their proportions and the additive rules were represented. According to these studies, during the process of achieving the final product, the additive rules are used before the subtraction and transformation rules, in order to obtain the final product (Karaman 2004). Figure 1 shows a diagram about the summary of this rule set.

Software that is developed operates through the 'additive rules'. The most important rule taken into account while structuring the algorithm is to avoid any deformation or subtraction applied to elements. The rule set depends only to the additive rules. Like a set of building blocks, these elements are stored on folders and selected files are uploaded to DXDraw window by the software.

2.2. Generating the rule set:

In case study, the mentioned mosques were examined in three steps: Examination of spaces of mosques; Examination of roofing systems of mosques; Definition of proportions and their examination in 2D and 3D environments.

In the first step, the *analysis of spaces* in the selected examples resulted with a branched diagram that also defines the rule sets (Figure 5). After determining the structural system, side naves -north and south- are placed to their posts one by one, by connecting to the main space. Software contains more alternatives then the number of example mosques. We can resemble the software to a set of building blocks, of which each block is placed around the main space according to rules defined (Figure 6). Figure 7 also shows some example variations on mosque spaces generated by the software.

Upon completion of spatial configuration, selection of *roof system* will be the second step. Figure 8 presents the covering systems used on example mosques. A selection has been made from a variety of roof types according to the spatial configuration.

On the third step, in the geometrical configuration and the *proportional analysis*, points of examination can be underline as follows: Definition of the methodology used in determining the spatial formation; The shape and proportional relationship of these units to each other; Dimensional relationships on plans, and the relation with the elements on sections…

The notion of geometrical and proportional configuration in Ottoman Architecture, has hardly changed over the centuries. And this consistency enables the set of rules that are used in common. The data, which would found the basis of the grammar rules that are essential in the development of the software, is obtained. The components, which are going to be used in the software, were selected, and the proportions were defined in the frame of Aksoy's (2001) and Şener's (2000) researches.

2.3. The logic of the software and its development:
The components of mosque, which are identified according to the constitution of the rule set, have been modeled using Cinema 4D software. These components then saved one by one in DirectX 3D format, in order to be read and used as an output by the DirectX library in Delphi. Following the logic of the algorithm, each element appears as 3D model and added up to the previous group of elements.

As mentioned before, if the system is considered like building blocks, every component of the mosque may be assumed as one block. We can think of a metaphor of having of all necessary pieces of a mosque in a box and each piece has only one place to go and the software does not allow the user place them incorrectly. Like a solitaire game, the pieces for the mosque shape grammar, selected by the user fall to their correct place and the pieces that can't be apart of the active composition get automatically disabled.

The components that may be added to the model are shown in colored, on the section numbered 1. The components that are not possible to add are grayed out. The algorithm updates all components after clicking on each by making them active (in color) or passive (in gray) (Figure 9). This limits the user to use repetitive or multiple elements. Software runs from top down meaning as selections being made and the top alternatives have being exhausted, the options from the next phase are enabled and shall be selected. Each time user makes a selection the item is being highlighted with a green frame to enable control of the element.

Maxon Cinema 4D is a tool for digital modeling, rendering and animation. It can be also define as a CAD system. By using the modeling tools, not only some primitive objects may form, but also other complicate forms may create by using various nurbs, and free-transformed liberated surfaces. The software allows the object formation by using low polygon modeling technique.

The C.O.F.F.E. scripts, which are integrated to the software with its editor and composer, can be programmed by using C++ programming language, or can be run externally as the plug-in of the software. The formed objects may save as various file formats, before being forwarded in to numerous preferred platforms.

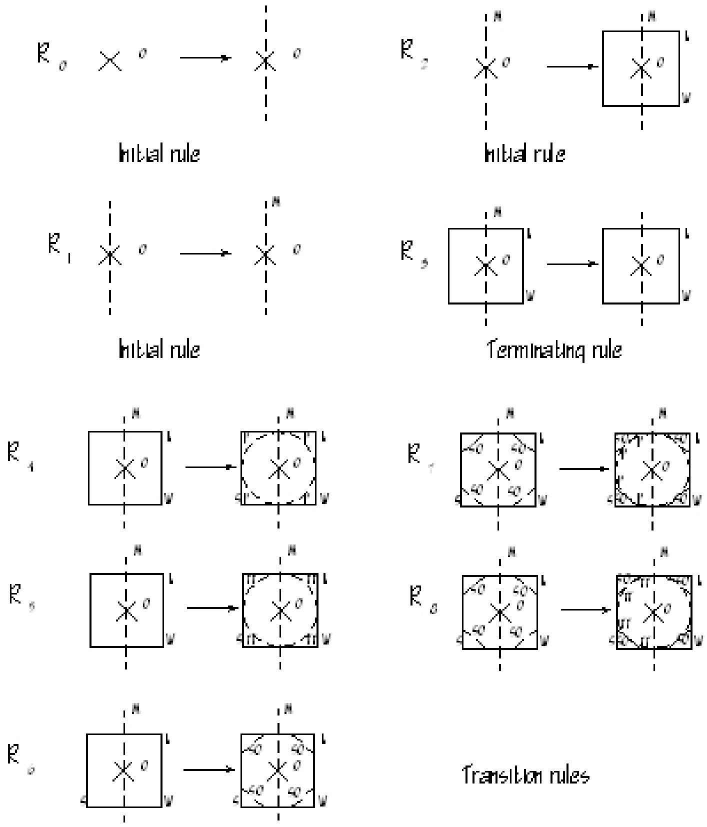

Figure 5. *Drawings about the rule sets.*

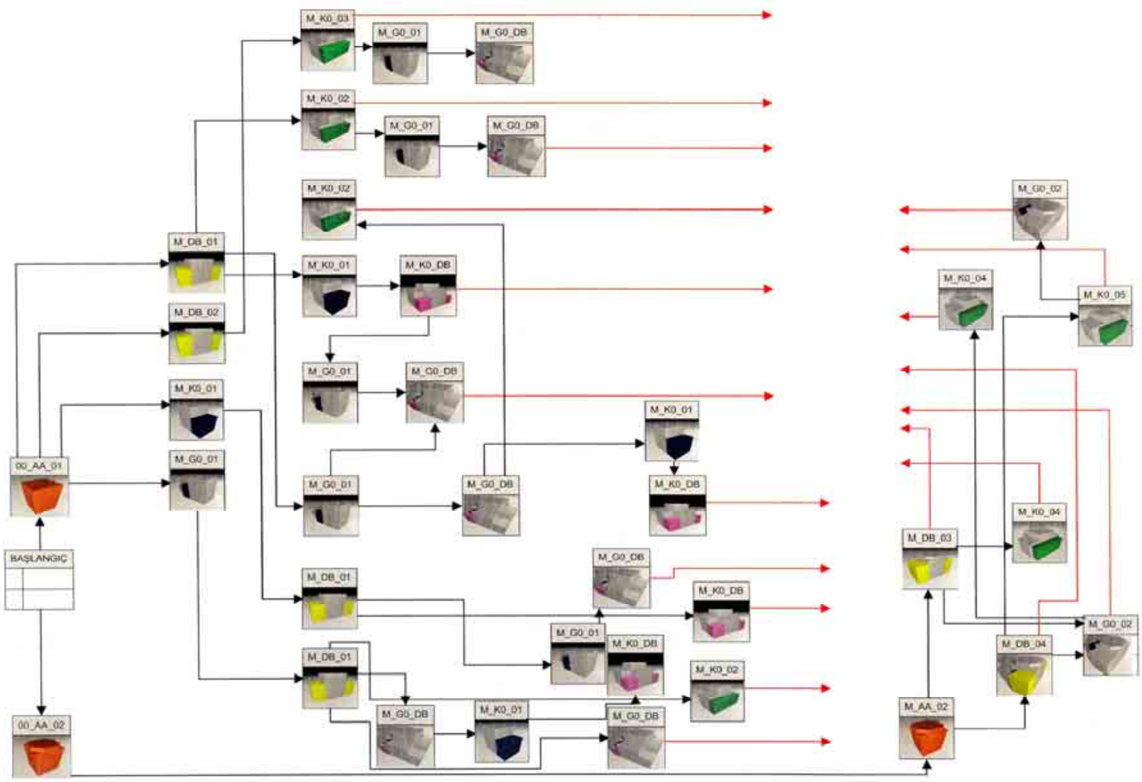

Figure 6. *Spatial probability diagram.*

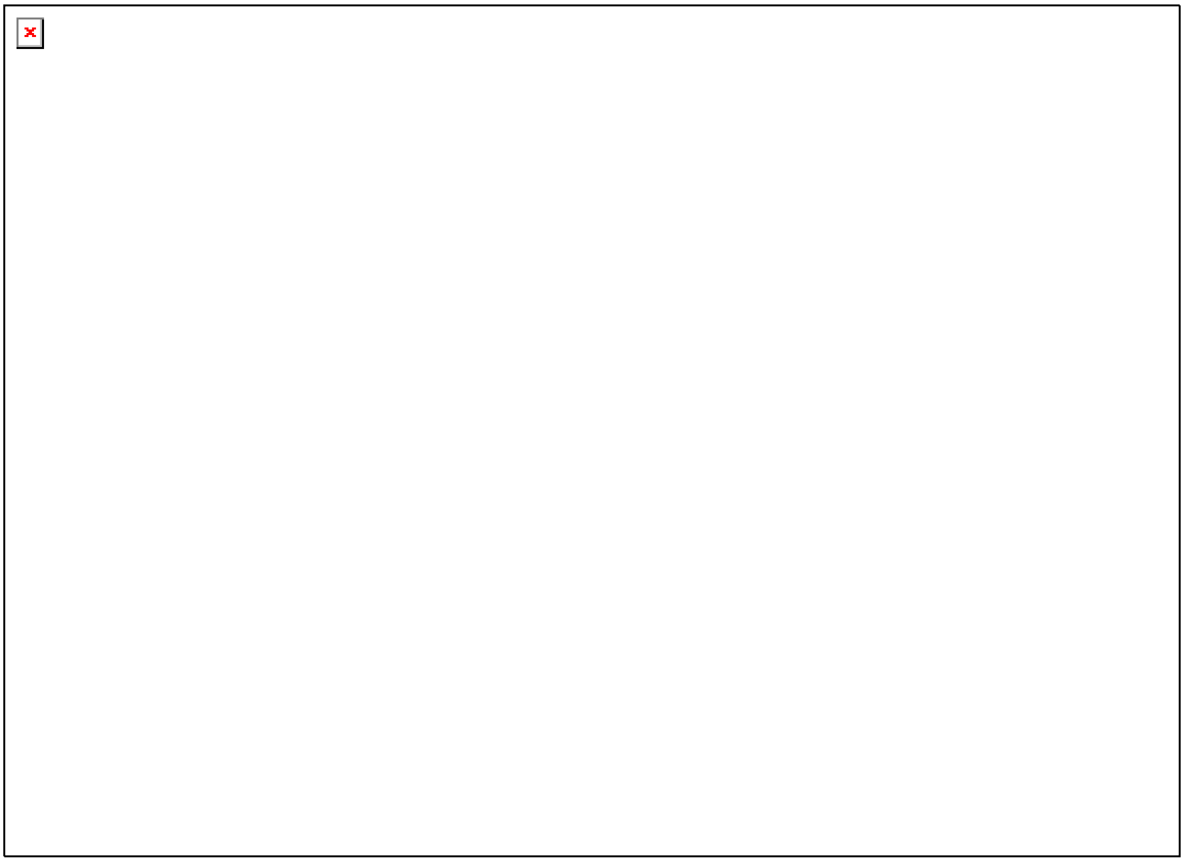

Figure 7. *Possible courtyard and minaret diagram.*

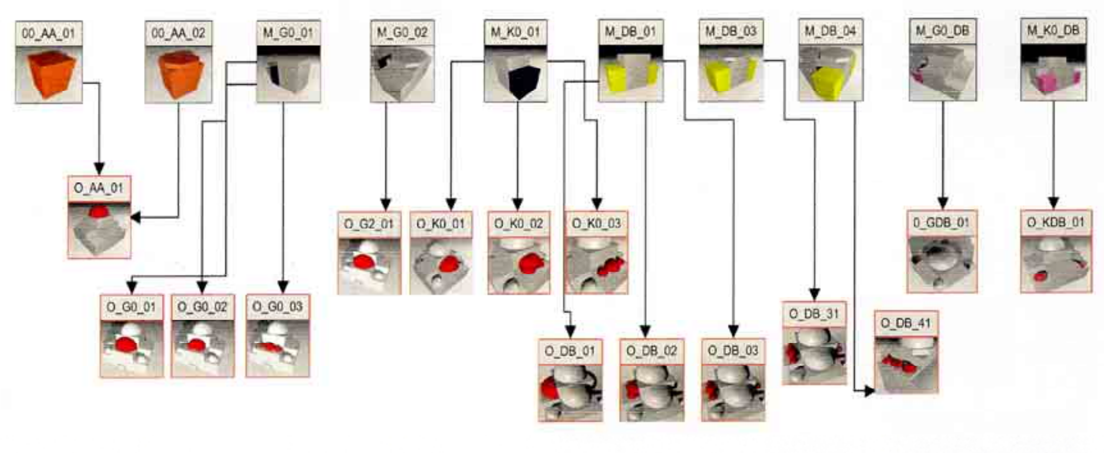

Figure 8. *Possible roof system diagram.*

The objectives of using Cinema 4D software in this study can be point out as follows: Creating the mosque forms as three dimensional primitive objects; The formation of objects by using modification tools in the necessary conditions; Easiness of undo actions. Adjoining the 3D objects easily and possibility of observing them as a whole. Easiness in the perception of the objects and possibility of coloring them on the operation screen by using Gouraud Shade method.

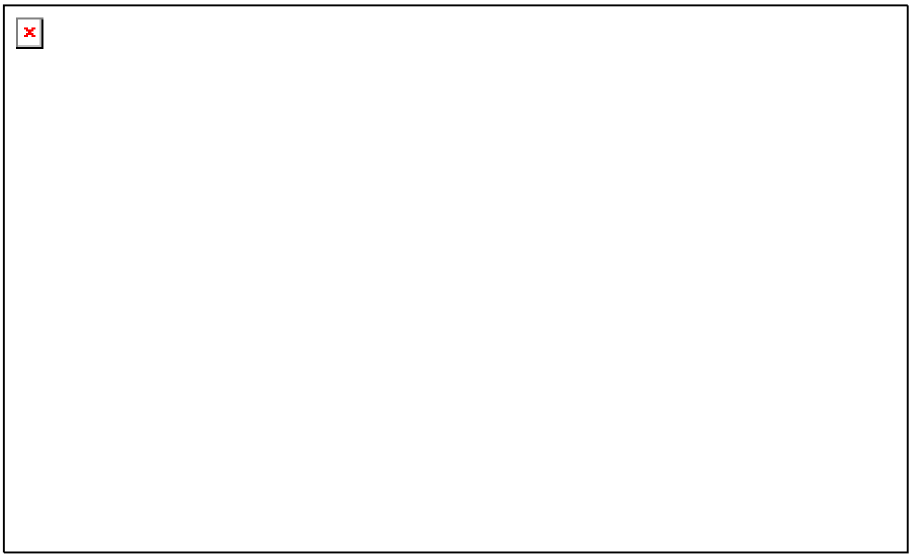

Figure 9. *Example interface of the program.*

2.4. The use of Maxon Cinema 4D and DirectX in the study:
The illustrations about the major spaces in three dimensioned presentations were constituted by Maxon Cinema 4D Software®. The spaces were the digitally modeled one by one, and they saved as separated X formatted files (DirectX files).

After determining the possible compositions of solid mosque variations, the objects are drawn to constitute as a total, by bringing out the essential proportions and the dimensions. The aim is both to examine the formal bonding of the objects, and to provide the appropriate formation of the every object in correct position with precise dimension. Afterwards the objects separated from this merged entire, and saved as DirectX 3D formatted independent files.[3]

After formation of these objects in a 3D environment, gathering of the pieces and the formation of the shape grammar are essential in the combination. Thus the use of Direct X gains importance with the advantage that provides for the study. As the final product of the project can be achieved with the help of these combinations, for the interpretations of the combinations by the computer, Delphi Program and Editor have been chosen. Editor Programs may not recognize the drawing files constitute by CAD applications. In this case, one thing that can be done is to complete the scripting of interpretation directly in CAD environment, or to merge the CAD application with editor in a common 3D environment. Therefore DirectX provides -us- an environment that both may recognizable by Editor, and can store the forms and shapes, which were drawn in general CAD applications.

In the DirectX library section, there exist other libraries for Delphi and other editors. In any case of lacking a library option, then there is a section available, which is coded to allow the scripting of DirectX and this editors component. So, this provides the basis that lets the programmer to constitute his own library when required.

In the practice, the saved X files which were stored separately, are recognized easily by Delphi, and reinterpret according to the flow of the

[3] This independent filing system provides the opportunity to the system editor to read these detached files when needed, and re-compose them according to the requirements of users. Besides, as every object would be placed in predefined locations, the bonding process would be without any problem.

program. The data, which has been up loaded to DXDraw screen, and reinterpreted according to the flow of the program, is presented to the user.

2.5. Programming to rule sets:
As mentioned before, the main aim of this software is to constitute the examples about possible mosque forms. To fulfill this condition, the spatial combination conditions on the 2D planar system are being examined, initially. Afterwards, the dome alternatives, which would cover the spaces, are determined. Following the 2D studies, the components are drawn in 3D, and accuracy of adjoining conditions is controlled. With the additions to the spaces, roofing systems and other sub-systems in the example mosques, the variations of the final product has amplified. Regarding to these variations, the tree diagrams which makes the program to run, is constituted.

During the software generation, when the adjoining principles of the spaces are determined, not only a structure has formed to constitute an example mosque. In this means, a component used in a building may also be used in another building too. This has provided the variety in product.

All the possible variations like; spatial probability (Figure 6), possible roof system (Figure 8), possible courtyard and minaret (Figure 7) configurations are formed by the software… For each icon a track has been defined and they named from 1 to 37 as 'image(x).procedure'. Some quotations from the program coding and their explanations are listed below as the example for the process.

The procedure definition for 'Image 2':

```
Procedure TMainForm.Image2Click(Sender: TObject);
Mesh definition for I/DXDraw screen
MeshBuilder: IDirect3DRMMeshBuilder

If image2.enabled then Begin
Status table [2] := true;
Last clicked:= 2.
  -        -        ,
Count := count + 1 ;
Begin

// Activation or Inactivation of the other icons related to this component

image3.Picture.LoadPromFile('iconlar\mekan\M- AA - 02-g.jpg');
image3.enabled:= false;
image4.Picture.LoadPromFile('iconlar\mekan\M - DB_O l.jpg');
image4.enabled := true;
image5.Picture.LoadPromFile('iconlar\mekan\M - DB - 02.jpg');
image5.enabled:= true;
image8.Picture.LoadFromFile('iconlar\mekan\M- GO - 01.jpg');
image8.enabled := true;
image 1 O.Picture.LoadPromFile('iconlar\mekan\M - KO - 01.jpg');
imageıo.enabled := true;

// Framing the icon by green color after the selection and uploading of the
other icons from the file.

image2.Picture.LoadPromFile('iconlar\mekan\M - AA - 01- Y.jpg');

// Uploading DirectX Files constituted related with the icon and other mesh
settings.
```

```
DXDraw.D3DRM.CreateMeshBuilder(MeshBuilder);
Mesh.Builder.Load(pChar('x\M_AA_Ol.x'), nil, D3DRMLOAD_FROMFILE, nil,
nil); MeshBuilder.Scale(0.002, 0.002, 0.002);
MeshFrame.AddVisual(MeshBUilder);

// Uploading the multi-controls in the program, level I_control procedure has
developed to control two or more components.

Level _kontrol();

// Locking of the icon to disable itself from re-clicking to avoid re-use of the
same icon, to configure subsequent uses of the same objects in the spatial
configuration.

image2.Enabled :0 false;
end; end;
```

When the rules are set, not only each unique clicking possibility is defined but also multi-control options (for one or more than one possible conditions) are defined. The code that is given above, explains the procedure definition of an icon given in a section. On the other hand, the example explained below, demonstrates the how, the two or more files that are related with an icon, are transferred to the DXDraw screen.

```
// Stating the definitions for icon 23

procedure TMainForm.Image23Click(Sender: TObject);

// Stating the definitions for mesh upload
MeshBuilder: Idirect3DRMMeshBuilder; Begin
Status table[23]:= true;
Last clicked:= 23.
  -          -          ,
Count := count + 1;

// Setting the conditions of other related icons, when icon 23 is selected

image24.enabled:= false;
image24.Picture.LoadFromFile('iconlar\kubbeler\O - GO - 02-g.jpg');
image25.enabled:= false;
image25.Picture.LoadFromFile('iconlar\kubbeler\O - GO - 03-g.jpg');

image23 .Picture.LoadFromFile('iconlar\kubbeler\O - GO_O 1- Y .jpg');
DXDraw.D3DRM.CreateMeshBuilder(MeshBuilder);

// Recall of necessary X files related to Icon 23.
Definition of ‘if then’ statement. Recognition of O_GO - O I.x or 0- G2 _O I.x
files if Icons 8 or 9 are selected.  Representatively, Icon 23 refers a dome that
will be located to the south nave. And it recalls as a dome file, which is in the
same character with the selected south nave, but in different dimensions.

İf status – table [8] then
Begin
MeshBuilder.Load(pChar('x\O _GO - Ol.x'), nil, D3DRMLOAD _fROMFILE, nil,
nil); MeshBuilder.Scale(0.002, 0.002, 0.002);
MeshFrame.AddVisua1(MeshBuilder);
End;
if status – table [9] then
Begin
MeshBUilder.Load(pChar('x\O - GO - Ol.x'), nil, D3DRMLOAD _fROMFILE,
nil, nil); MeshBui1der.Scale(0.002, 0.002, 0.002);
Mesh.frame.AddVisua1(MeshBuilder);
End;
İmage23.enabled := false;
End;
```

The *process of the program development* can be summarized as follows:

- Selecting the mosque components from the exemplary mosques
- Examining the adjoining of components first in 2D after 3D environments.
- Constituting the algorithm
- Drawing the elements in three-dimensional and inserting them in to three-dimensional views. Saving them as X files.

Reciprocally to the selections, the software recognizes the X files that are stored in the defined folders. And these files recall to the DXDraw screen. In this situation, the program can be compared to the data-base programs. But the number of the X files that are used in the program cannot be increased. The program is closed to the development, without constituting new X files, making any changes in reference code.

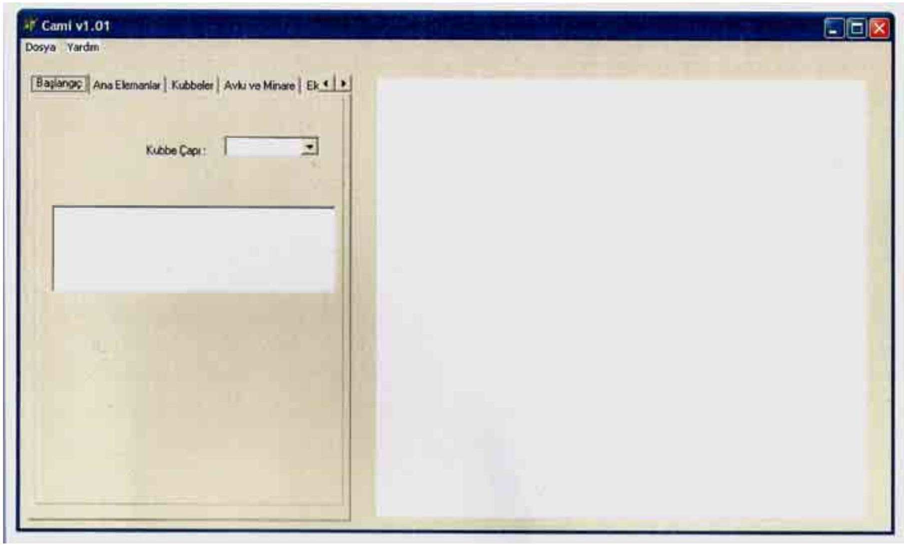

Figure 10. *Example from the opening screen.*

On the other hand after mentioning how the Delphi scripting operates in the software, it is essential to give a brief about the *software interface* (Figure 10). The basic points of *interface design* can be mentioned as follows; providing the easy access of the user to every functions and inputs according to the field of the use, the program, prohibiting the errors and obtaining the final product. On the other hand the orientation that is used in the determination / formation of the program interface can be highlight as follows;

- Determining the first criteria of user; the diameter of the dome.
- Selecting the components according to the determined dome diameter
- Obtaining the final product according to the determinations
- The hierarchical selection of the components; selection of the space, selection of the roofing system, courtyard, minarets.

The image of the program moving in the DXDraw screen disables the user and changes the direction of the movement. In the trials, the software operated according to the scripted algorithm, and the transfer performance of the X files to the DXDraw screen, is acted in the excepted levels. The control procedure that exists in the program code is configured and run to provide the possibilities of further developments in future. Covered system shape grammar application has successfully transferred from paper-based system to computer.

The *objectives* and the *results* of the software can be outlined as follows;

- Examining the typology of Classic Mosques and explaining the components to the users.
- Informing the users about the proportions of the components
- Defining the solid adjoining rules of the components to the user.
- Guiding the user about the possible size of the dome diameter, and activating the program modules after the selection of the dome diameter, and user orientation.
- Forbidding the user from making error in the selection of the mosque components, and explaining the rule sets to the user by this means.

3. Further information about the software:

3.1. The integration of the program as a plug-in with other 3D modeling programs:

As mentioned before existing program runs independently from the other programs in its platform. When the program integrated as a plug-in to another 3D modeling program, the possibility of developing the new program gains important. When the additions applied to the 3D engine, all the modeling application like, deformation and transformation specialties of the motor can be used. In the development phase of the program, unlike scripting a new algorithm for the mosques, a general shape grammar algorithm has been generated, which would also be an example for the future applications. A new system works as a shape grammar manager, which can test the complete grammar without re-programming for any other grammar applications. If the operating system of the program can be compared with the three diagrams, one or more deformations stimulated to every joint. And when the selection possibilities defined after the joints, all the shape grammar programs that require 3D inspection can be examined under this program. This can be interpreted as a shape grammar engine that can be designed for both an open or closed shape grammar applications and development.

3.2. Material and visuality in the digital representation:

After the detailed examination of the adjoining components for the product that appears on the DXDraw screen, they can model more specifically in the Cinema 4D program. The ornaments can be applied to the necessary spaces. Additional material mappings can be applied. By this means a more rich visually can be presented to the user in the final product. Further more with a render engine that can be integrated to the program, it is possible to obtain simple realistic renders and shadow light demonstrations.

With the introductory short movies, or with the real mosque images that can be inserted to the program commands, the components that are used in the program can be introduced to the user more detailed. These educational use exercises are important, so that with the help of visual elements the user can reach further information about the mosque architecture.

3.3. Possible use of the software in related fields:

The software provides the possibility to use it in *education*. With this software, the mosque components are introduced to the students, and the adjoining rules are taught. Students learn the essential components of the mosque by finding the correct configuration of the components in their tries. The program forbids the user from making any error. The adjoining rules of the components must be controlled in every command that has given.

The user finds the opportunity to examine their mosques in the solid configuration. All the components that the program uses are in accord with each other. Through the DXDraw window, user can follow the final product through different viewpoints, and able to change the viewpoints according to requirements. By this means the user find the opportunity to inspect the final product from various views.

The generated software may also use to prevent the *informal development* in architectural practice. Due to the Classical Mosque typology that has been mentioned on the previous paragraphs, the proportion holds an important role. Contrary to this approach, in the recent examples, the notion of proportion is not being paid attention and it is in misuse.

While the contemporary construction techniques, has make the constructions of mosques more easily, it leads the way to weaken the bonds of dependency of using the former components from the Ottoman Era. Unlike the opportunities of the technological promises, -from the current unappreciated examples- it is observed that the constructors or clients misuse these redundant components, and this miss-interpretation causes the formation of un-proportioned examples. For example constructing the minaret as high as possible, thinking that the mosque may appear more magnificent. Therefore it is so important that the program explains to user the proportions of the solid, to prevent these kinds of misuses. On the other hand, in the case of supplying an output demonstrates the sections of the spaces; this may help to avoid the un-proportional constructions.

3.4. Suggestions for the further development of the software:

Departing from the goals, the generated software has reached to the planned objectives scope, and it has been succeeded at its first trial. Consequently, for the further progress of the program, some suggestions can be offered both to the users and the developers.

For the *web-based applications*, the program can be run through the Internet, to reach more users. Besides, with a more open database, users can customize the program in the necessary cases, and even they can upload their X files. In this regards, the program turns in to a uniting and integrating engine. In addition, user can sign his personal algorithm through the web and thus defines his customized adjoining rules. The access of the other users can be disabled by a server-based system if needed. With the password system only the defined user are enabled to access the system. On the other hand during the program use, the user can reach to the statistical data like; the most used component, the final products…

For the *object-oriented applications*, a control procedure, which has been scripted for the components of the whole, is running in the existing program, and examines the adjoining rules. The program recognizes these components as X files only. On the other hand in an object-based program, all the components are kept with their names in the program. For example when the main space has constituted, the program defines the component that is used as the main space. It is easier to develop the program by this means. Furthermore with the affiliations to the object, individualized inspection can be made to preliminary and final products. When it is considered that the some construction cost and material information has been introduced to the system, for the added spaces. On the final product phase, these data is examined and departing from these a total value can be projected. The most important characteristics of the object-based systems are solving the definition of the objects and the gathering rules with an algorithm. The program recognizes the sub-spaces adjacent to the main space, and comments as positive or negative in the adjoining.

This software also supports the advanced studies about *façade systems* and *design*. As the program inserts the shape analysis that is studied for the facade, at the same time provides the solid and void proportions for the existing solid composition. By this means, new studies for production may become possible, and further with an output derived from the program, proportion and facade examination may be done.

The digital output module is consisted by sub-modules that enable transfers between other Windows based programs. With the help of these sub-modules, when the final product is achieved, the information transfer to any 2D or 3D drawing programs can be provided. With the solid analysis that has been constituted as mentioned above, a base for the production has been formed.

4. Conclusion:

The content of this study is generating a closed system shape grammar expert. Following step provides the possibility of computerized generation of a mosque, and adaptability of this application to other grammars. Unlike the recent expert systems, this software proposes a structure that can be used in further artificial intelligence applications.

The software that has been developed in this study, not only provides the possibility in architectural education use, but also conducts further information about the proportion to the architects. The software which has been developed by using CAAD and CAD systems is constituted with a background that can be integrated in to this systems in the future uses. And finally when it is integrated to a CAD system, a more powerful modeling motor can be obtained, and this provides the possibility of generating a multi-level open system grammar rules unlike an additive grammar.

References

Agarval, M., Cagan, J., (1997), 'Shape Grammars and Their Languages – A Methodology for Product design and Product Representation', **ASME Design Engineering Technical Conferences**, September '97, Sacramento, California.

Akın, Ö., Cumming, M., Shealey M., Tuncer, B., (1996), EADT, 'An Electronic design Assistance Tool'; **Case Base Representation of Design**, CMU, Pittsburg P.A., http:// www.andrew.cmu.edu/user/oa04/Papers/edatACADIA.pdf.

Aksoy (2001), Varol, Z., '**Klasik Osmanlı Dönemi Sinan Camilerinin Biçim Grameri' Açısından İrdelenmesi**', ITÜ Institute of Sciences, Master Thesis.

Çağdaş, G., (1996a), 'A Shape Grammar: The Language of Traditional Turkish Houses', **Environment and Planning B**, Vol. 23, p: 443-464.
Çağdaş, G., (1996b), 'A Shape Grammar Model for Designing Row-Houses', **Design Studies**, Vol. 17, No: 1, p: 35-51.
Fleeming, U., (1987), 'More than the Sum of Parts: The Grammar of Queen Anne Houses'**, Environment and Planning B**, Vol. 214, p: 323-350.
Karaman (2004), U., '**Klasik OsmanlıCamileri İçin Kütle Grameri Algoritması ve Eğitim Yazılımı**' , ITÜ Institute of Sciences, Master Thesis.
Konning, H., Eizenberg, J., (1981), 'The Language of Praire: F.L. Wright's Praire Houses', **Environment and Planning B**, Vol. 8, p: 295-323.
Krishnamurti, R., Giraud, C., (1986), 'Towards a Shape Editor: The Implementation of a Shape Generation System', **Environment and Planning B: Planning and Design**, p: 391-404.
Mittchel, W.J., (1990), '**The Logic of Architecture: Design Computing and Cognition**', MIT Press, Cambridge.
Stiny, G., (1980), 'Kindergarten Grammars: Designing with Froebel's building Gifts', **Environment and Planning B**, Vol. 7, p: 409-462.
Stiny, G., (1976), 'Two Exercises in Formal Composition', **Environment and Planning B**, Vol. 3, p: 187-210.
Stiny, G., Mittchel, W.J., (1980), 'The Grammar of Paradise: On the Generation of Mughul Gardens', **Environment and Planning B**, Vol. 7, p: 209-226.
Şener (2000), S. M., '**Shape Grammar Work on Classical Ottoman Mosques'**, Seminar at Carnegie Melon University, Department of Architectural Design Computation.

Klasik Osmanlı camileri için kütle grameri algoritması ve eğitim yazılımı

Bu çalışma, İTÜ'de yüksek lisans tezi olarak kabul edilen "Klasik Osmanlı Camileri için Kütle Grameri Algoritması ve Eğitim Yazılımı" tezi kapsamında hazırlanan biçim grameri algoritmasını ve yazılımını tanıtmaktadır. Bir kütle algoritması örneği olarak da kabul edilebilecek olan bu yazılımın ayırt edici özelliği Delphi üzerinde biçim grameri algoritmasını çalıştırmaya imkân vermesidir. Çalışma, eğitim amaçlı bir uzman sistemin mantık altyapısını kurarak, örnek bir model üretmek ve ilerdeki aşamada yapay zekâ programlama denemelerine temel oluşturmak amacı ile yapılmıştır.

Osmanlı İmparatorluğu'nun güçlü olduğu dönemlerde, imparatorluğun gücünü ve ihtişamının temsili olarak da kabul gören camiler zamanın en ileri inşaat teknikleri ile ve günümüzde dahi kabul gören estetik bir zarafet içinde yapılmışlardır. 1980 sonrasında, bu döneme öykünerek, Klasik Osmanlı Dönemi camilerinin taklidi niteliğinde yapılan camilerin büyük bir çoğunluğu, biçimlenişlerindeki ve oranlarındaki uyumsuzluklar ile onları özgün tasarım ilkelerinden farklı bir noktaya doğru yöneltmiştir. Yapılan yanlışların önüne geçmek amacıyla, gerek mimarlık mesleğine adım atan, gerekse de bu konuda bilgilenmek isteyen mimarlara kılavuz olabilecek bir yazılımın hazırlanması hedeflenmiştir.

Bu bağlamda; çalışma; bir algoritma çerçevesinde oluşturulmuş biçim gramerini bilgisayara yorumlatmak, bir sonraki aşama olan yapay zeka ile biçim grameri analizine salt yapı sağlamak, programı eğitim amaçlı bir sistem olarak kullanabilmek, programlama dilleri ile CAD sistemlerine entegre çalıştırmak olarak sıralanmaktadır. Yazılımın öznesi olarak, form ve oran bakımında oldukça zengin ve tutarlı bir dil oluşturan Klasik Dönem Osmanlı Camileri ele alınmıştır. Bu süreçte Anadolu Selçuklu Dönemi'nden Klasik Dönem Osmanlı Mimarisi Dönemi'ne kadar olan süreçte yapılmış cami örneklerini inceleyen çalışmalar ile yakın geçmişe kadar inşa edilmiş cami tipolojileri araştırılmış ve bunlar kütle gramerine dayalı olarak sayısallaştırılmıştır.

Çalışma, Şener'in (2000) daha önce gerçekleştirdiği 'Klasik Cami Mimarisi Biçim Grameri Kuralları' çalışmasından elde edilen bilgiler doğrultusunda, kütlesel açıdan inceleyen ve eğitim amaçlı kullanılacak basitleştirilmiş yeni bir kapalı gramer sisteminden hareket eder. Algoritmanın ortaya konmasının ardından, programın yazılması sürecinde; programlama dillerinden en uygun olanı seçilmiş, algoritma seçilen dil aracılığı ile bilgisayara tanıtılmış, bileşenler tekrar bu dile göre yenilenmiş, bir CAD sistemi ile bileşenler oluşturulmuş ve programın kodlanmıştır.

Bileşenlerin bir araya gelmesinde ebeveyn-çocuk (parent-child) ilişkisi irdelenmiş, daha sonra Delphi Programlama dili kullanılarak bu ilişki kontrol noktalarına aktarılmıştır. DXDraw'in kullanımı ile oluşturulan üç boyutlu nesneler sayesinde kullanıcının algılaması kolaylaştırılmıştır.

Söz konusu yazılım Klasik Dönem Osmanlı Camileri’ndeki kütlesel oran ilkelerini üç boyutlu olarak göstermekte ve cami bileşenlerinin birleşme koşullarını anlatmaktadır. Yazılım, cami tasarımı sürecinde, kullanıcıya bir lego oluşturur gibi caminin tüm elemanlarını belirli bir hiyerarşide sunar. Bu sayede en temel öğe olan kubbeden başlayarak, temel tasarım ilkelerine uygun bir şekilde, doğru oranlanmış birleşim elemanlarıyla son ürün oluşturulabilmektedir.