ANKARA YILDIRIM BEYAZIT UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES



PROCEDURAL MODELING OF MOSQUES

M.Sc. Thesis by

Elif YAYLA

Department of Computer Engineering

January 2019

ANKARA

PROCEDURAL MODELING OF MOSQUES

A Thesis Submitted to

The Graduate School of Natural and Applied Sciences of

Ankara Yıldırım Beyazıt University

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Computer Engineering, Department of Computer Engineering

by

Elif YAYLA

January 2019

ANKARA

M.Sc. THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"PROCEDURAL MODELING OF MOSQUES"** completed by **ELİF YAYLA** under the supervision of **ASSIST. PROF. DR. M.ABDULLAH BÜLBÜL** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

Assist. Prof. Dr. M.Abdullah BÜLBÜL

Supervisor

Assist. Prof. Dr. Hilal KAYA

Jury Member

Prof. Dr. Tolga Kurtuluş ÇAPIN

Jury Member

Prof. Dr. Ergün ERASLAN

Director

Graduate School of Natural and Applied Sciences

ETHICAL DECLARATION

I hereby declare that, in this thesis which has been prepared in accordance with the Thesis Writing Manual of Graduate School of Natural and Applied Sciences,

- All data, information, and documents are obtained in the framework of academic and ethical rules,
- All information, documents, and assessments are presented in accordance with scientific ethics and morals,
- All the materials that have been utilized are fully cited and referenced,
- No change has been made on the utilized materials,
- All the works presented are original,

and in any contrary case of the above statements, I accept to renounce all my legal rights.

ACKNOWLEDGMENTS

Firstly, I would like to express my sincere gratitude to my supervisor, Assist. Prof. Dr. M. Abdullah BÜLBÜL for his tremendous support and motivation during my study. His immense knowledge and precious recommendations constituted the milestones of this study. His guidance assisted me all the time of my research and while writing this thesis.

I am grateful to my friend Duygu DEMİRTÜRK for his support during my study.

Finally, I must express my profound appreciations to my family for providing me emotional support, loving care and continuous encouragement throughout my years of study and through the period of writing this thesis. This accomplishment would not have been possible without them. Thank You.

2019, 31 January **Elif YAYLA**

PROCEDURAL MODELING OF MOSQUES

ABSTRACT

Procedural modeling techniques are widely used in modeling architectural structures as well as natural structures. Procedural modeling continues to be the focus of interest in producing virtual environments with the potential to produce a variety of detailed content along with other advantages it provides. Procedural modeling, which is frequently used in the modeling of building facades, reduces the cost considerably.

In this study, we used procedural modeling techniques in the 3D modeling of mosques with quite a lot of detail. The purpose of choosing the mosque as modeling is the fact that it has detailed structures that do not exist in the building structure as well as cultural values. In our study, an approach is presented to the user by automatically modeling 3-dimensional mosques with the specific parameters taken from the user. The presented method determines the hierarchical parameters of the elements of the mosque according to the high-level parameters taken by the user and performs the modeling. Hierarchically designed parameters, while creating the semantics of the model, on the other hand, a system that the user can use without requiring technical knowledge is presented. The user can also intervene in the final design by modifying the low-level parameters in case of necessity. In this work, we present a system for modeling mosques with only little user intervention and we aim to extend the system to allow for modeling other cultural elements.

Keywords: Procedural modeling, computer graphics, mosque architecture.

CAMİLERİN PROSEDÜREL MODELLENMESİ

ÖZ

Prosedürel modelleme teknikleri doğal dokuların yanında mimari yapıların modellenmesinde oldukça yaygın olarak kullanılmaktadır. Prosedürel modelleme, sağladığı diğer avantajlar ile birlikte çeşitli ayrıntılı içerik üretme potansiyeli ile sanal ortamlar üretme konusunda ilgi odağı olmaya devam etmektedir. Bina yüzeylerinin modellenmesinde de sıkça kullanılan prosedürel modelleme maliyeti önemli ölçüde azaltmaktadır.

Biz bu çalışmada, oldukça fazla detaya sahip olan camilerin 3 boyutlu modellenmesinde prosedürel modellemeyi kullandık. Modelleme olarak camiyi seçmemizin amacı, kültürel değerlerinin yanında bina yapısında bulunmayan ayrıntılı yapılara sahip olmasıdır. Çalışmamızda, kullanıcıdan alınan belirli parametrelerle kullanıcıya otomatik olarak 3 boyutlu cami modelleyen bir yaklaşım sunulmaktadır. Sunulan yöntem kullanıcıdan aldığı yüksek seviyedeki parametrelere göre camiye ait elemanların daha alt seviyedeki parametrelerini hiyerarşik olarak belirlemekte ve modellemeyi gerçekleştirmektedir. Hiyerarşik olarak tasarlanan parametreler modelin semantiğini oluştururken, diğer yandan kullanıcıya teknik bilgi gerektirmeden kullanabileceği bir sistem sunulmuştur. Kullanıcı ihtiyaç duyduğunda alt seviye parametrelere de müdahale ederek tasarımda değişiklikler yapabilmektedir. Çalışmada dijital ortamda az müdahale ile cami modellerinin oluşturulmasını sağlayan bir sistem sunulmaktadır ve bu sistemin diğer kültürel öğelerin de modellenebilmesi için genişletilmesi hedeflenmektedir.

Anahtar Kelimeler: Yordamsal modelleme, bilgisayar grafiği, cami mimarisi.

CONTENTS

M.Sc. THESIS EXAMINATION RESULT FORM ii
ETHICAL DECLARATION iii
ACKNOWLEDGMENTS iv
ABSTRACT v
ÖZ vi
CONTENTS vii
LIST OF FIGURES ix

CHAPTER 1 - INTRODUCTION 1
1.1 Motivation 1
1.2 Scope of the Work 1
1.3 Contributions 2
1.4 Thesis Organization 2

CHAPTER 2 - BACKGROUND 3
2.1 Procedural Techniques Research 3
2.1.1 L-Systems 5
2.1.2 Fractals 7
2.1.3 Perlin Noise 8
2.1.4 Tiling 9
2.2 Related Works 10
2.3 Mosques 21

CHAPTER 3 - OUR WORK 24
3.1 Architecture of the System 24
3.2. Parameters 25
3.3 Procedural Mosque Generation 26
3.3.1 Find the Most Appropriate Rectangle According to the Given Polygon Information 26
3.3.2 Determining the Expected Size of the Mosque According to the Given Population Information 29
3.3.3 Modeling of the Mosque According to the Desired Method 31
3.3.4 Detailed Description of the Parameters 33

CHAPTER 4 - RESULTS AND FUTURE WORKS 47

REFERENCES 52

CURRICULUM VITAE 57

LIST OF FIGURES

Figure 2.1 City samples produced with different parameters [41] 4
Figure 2.2 Example of the parametric l-system [3] 5
Figure 2.3 Initial sequence of strings in Figure 2.2 [3] 6
Figure 2.4 Turtle interpretation of a string [3] 6
Figure 2.5 Parametric L-systems samples [3] 7
Figure 2.6 Koch snowflake [7] 8
Figure 2.7 A vase of volumetric marble texture formed by Perlin Noise [13] 9
Figure 2.8 A 2D game Mario [9] 10
Figure 2.9 Output of the Random3DCITY [22] 11
Figure 2.10 Examples of the city produced with 190 CGA shape rules [29] 12
Figure 2.11 A scenario with CGA++ [2] 12
Figure 2.12 Attribute Matching System [30] 13
Figure 2.13 Cartesian, cylindrical and spherical coordinate planes [31] 14
Figure 2.14 Modeling process of shape grammar [32] 15
Figure 2.15 The material and the building produced [33] 16
Figure 2.16 The framework of the city simulation model [34] 17
Figure 2.17 Input model and output model [36] 18
Figure 2.18 Semantic model of the geometry engine [37] 19
Figure 2.19 The procedural HBIM workflow [39] 20
Figure 2.20 Procedural modeling and other approaches [40] 20
Figure 2.21 Drawing of the side facade of the Suleymaniye Mosque [45] 22
Figure 2.22 Drawing of the top facade of the Suleymaniye Mosque [46] 22
Figure 3.1 Architecture of our work 24
Figure 3.2 View of the mosque area from Open Street Map 25
Figure 3.3 Area criteria 28
Figure 3.4 Different areas found in different polygons 29
Figure 3.5 Population and area information for mosques 29
Figure 3.6 Two-storey mosque according to population information 30
Figure 3.7 Four-storey mosque according to population information 31
Figure 3.8 Ottoman/Mimar Sinan style (style1) 32
Figure 3.9 Modern style (style2) 32

Figure 3.10 High-level parameters 33
Figure 3.11 Low-level parameters 33
Figure 3.12 Modeling steps 34
Figure 3.13 Masjid parameters 35
Figure 3.14 Example size of the window 36
Figure 3.15 Example size of the window 36
Figure 3.16 Masjid windows with style 1 37
Figure 3.17 Masjid windows with style 2 37
Figure 3.18 Mosque model with floor parameter 1 38
Figure 3.19 Mosque model with floor parameter 3 38
Figure 3.20 Ceiling parameters 39
Figure 3.21 Default sized domes 40
Figure 3.22 Mosques with different sized domes 41
Figure 3.23 Domes with windows and cubic structures 41
Figure 3.24 Minaret parameters 42
Figure 3.25 Mosques with two and four minarets 43
Figure 3.26 The modern style mosque has a single minaret 43
Figure 3.27 View of the minaret with two balconies and a crescent 44
Figure 3.28 Inner garden parameters 45
Figure 3.29 Inner garden with fountain 45
Figure 3.30 Examples of different areas that surrounding a garden wall 46
Figure 4.1 Hierarchical representation of the parameters 48
Figure 4.2 Example of different parameters 50
Figure 4.3 Example of different parameters 51

CHAPTER 1

INTRODUCTION

1.1 Motivation

There is a growing need for three-dimensional applications, imaging technologies, and three-dimensional content to be visualized through the widespread use of virtual reality environments. These developments are accompanied by efforts to make the contents easy and high quality. Even though the modeling software has been developed, the production of the 3D model with this software is very troublesome and time-consuming. The most time-consuming part is the creation of the geometry of the model, the acquisition of natural textures such as plants and waterfalls. With the development of technology, the need for detail and realism increases, making it difficult to meet expectations.

Along with computer technologies that have developed in recent years, modeling methods have also changed and it is possible to model natural structures such as plants, trees, and ecosystems in a realistic way and produce more natural scenes.

Meeting the need for modeling is possible by implementing procedural modeling techniques to achieve more detailed, more realistic, more natural structures. In order to create complex textures, to add noise to these textures, to model the life of different plants, to produce detailed surfaces such as skin, and to create 3D models, procedural techniques are used. With the help of procedural modeling techniques, the modeling of these difficult and complex structures takes place in a shorter time. The procedural techniques that help solve the problem of time and cost reduction enables us to create content fast and efficiently [8].

1.2 Scope of the Work

In our work, we focus on the procedural modeling approach so that 3-dimensional mosque models can be created automatically on large scale. Procedural modeling

techniques are used effectively in a wide range of detail areas such as urban planning, plants, and ecosystems, and produce complex structures from a small number of rule sets.

The procedural model starts at an initial state and the rules are applied repeatedly to the generated components. The structure of the model evolves hierarchically by adding increasing details. The best example of this is the L-Systems. L-systems were first used as a mathematical theory of plant development. The main theme of L-systems interpreted on the basis of turtle theory is based on rewriting [1-4].

1.3 Contributions

The most important contribution is the fact that the parameters used in the creation of the mosque model are within a hierarchical structure. The determined parameters consist of two parts. The first determined parameters are high-level parameters and the 3D model is formed according to the rules determined by these parameters. At this point, it is sufficient for the user to specify only high-level parameters for the model to be created. The user can intervene in low-level parameters if needed. This approach is a result of the hierarchical structure of the system and increases the importance given to the study.

A further advantage of the system is that the user annihilates the need for detailed technical knowledge of modeling. The semantic information in the hierarchy of the mosque parameters is sufficient for the user. In accordance with this information, sections such as domes, minarets, masjid part, masjid windows, courtyard, garden wall, which are part of the mosques, are modeled.

1.4 Thesis Organization

The thesis is organized as follows: Firstly, utilized concepts and background information are presented and then technical contributions are given. In the second part, basic procedural techniques, related works, and information about mosques are given. In Chapter 3, the steps of the study are explained in detail. Finally, in Chapter 4, the results of the study are presented with future studies.

CHAPTER 2

BACKGROUND

2.1 Procedural Techniques Research

In this section, we present procedural techniques and a number of applications in the field of computer graphics. The procedural technique dynamically constructs a structure with the help of a set of rules. The existence of rules plays an important role in creating different variations of the structure or geometry that is formed. These techniques are used to produce complex, repeating algorithms of L-systems, which produce natural structures such as a snowflake, plants, [5,6].

Ebert et al. specify the characteristics of successful procedural techniques as follows [7]:

Abstraction: With the minimum knowledge required for the production of the model, an algorithm can be created without the need for further details by a series of procedures.

Parametric Control: The parameters generated to control the necessary parts of the output produced by the developer corresponding to behavior in creating the procedure.

Flexibility: To overcome the boundaries, it is possible to produce different results by changing the specified parameters.

Procedural techniques have been successful in producing complex algorithms for many purposes [8].

Since the number of polygons forming the geometry or structures is not constant, the complexity or detail level of the procedurally generated models can be different. In this regard, the level of detail is particularly important in real-time applications [8].

Procedural Content Generation is used to avoid using too much of the workforce when considering the limited time and resource management while creating content with procedural techniques [41].

Numerous games are made with procedural content production techniques. No Man's Sky, BorderLands, Civilization IV, Minecraft, Spelunky are examples of 2D and 3D games. Olsson and Frank presented a study that showed that City Production could be done using Perlin Noise in their work. Perlin Noise is in section 2.1.3. The result produced with different parameters used to measure viability is shown in Figure 2.1 [41].

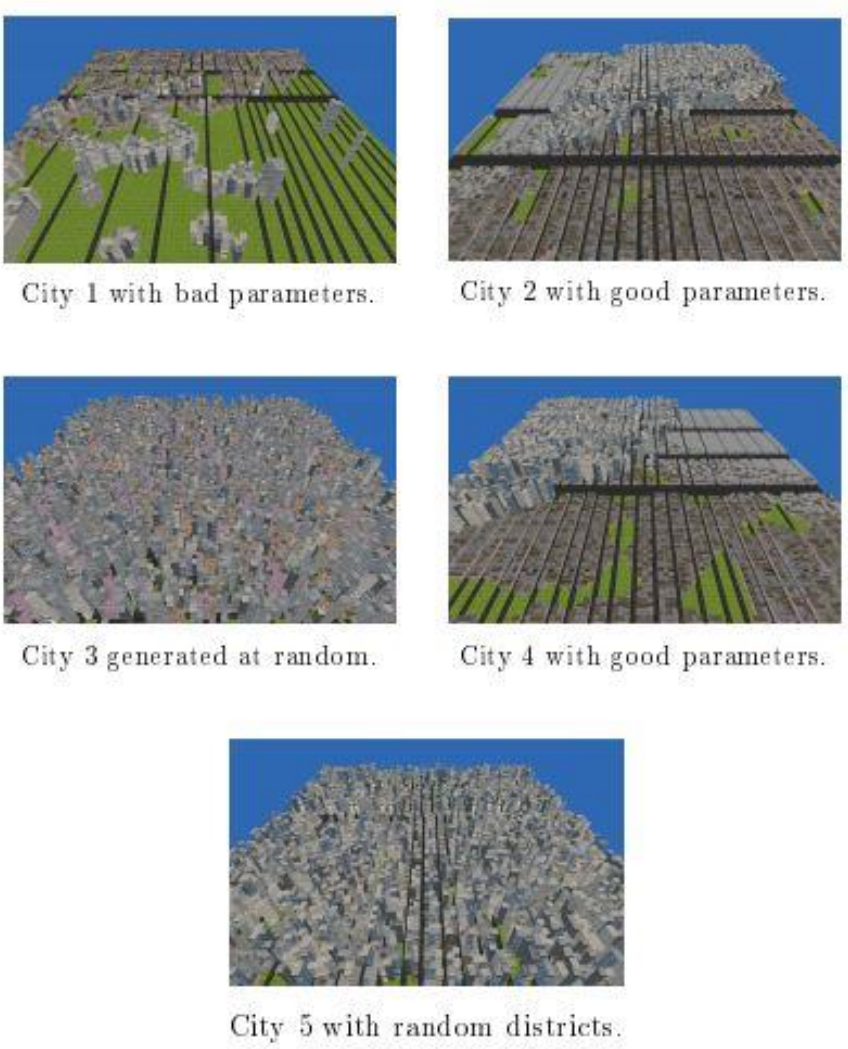


Figure 2.1 City samples produced with different parameters [41]

2.1.1 L-Systems

L-systems are a mathematical theory developed by biologist Aristid Lindenmayer [9]. It is designed to model the development of multicellular organisms and has become popular in the field of computers because of its similarity to automata [3]. The basic principle of L-systems is the formation of a complex structure by repeating some basic movements after a determined initial object [3,9].

G=<V,∑,ω, P> is defined in parametric L-systems which are suitable for modeling complex plant growth [3].

Here, these are represented,

- V the alphabet
- ∑ set of parameters
- ω axiom
- P finite productions

The rule of production: pred: cond -> succ.

Figure 2.2 shows an example of a string generated by the parametric 1-system [3]

$$
\begin{array}{lllll}
\omega & : & B(2)A(4,4) & & \\
p_1 & : & A(x,y) & : y <= 3 & \rightarrow \quad A(x*2, x+y) \\
p_2 & : & A(x,y) & : y > 3 & \rightarrow \quad B(x)A(x/y, 0) \\
p_3 & : & B(x) & : x < 1 & \rightarrow \quad C \\
p_4 & : & B(x) & : x >= 1 & \rightarrow \quad B(x-1)
\end{array}
$$

Figure 2.2 Example of the parametric l-system [3]

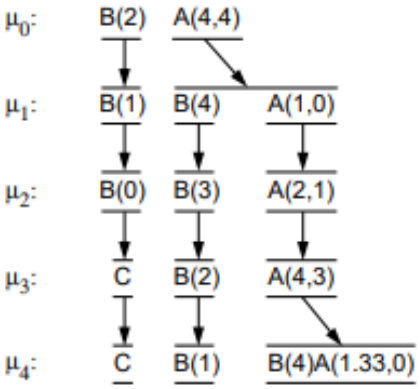


Figure 2.3 Initial sequence of strings in Figure 2.2 [3]

L-systems can be visualized using graphics instead of string structures [9]. Models produced by L-systems can be interpreted geometrically as turtle commands. The path that the turtle leaves behind with the instructions given at its current location is the interpretation of the tortoise of L-systems. Figure 2.4 shows the turtle interpretation of a string [3]. Also, in Figure 2.5, the examples of the parametric L-systems are shown.

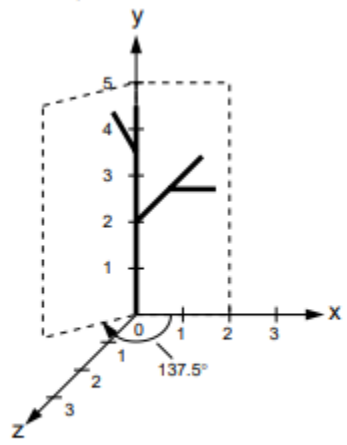


Figure 2.4 Turtle interpretation of a string [3]

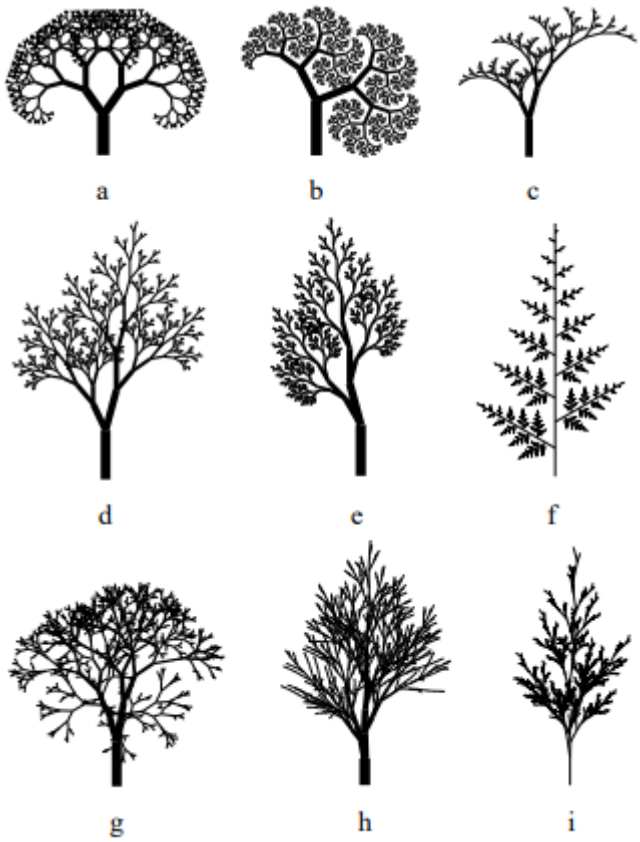


Figure 2.5 Parametric L-systems samples [3]

2.1.2 Fractals

The concept of fractal was introduced in 1975 by the word fractus, meaning broken in Latin by Benoit Mandelbrot. The shapes in nature are not regular, but cannot be easily identified because they show a rather complex structure [10].

The structure of the fractal can be described by its similarity to itself. Since fractal shapes have a continuous repetitive structure, they are deeper in detail. Therefore, they are expressed by repetitive algorithms. The best example is Koch Snowflake (Figure 2.6). Since there are no limits when repeating fractal structures, they have an infinite number of details [7,11].

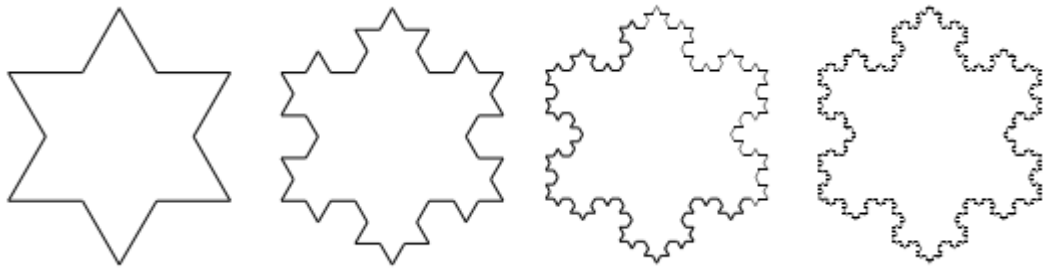


Figure 2.6 Koch snowflake [7]

Plants can be modeled with the help of trees or with fractions of various natural structures. Repeated algorithms are used to provide the desired level of detail. Thus, complex structures can be obtained by repeating simple equations [12].

2.1.3 Perlin Noise

Developed by Ken Perlin, Perlin noise is stretched to create natural textures. It was first used in the Tron film in 1982 as it was used in the modeling of tissues such as fire and clouds [5,9]. A few noise layers are assembled at the Perlin Noise to provide a smooth transition when the tissues pass from one point to another [9]. In contrast to two-dimensional textures with Perlin Noise, solid tissues can also be obtained [13]. Figure 2.7 shows a vase of volumetric marble texture formed by Perlin Noise. Transitions within the tissue are more realistic than those made by existing 2-D tissue techniques [14]. When the Perlin Noise is used with high-level parameters, a structure is created allowing the user to control the input and output. Thus, a wide variety of textures can be obtained and can be combined and repeated as tiles [9].

When noise is generated, the four corners of the square image represent four gradients. There are four vectors representing the difference between point and corner for a pixel. Perlin Noise computes a pseudo-random gradient at each of the eight nearest vertices on the integer cubic lattice. Then, it does a splined interpolation [47,48].



Figure 2.7 A vase of volumetric marble texture formed by Perlin Noise [13]

2.1.4 Tiling

Tiling technique, which is used frequently in computer games, is used in repetitive scenes in 2D games [15]. With this technique, detailed and repeatable structures are provided. Textures can be blended to model complex structures. Textures such as grass, rock, and sand can be used for land structures [9]. With the use of parameters, image maps can be created by changing factors such as height and slope [16]. Figure 2.8 shows a screenshot for Super Mario Bros., a 2D game [9].



Figure 2.8 A 2D game Mario [9]

2.2 Related Works

Given the considerable importance of automatic 3D building modeling, the existence of various approaches can be mentioned. These are laser scanning, handheld devices, conversion from architectural models, radar, and procedural modeling. It is inevitable to think together with the concept of the level of detail for each approach [17-26].

The concept of detail level is one of the basic concepts in 3D city modeling [26]. The LOD (Level of detail) concept is used to describe the geometric details of building models [27]. Biljeki and Stoter use this concept in their work to produce 3-dimensional city models procedurally, with multiple levels of detail. With the procedural modeling engine they developed, models are created in CityGML. One of the functions of procedural modeling engine Random3DCITY is the artificial modeling of buildings as in the real world and the other is to increase the number of models. In Random3DCITY, the example of Figure 2.9 shows 100 different buildings produced in 4 different detail levels. The locations and directions of these buildings have been determined at random [22].



Figure 2.9 Output of the Random3DCITY [22]

It is difficult to produce detailed and realistic buildings for the procedural production of a 3-dimensional building from a 2-dimensional area. Many studies on this subject are based on grammar, L systems or split grammar. [28].

In their study, Pascal et al. [29] describe CGA shape grammars, which have a new form of grammar and are used for the procedural modeling of the facade. With the grammar-based approach, complex models are produced more efficiently. In the study, finite basic shapes are passed through a production process with the help of a set of rules and modeling is completed. Firstly, a volumetric model is produced by the rules and then the details are added. In this process, the shape rules help to fulfill the hierarchical requirements set by the user. The creation of a hierarchical structure with details created by repetition is presented as an advantage of the study. With this structure, different kinds of architectures can be created with different complexities. Figure 2.10 shows an example of a city with 190 CGA shape rules written manually.



Figure 2.10 Examples of the city produced with 190 CGA shape rules [29]

In his study of Schwarz et al. [2], CGA ++ has been developed as a new procedural modeling language in architecture. Although there are very impressive results produced by existing grammar-based approaches, there are a number of obstacles to which modeling approaches will be implemented. One of these is that in many context-sensitive approaches, within the rules that determine how a form of development, there is no necessary information on other forms. Such challenges are overcome when developing this CGA++ approach. The grammar taken as input in the application in the study comes into the intermediate form after several operations and when the first shape is given, the leaf shapes are obtained as the final model.

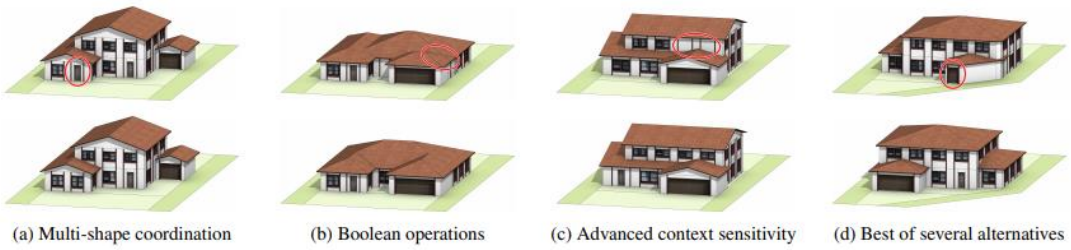


Figure 2.11 A scenario with CGA++ [2]

A scenario with CGA++ language is shown in Figure 2.11. In the scenario created with a house, a garage, and an additional building, many different structures are modeled. a) Modeling decisions work in a coordinated manner between many shapes and ensure that a door is absolutely formed. b) It is possible to create models with multiple shapes and a roof to cover the whole model is created to prevent overlap. c) Proper coordination is provided instead of removing partially closed windows. d) More than one alternative is possible and a selection can be made.

Another example of automatic work using shape grammar in architecture is the work of Wonka et al. [30]. The aim of this study is to develop an interactive application which works efficiently in partial or detailed parts of architectural structures with high detail. High-quality models are designed according to the information given by the designer and it is planned to create a model based on the accuracy of the model in the places where information is not given. The different aspect of other studies is to keep all rules in a single database, rather than creating a separate grammar rule for each model. Thus, there will be different options in the modeling stages. The Attribute Matching System (Figure 2.12) uses the rules to ensure the best match between shapes and features. Due to the flexibility of the system, both high and low-level designs can be created by changing the rules.

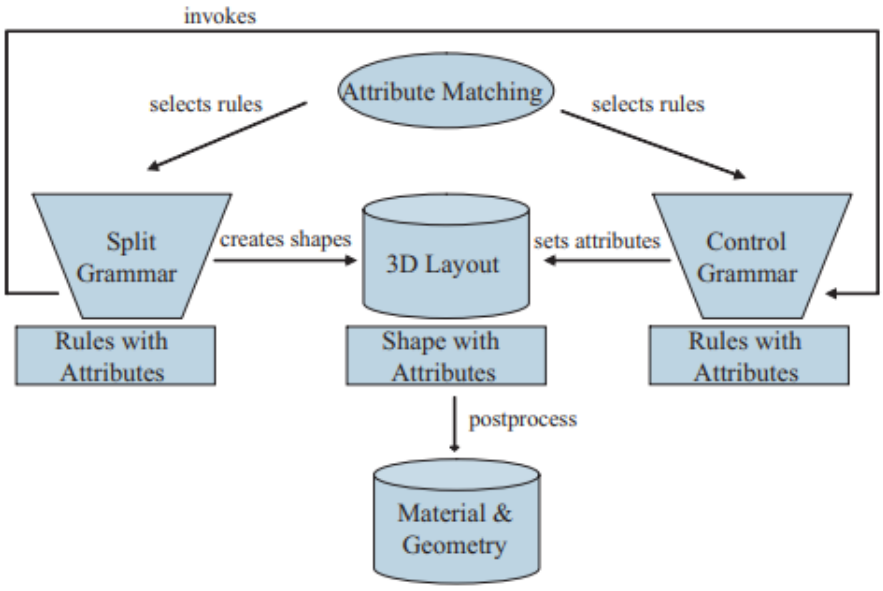


Figure 2.12 Attribute Matching System [30]

Edelsbrunner et al. Offer a new method [31] with the help of shape grammars in different coordinate systems for modeling round geometry. In the study, a cylindrical and spherical coordinate system has been developed for the creation of dome-like structures that can adapt to the different dimensions and parameters for the date models produced procedurally. Different from the cartesian coordinate plane, shape grammars were used in this method. Figure 2.13 depicts wall specimens that are separated into nine sections according to the procedure in cartesian, cylindrical and spherical coordinate planes.

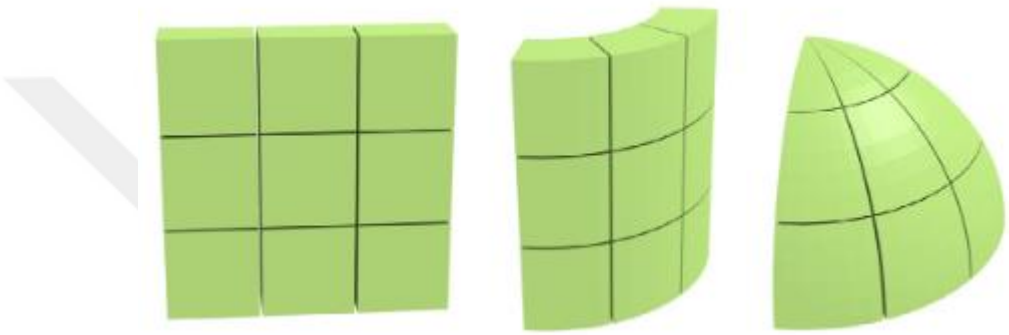


Figure 2.13 Cartesian, cylindrical and spherical coordinate planes [31]

In another study [32], a 3-dimensional simulation is carried out on religious buildings with similar typological features. In this study carried out on the buildings in the Vojvodina region, procedural modeling and a mathematical model were used together. CGA Shape Grammar was used to design the procedural model, while Fuzzy Logic and statistical analyses were used for the mathematical model. It is shown that a building can be modeled in an infinite variety by creating variations of a non-existent building that contains the characteristics of an example building group. Figure 2.14 shows the modeling process with details of a structure with the help of shape grammar.

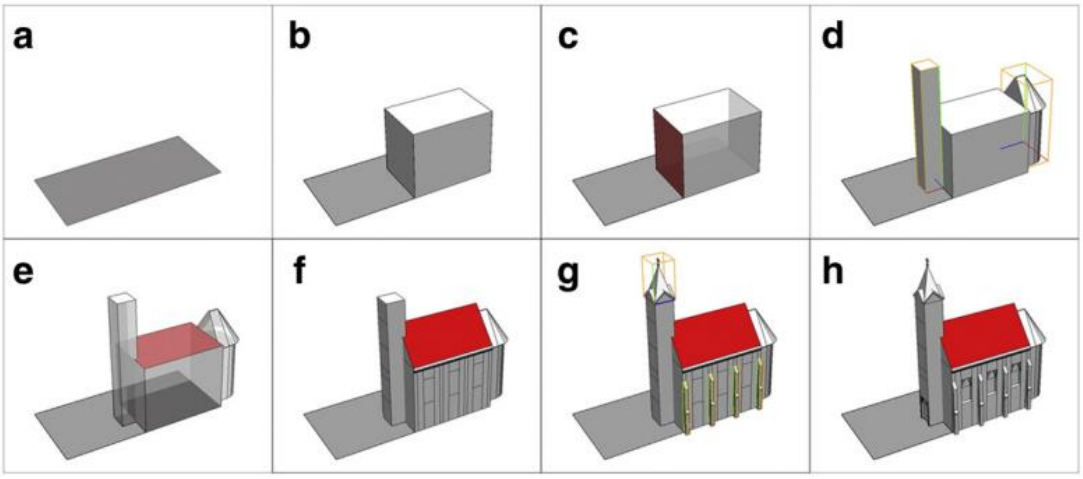


Figure 2.14 Modeling process of shape grammar [32]

Kelly and McCabe's work can be shown as a study where the user can see the effects in the system by changing the parameters. In this study, an automatic city-forming system with procedural methods is presented [33]. Ways to form the basic structure of cities are formed by the procedural methods used in the modeling of natural structures such as plants. Then, automatically removed buildings are added procedurally or manually. Buildings are constructed by determining the boundary of the polygon on the part created by the lot subdivision process. The control parameters determine which type of building is positioned. After the building is positioned, the formation of the model is completed from bottom to top. Thanks to the interface provided by the system, the user can control the specified elements and procedural production. The material used and the building produced are shown in Figure 2.15.

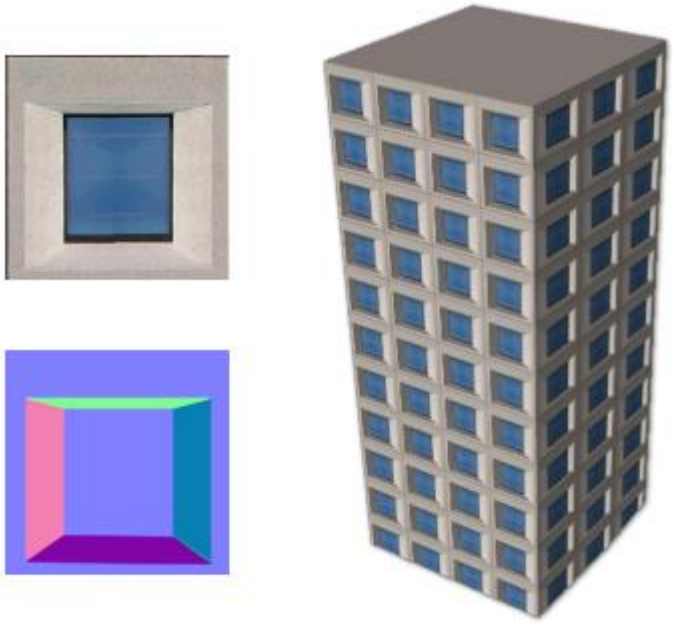


Figure 2.15 The material and the building produced [33]

In the urban simulation system whose parameters are population density, road, and land use information [34], the desired structure is obtained by creating a population map with population density information. The output is under control with fewer entries than the other studies. This platform is designed for complex city models. The output gives the user city layout, road network, and land use. Figure 2.16 shows the diagram of the study.

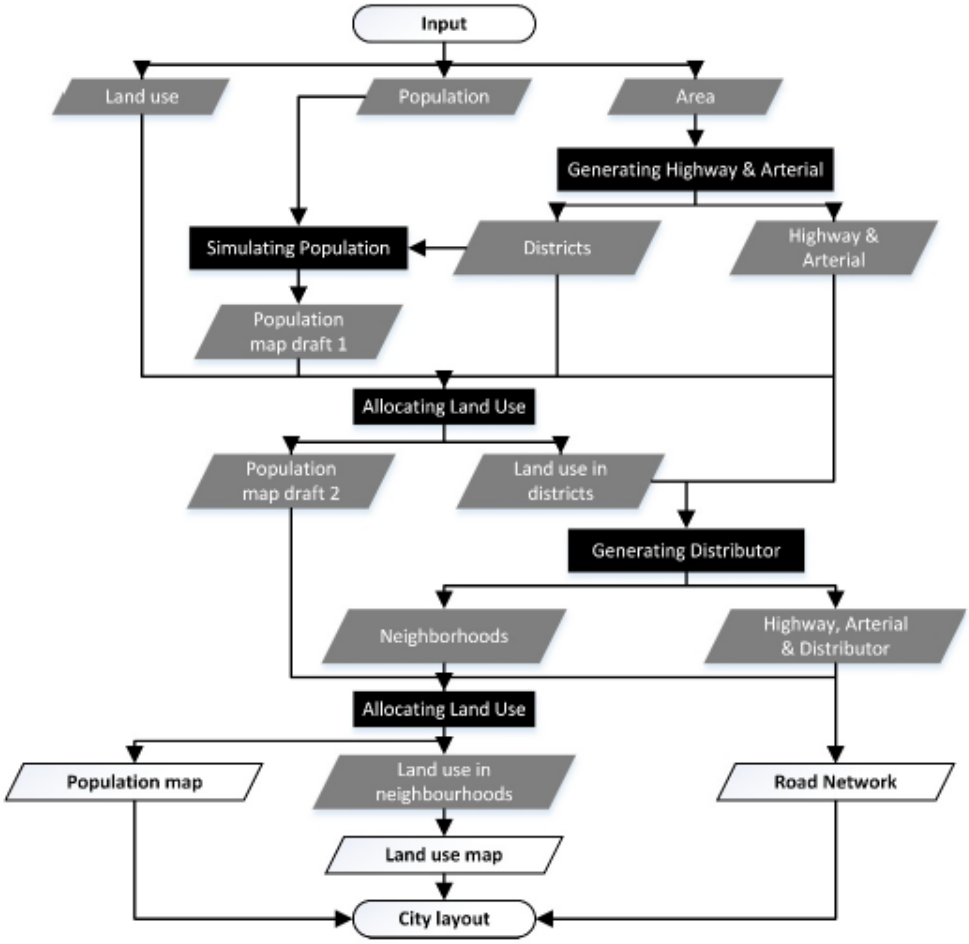


Figure 2.16 The framework of the city simulation model [34]

Uğur and colleagues' study [35] can also be shown as an example of a parametric approach to procedural modeling. In this application running on the web, a three-dimensional building model is created automatically according to a set of parameters specified by the user.

Merell and Manocha [36] propose an algorithm for the procedural modeling of complex and 3D structures. Various constraints have been used in order to have a more natural appearance of the outputs produced in this algorithm. The study produces a larger and more complex output with an input received in 3D with the model synthesis algorithm. The system takes a model as input and provides a complex output (Figure 2.17).



Figure 2.17 Input model and output model [36]

Although both the grammar and the other methods are very effective in studies, there is a number of studies in which the details or parameters of the modeled structures are kept in a hierarchical manner. In this sense, another study that helps the user to perform the modeling process can be shown in Finkenzeller and Bender's operation [37]. In this study, the necessary structural information together with the geometric structures related to the model expresses the semantics of the model. With the method based on the typed graph, the user can change the building he wants to model and the style of the building at a semantic level. This allows the geometry engine to generate more complex buildings faster.

The semantic model of the geometry engine where any style can be applied to a building is shown in Figure 2.18. It is possible for the user to make changes in the intermediate model stage where the building and style meet. The disadvantage of this method is that the study can only be applied in standard building types. Production in curved structures is not yet possible.

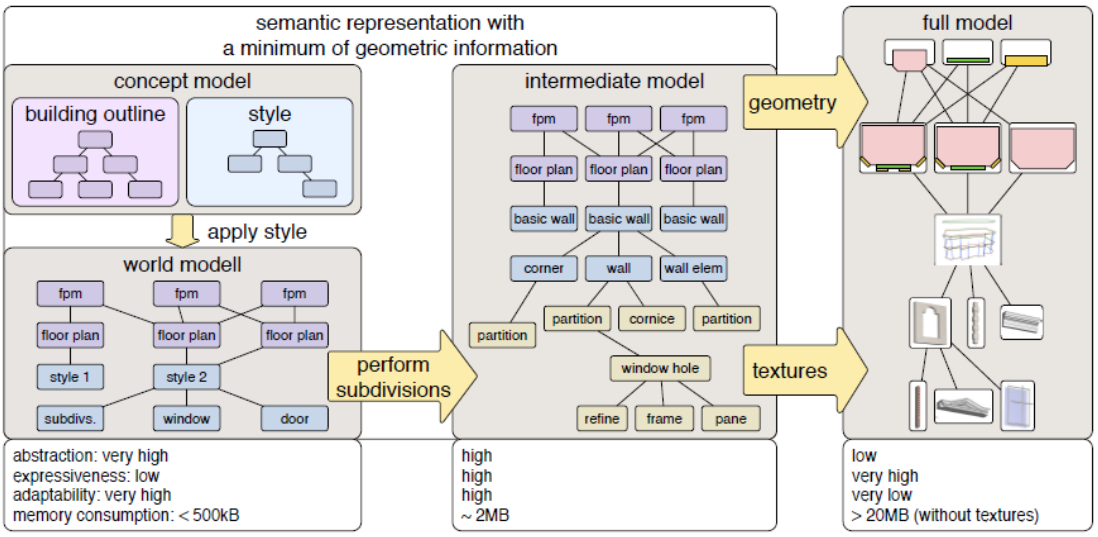


Figure 2.18 Semantic model of the geometry engine [37]

In another study [38], simulation of crowds with city semantics was made easier by procedural methods. The realization of more realistic scenarios is easier and faster with the rule-based approach by using the knowledge of individuals who make a simulation of the crowds important and the use of city semantics together.

It is possible to maintain damaged historical structures, even though zero-modeling is performed with procedural modeling methods. A laser scanning survey was conducted in 2014 to measure the impact of post-war damage on the Four Courts in Dublin [39]. Historical Building Information Model was created with the information collected here. The study consists of two parts. The first part of the Historical Building Information Model which contains the damaging information is formed while the second part consists of a dome and body which is completed automatically with procedural rules and algorithms. In order to complete the facades of the building, the plug-in has been developed to provide semi-automatic creation of existing models with procedural rules. The flow chart of the system is shown in Figure 2.19.

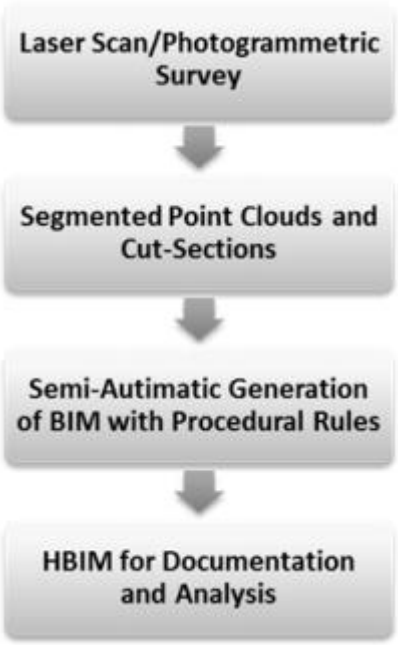


Figure 2.19 The procedural HBIM workflow [39]

Finally, in the study by Demir and Aliaga [40], due to the time-consuming processes of the architectural models, it is ensured that 3D cities can be created by procedural modeling by means of parameters. Improved procedure structure with user guidance is recommended. The user is allowed to select the best grammar each time. In this way, the user can control the characteristics of the grammar. Figure 2.20 shows a diagram of procedural modeling, inverse procedural modeling and guided proceduralization approaches.

	Process	Function	Approaches
Procedural Modeling	code →	$P(G) = M$	Wonka03, Muller06, Lipp08, Vanegas09, Schwarz15, ...
Inverse Procedural Modeling	code + target →	$P(G, T_M) = M_{opt}$	Aliaga07, Zhou12, Talton11, Vanegas12, Nishida16, ...
Proceduralization	→ code	$P^{-1}(M) = G$	Bokeloh10, Toshev10, Demir15, Demir16, ...
Guided Proceduralization	+ TaRgEt → CoDe	$P^{-1}(M, T_G) = G_{opt}$	This paper

Figure 2.20 Procedural modeling and other approaches [40]

2.3 Mosques

The mosque was defined as the place where Muslims gather to worship. The place of worship, originally called the masjid, was called mosque in time. While the cities or big mosques are called “great mosques”, the mosques built by the sultans are called “Selatin Mosques”. Although the mosque structures have been seen in different buildings in different periods, they have the characteristics that fulfill the basic purposes in the general structure. The mosque, due to its structure, represents the highest level of architecture and engineering. The first impression is the presence of domes on a prismatic body. In general, this structure has been preserved and has not undergone much change. The most basic structure of the mosque is that there is a wall perpendicular to the line coming from Mecca. This wall is also an indication of the Qibla direction. The mihrab on the wall is an important part of the mosque and it is the element that determines where the community in the mosque is facing [42,43].

Considering the highly developed Ottoman architecture, the main part of the mosque's prayer is called “sahn”. In some mosques, a portion of the prayer area is reserved for women to pray and this section is called “women's area”. In the exterior architecture, the main entrance which is designed with a portico is called the “narthex”. This section is designed so that those who are late for prayer can easily hear the voice of the Imam. The main entrance and narthex are the most important facades. In the middle of the portico, there is a fountain in order to get ablution. The minarets outside the Masjid and the narthex part are one of the most important external elements. On the minaret, a balcony to read the azan is called “şerefe”, the cone on the top and the motif on it are called the “alem” [42,43]. The sketch of the side and top of the Suleymaniye Mosque from the examples of Ottoman Architecture is shown in Figure 2.21 and Figure 2.22.



Figure 2.21 Drawing of the side facade of the Suleymaniye Mosque [45]

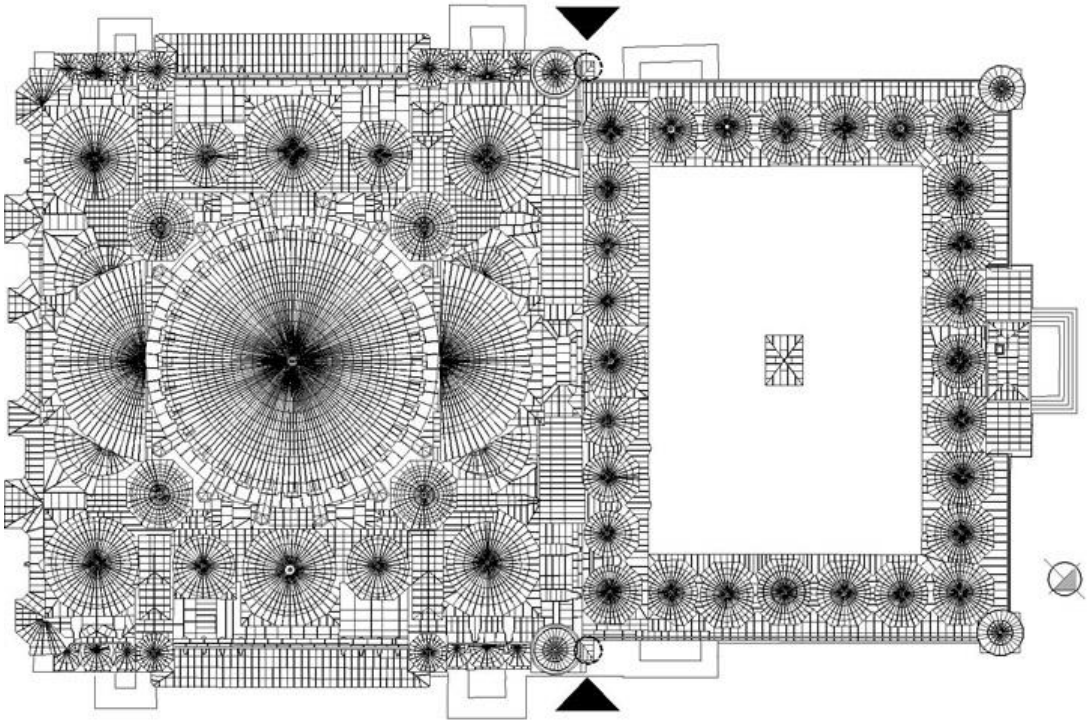


Figure 2.22 Drawing of the top facade of the Suleymaniye Mosque [46]

In the first mosque examples, mosques generally have a structure where important decisions are taken due to the social structure of that day. For this reason, the above-mentioned structures are not found in the first mosque samples. The first examples of the Ottoman architecture in the region of Bilecik, mosques in general, square-shaped, with a central dome and four-iwan stands out [42].

Mosques have a unique structure in our country and these structures have an important place in terms of cultural heritage and architecture. According to the statistics of 2016, there are 87381 mosques in our country [44]. Most of the mosques in our country are built in the style of Ottoman / Mimar Sinan or similar to them. Of course, each architectural work is unique with its distinctive aspects and design. However, although it may vary according to parameters such as capacity, landforms and allocated space, it is possible to mention the matured and stereotyped rules of mosque architecture for many years. The existence of such rules allows for the automatic creation of 3-dimensional mosque models for use in digital media.

CHAPTER 3

OUR WORK

3.1 Architecture of the System

In the presented study, 3-dimensional mosque model is formed procedurally according to the parameters obtained from the user. The application provides a system that allows the user to be involved in different levels of modeling. As shown in Figure 3.1, the user determines the basic parameters directly in the first stage. It is possible to intervene according to these parameters and detailed parameters which are formed according to certain rules. Then the 3D model will be formed by procedural modeling.

In the application, the parameters are taken from the user as a text file. While the system that takes the basic parameters from the user can model the mosque automatically, it is also possible for the user to interfere with the parameters that the system automatically determines.

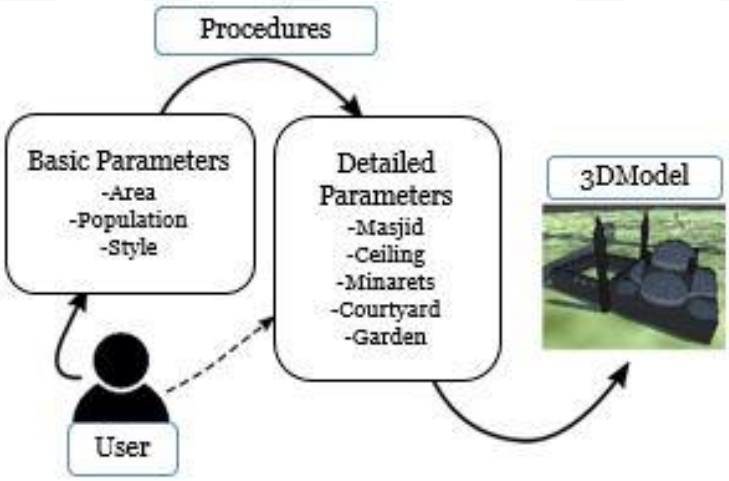


Figure 3.1 Architecture of our work

Modeling is carried out in the Unity[1] environment. Our 3D model is created on the map created by the data obtained from Open Street Map in the region specified as the mosque area. The polygon from the map may vary as a mosque area. The mosque model is

located in the area of these different polygons. Figure 3.1 shows the view of the mosque area from Open Street Map.

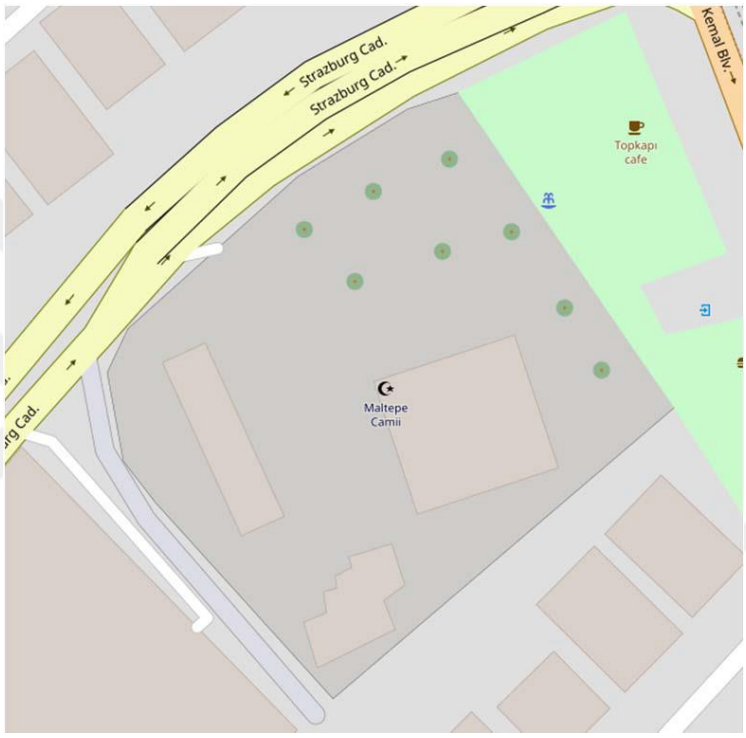


Figure 3.2 View of the mosque area from Open Street Map

3.2. Parameters

The basic parameters we use in our model are:

1- Given Area
2- Population information
3- Style

[1] www.unity3d.com

The second level parameters are determined automatically and our model is formed within the framework of these 3 basic parameters.

Our second level parameters are:

1- Masjid Walls
    a. Size of Windows
    b. Type of Windows
    c. Number of Floors
2- Ceiling
    a. Size of Domes
    b. Window of Domes
    c. Cubic Structures
3- Minarets
    a. Number of Minarets
    b. Number of Balconies
    c. Crescent
4- Inner Garden
    a. Walls
    b. Domes
    c. Fountain
5- Outer Garden

3.3 Procedural Mosque Generation

3.3.1 Find the Most Appropriate Rectangle According to the Given Polygon Information

The field information received from the map gives us polygon information that is not fixed. Each field is different from each other. According to this polygon information, the appropriate area is determined according to the chosen mosque style.

When the mosque is to be modeled in Ottoman architecture style, which is generally characterized by its square structures, the most suitable rectangle is determined within the polygon. To find the most suitable rectangle, the appropriate field is determined by the brute force method. In order to find the optimum area of the application, the most suitable rectangle is selected among all the rectangles found by the algorithm used. In order to decide this, we have a set of criteria (Figure 3.3). These are,

- The ratio of the rectangle that resembles the square

Since the mosque is a square structure, we determined the weight coefficient of this criterion as 2.

- Size of rectangle

This criterion has been added to find the largest area within the given area. The weight coefficient was calculated as 1.

- The coordinate of the rectangle in the area closest to the qibla

Since the remaining parts of the mosque in the given polygon will be a garden of the mosque, the fact that the mosque is as close to qibla as possible is selected as another criterion and its weight coefficient is determined as 1.

All rectangles in the polygon given according to these criteria will have a certain score value and the rectangle with the highest score will be selected as the optimum rectangle.

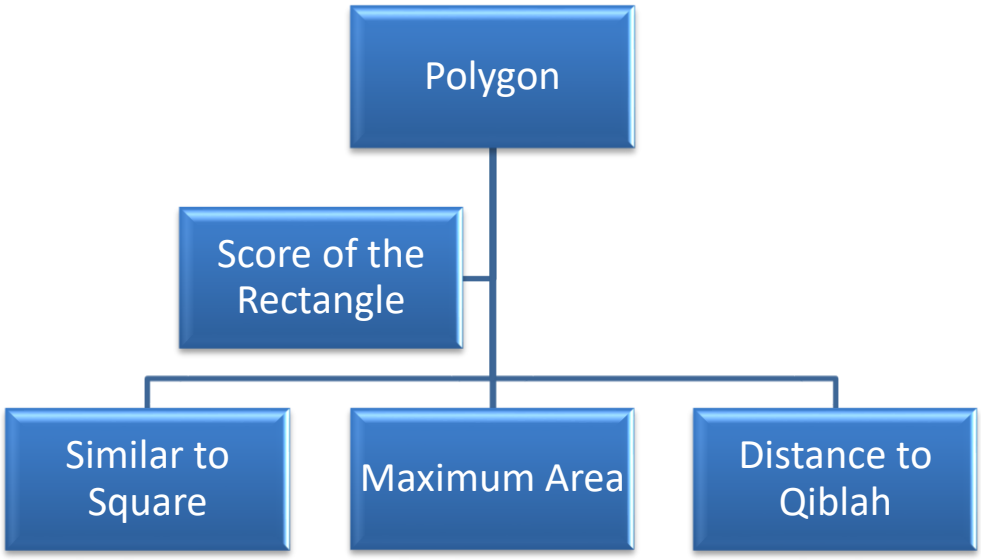
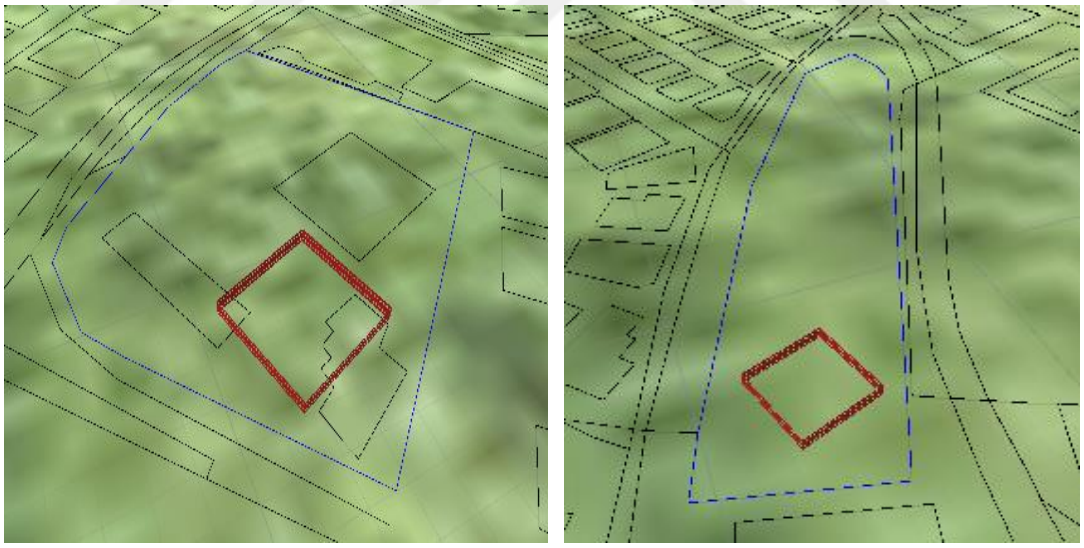


Figure 3.3 Area criteria

The examples of the most suitable area selected for different polygons from the user in our study are shown in Figure 3.4.



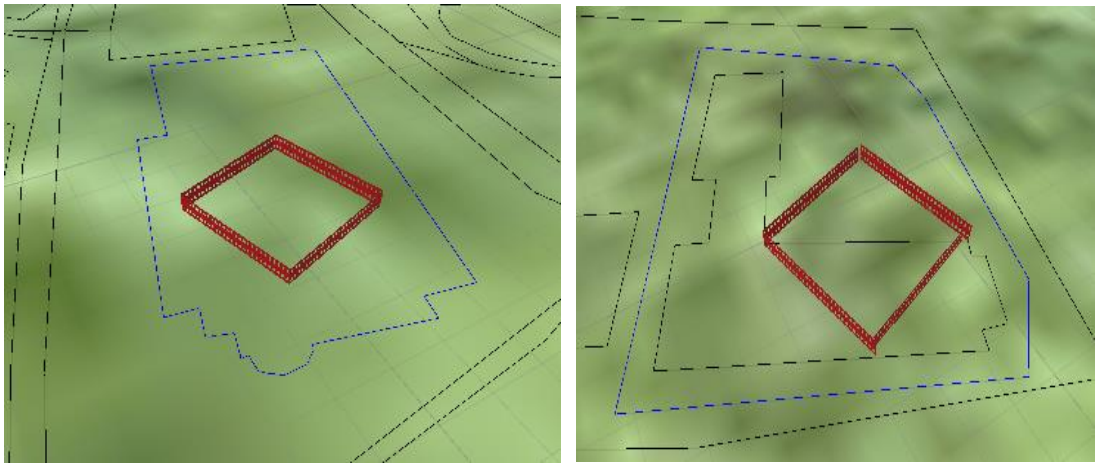


Figure 3.4 Different areas found in different polygons

3.3.2 Determining the Expected Size of the Mosque According to the Given Population Information

According to the Ministry of Environment and Urbanization Regulation on the Construction of Spatial Plans, the size of the space required for the small, medium and large places of worship determined in accordance with the required area and population per person is shown in Figure 3.5.

EK-2 TABLO		FARKLI NÜFUS GRUPLARINDA ASGARİ SOSYAL VE TEKNİK ALTYAPI ALANLARINA İLİŞKİN STANDARTLAR VE ASGARİ ALAN BÜYÜKLÜKLERİ TABLOSU							
NÜFUS GRUPLARI		0 - 75.000		75.001- 150.000		150.001 - 500.000		501.000 +	
ALTYAPI ALANLARI		m²/kişi	Asgari Birim Alan (m²)	m²/kişi	Asgari Birim Alan (m²)	m²/kişi	Asgari Birim Alan (m²)	m²/kişi	Asgari Birim Alan (m²)
İBADET YERİ	Küçük ibadet yeri	0,50	1.000	0,50	1.000	0,75	1.000	0,75	1.000
	Orta ibadet yeri		2.500		2.500		2.500		2.500
	Büyük ibadet yeri ve külliyesi		10.000		10.000		15.000		15.000

Figure 3.5 Population and area information for mosques

Based on the information given in the table, we determined 0.5 square meters per person in our study. Similarly, we have performed our study taking into account the minimum number of fields given according to other population information.

In light of this information, we aim to draw a mosque in the most appropriate way. For this, if the area of the rectangle with the highest score within the polygon does not meet

our population needs, then the capacity is increased according to the desired population by adding a floor to the mosque. The purpose of this application is that the capacity of the mosque to meet the needs of the region. Two different examples according to the population are shown in Figure 3.6 and Figure 3.7.



Figure 3.6 Two-storey mosque according to population information

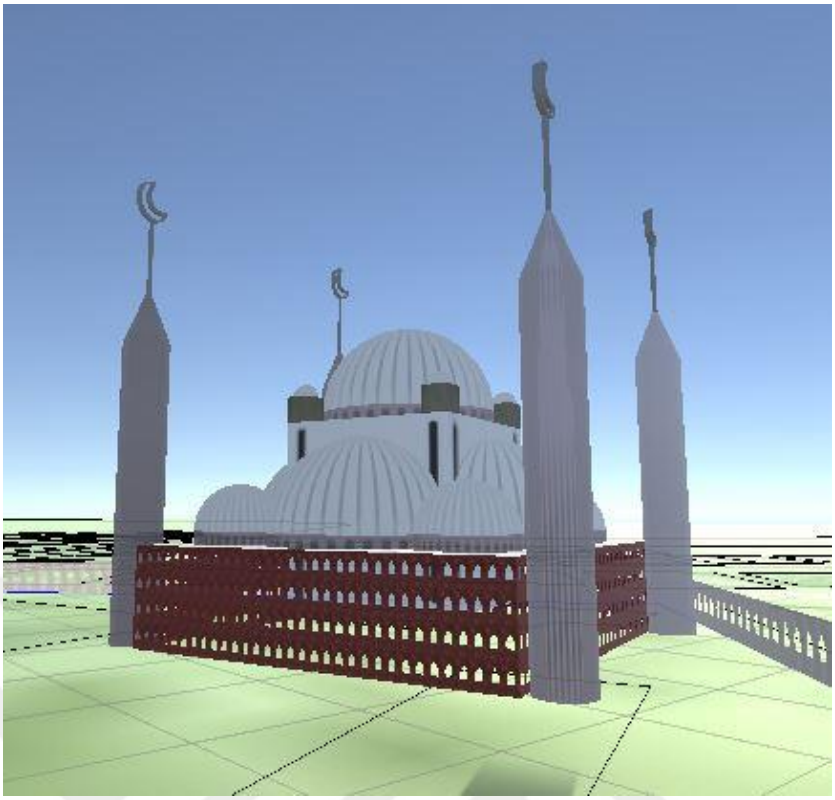


Figure 3.7 Four-storey mosque according to population information

3.3.3 Modeling of the Mosque According to the Desired Method

Our goal in the study is to enable the user to model the mosque according to the styles he wants. There are two different styles in our application: classic style (Ottoman/Mimar Sinan style) and modern style. The user can choose from these two styles. In the classical style, the square mosque structures that we observed in the Ottoman Architecture are exemplified. The details of these structures constitute the largest part of our application. The modern style mosque model, which we add in other ways, shows that the application can be applied separately according to different styles. Since each style has its own characteristics, each property means a set of rules to be reproduced on the modeled mosques. We have outlined the criteria for modeling the classical style mosques that form the main part of our study.

Figure 3.8 shows a classical mosque model. In Figure 3.9, an example of a modern mosque was modeled.

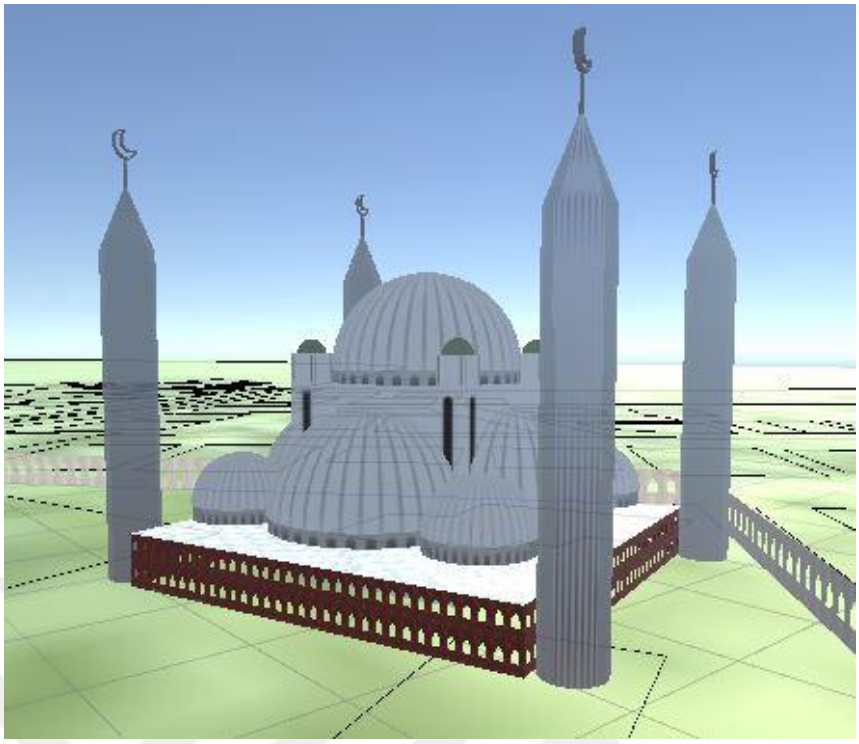


Figure 3.8 Ottoman/Mimar Sinan style (style1)

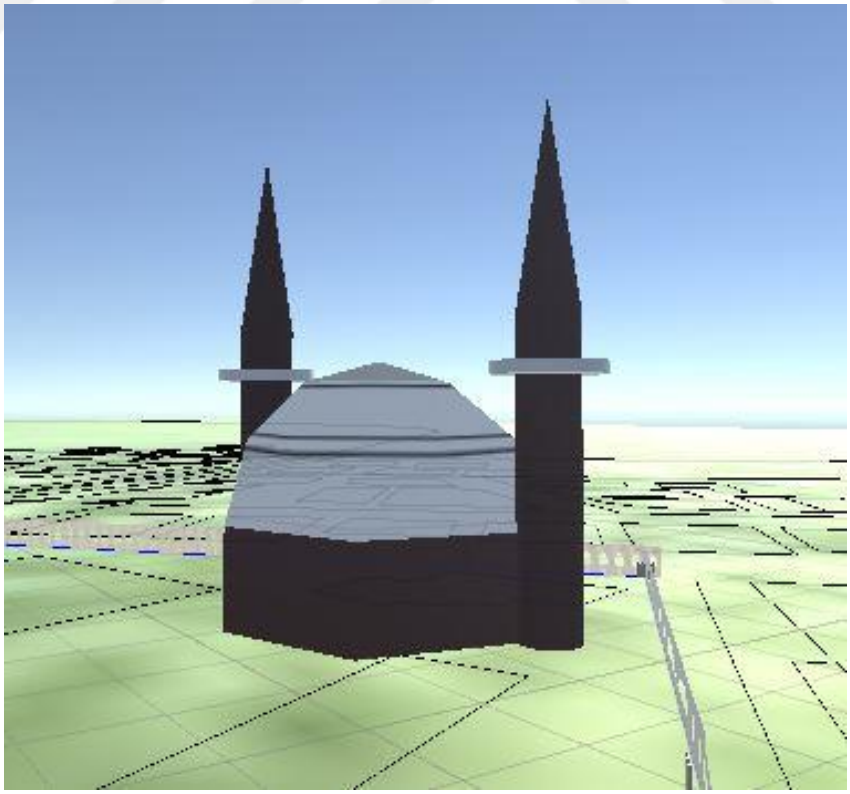


Figure 3.9 Modern style (style2)

3.3.4 Detailed Description of the Parameters

An overview of the low and high-level parameters is shown in Figure 3.10 and Figure 3.11.

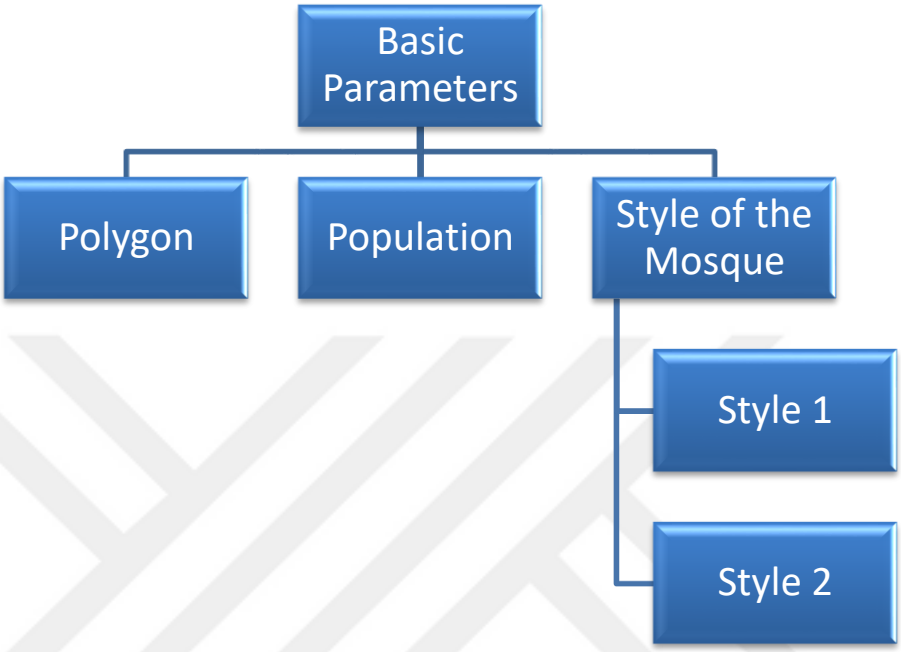


Figure 3.10 High-level parameters

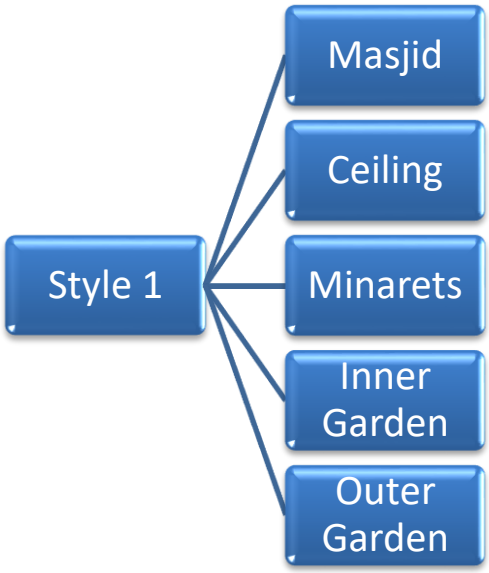


Figure 3.11 Low-level parameters

Firstly, Masjid is created according to the selected area for style 1. In the masjid part, there are windows which repeat on the selected area. Then, the roof covering the masjid is created and the ceiling part is modeled. In this part, the biggest dome is modeled in the middle of the masjid area then other mini domes are created. By default, the diameter of the biggest dome is one-third of the diagonal of the masjid.

Minarets are placed in 4 corners of the mosque. Optionally, a courtyard is added to which a fountain can be added, and finally, an outer courtyard is created on the area taken. The steps are shown in Figure 3.12.

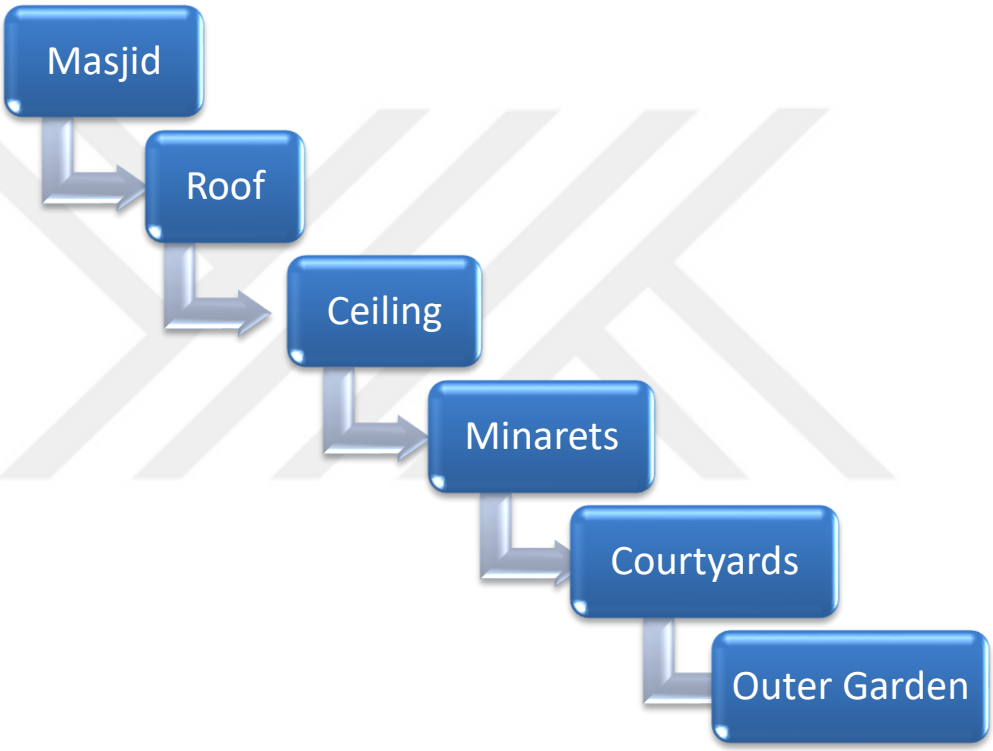


Figure 3.12 Modeling steps

3.3.4.1 Masjid

The mosque's masjid section, modeled in classical style, contains 3 parameters. These parameters are shown in Figure 3.13.

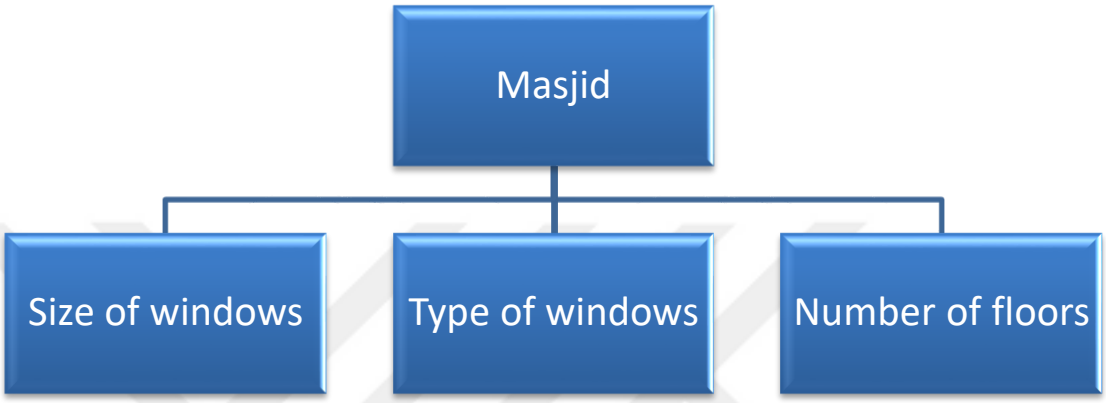


Figure 3.13 Masjid parameters

Here, the user can select the desired window type but also adjusts the number of floors and the size of the window. Figure 3.14 and Figure 3.15 show different window size.

According to these parameters, the masjid part is created. Masjid part includes windows which repeat around masjid bounds. Then, the roof is created on the masjid part.

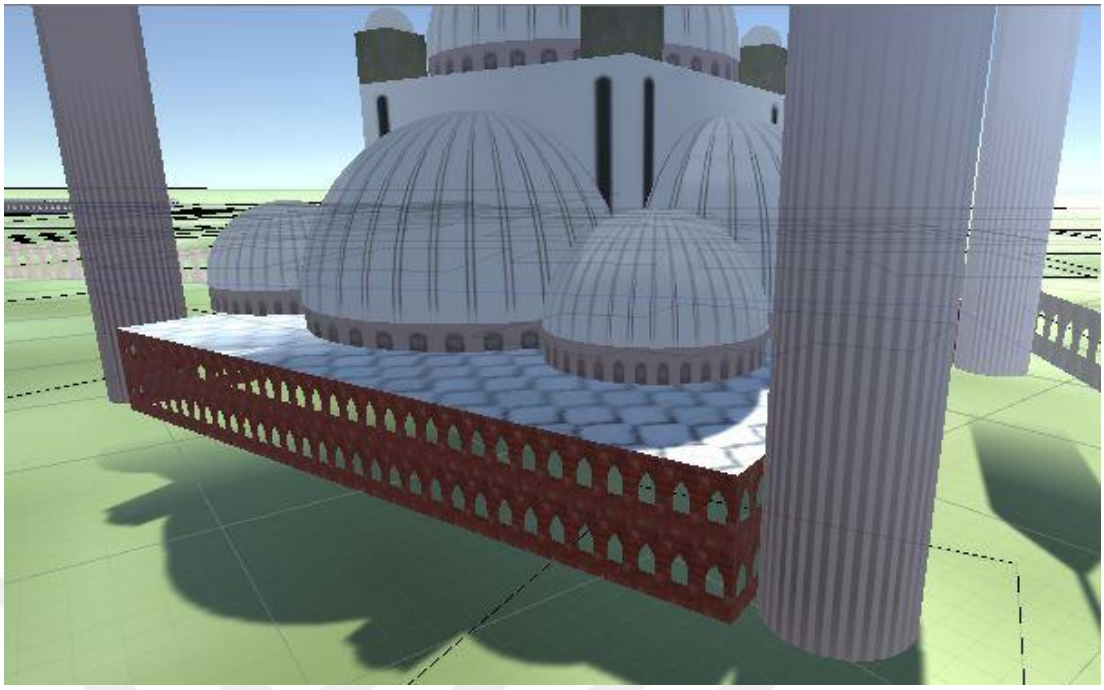


Figure 3.14 Example size of the window

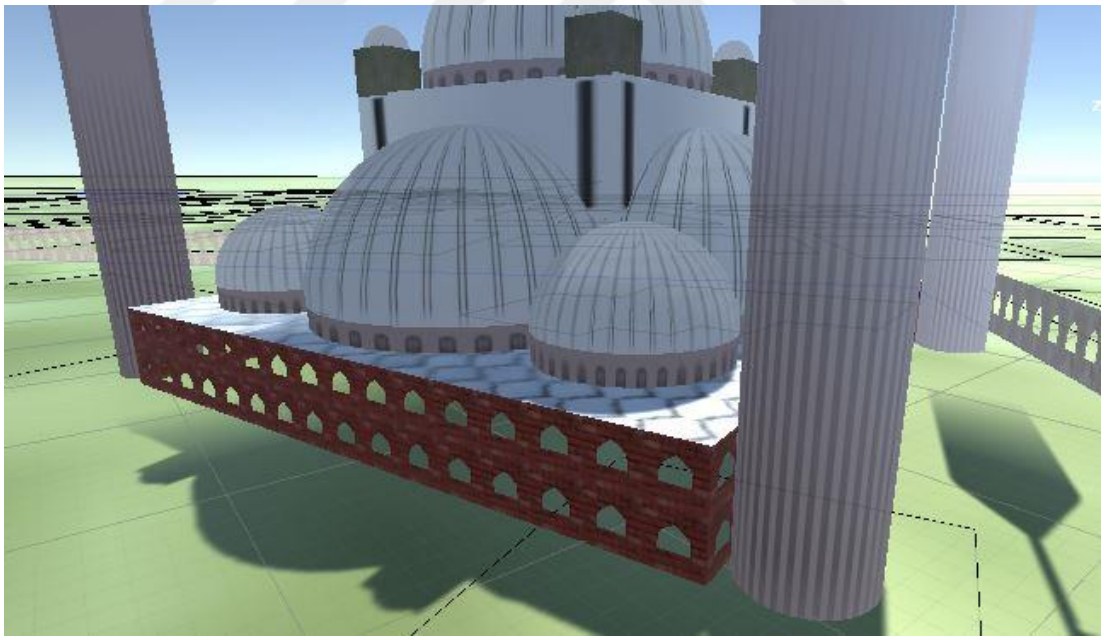


Figure 3.15 Example size of the window

The following examples (Figure 3.16 and Figure 3.17) show two different types of windows that the user can select.

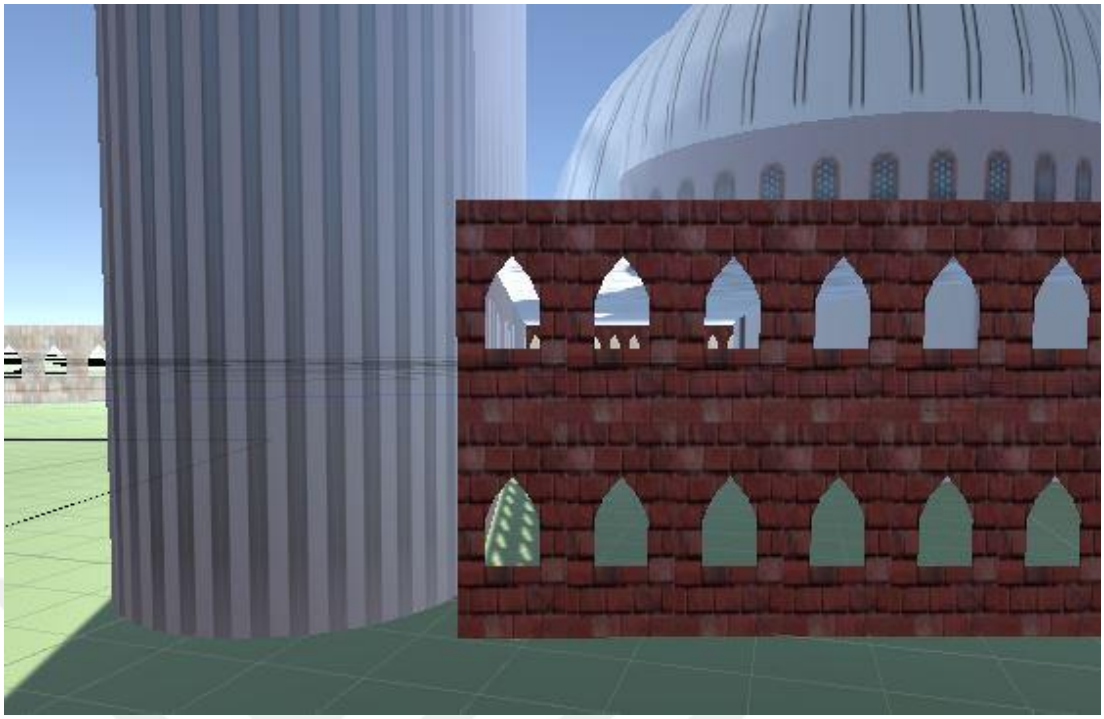


Figure 3.16 Masjid windows with style 1

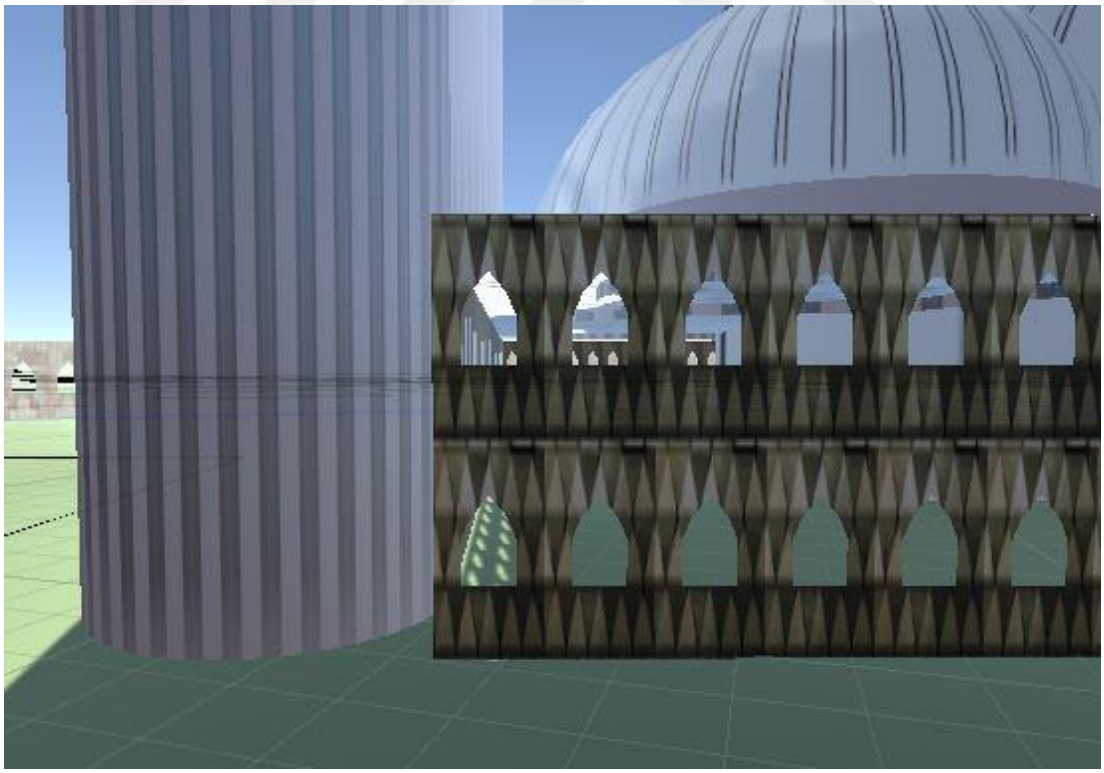


Figure 3.17 Masjid windows with style 2

The mosque model for the masjid part, which received the floor parameters 1 and 3, is shown in Figure 3.18 and Figure 3.19.

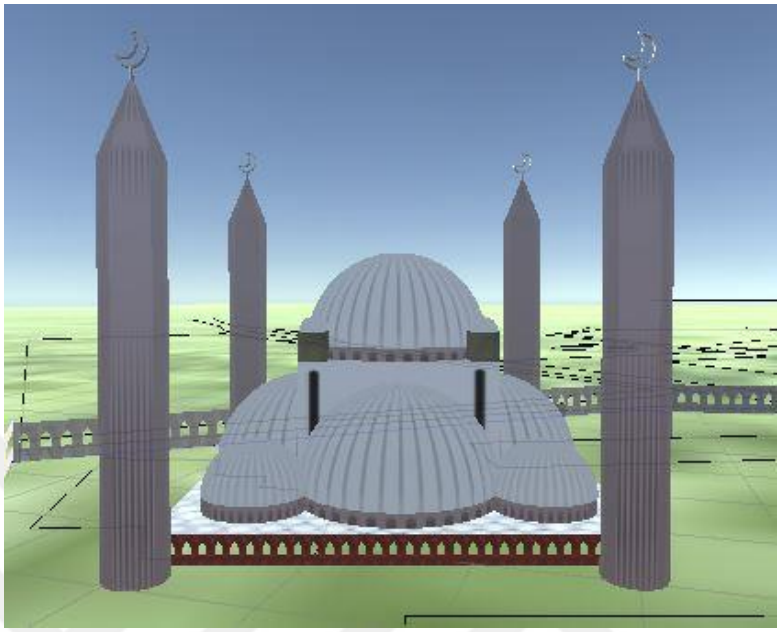


Figure 3.18 Mosque model with floor parameter 1

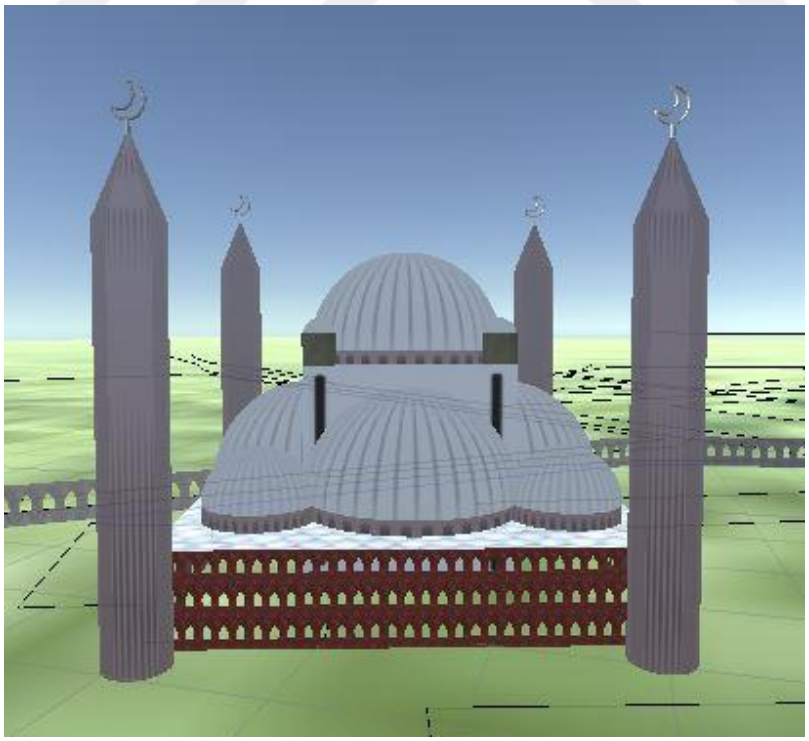


Figure 3.19 Mosque model with floor parameter 3

3.3.4.2 Ceiling

Three parameters are used for the roof part of the mosque modeled in classical style (Figure 3.20).

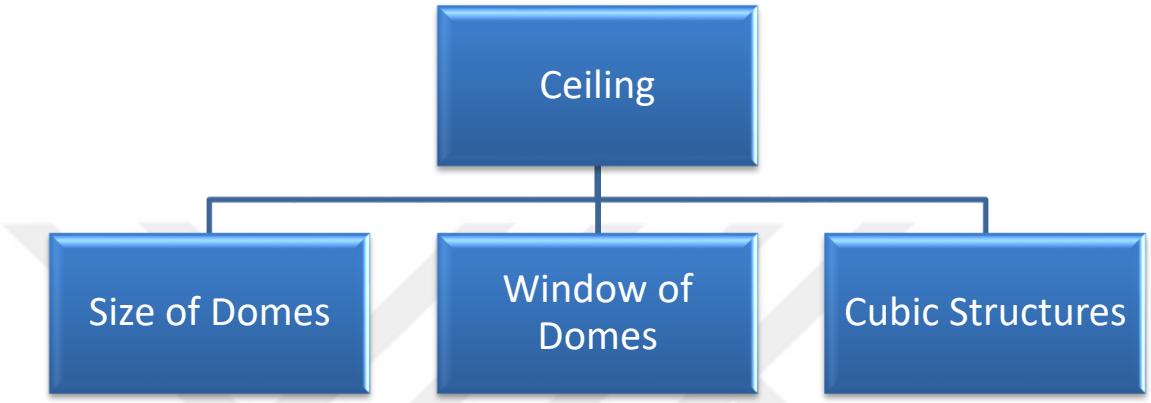


Figure 3.20 Ceiling parameters

In the ceiling part of the mosque has these attributes,

- One full dome on one cubic structure and four full domes over four cubic structures placed in the corners.

- Four half domes around the full dome

- Small domes which can be added according to the dimensions of the mosque on the remaining part

By default, the diameter of the main dome of the mosque is determined to be one-third of the diagonal of the mosque's masjid part, but the user can change this size.

The mosque shown in Figure 3.21 shows the modeled version of the dimensions that we set as default.

The largest dome with the diameter which is determined according to the parameters is placed in the middle of the roof. A cube is placed under the dome, which is the same size as the largest dome. On the cube in four corners, cube-shaped structures with small domes of the same size are placed. Then four semi-domes are placed around the largest dome, the radius of which is the same as the largest dome. Finally, small domes are placed in the remaining parts.

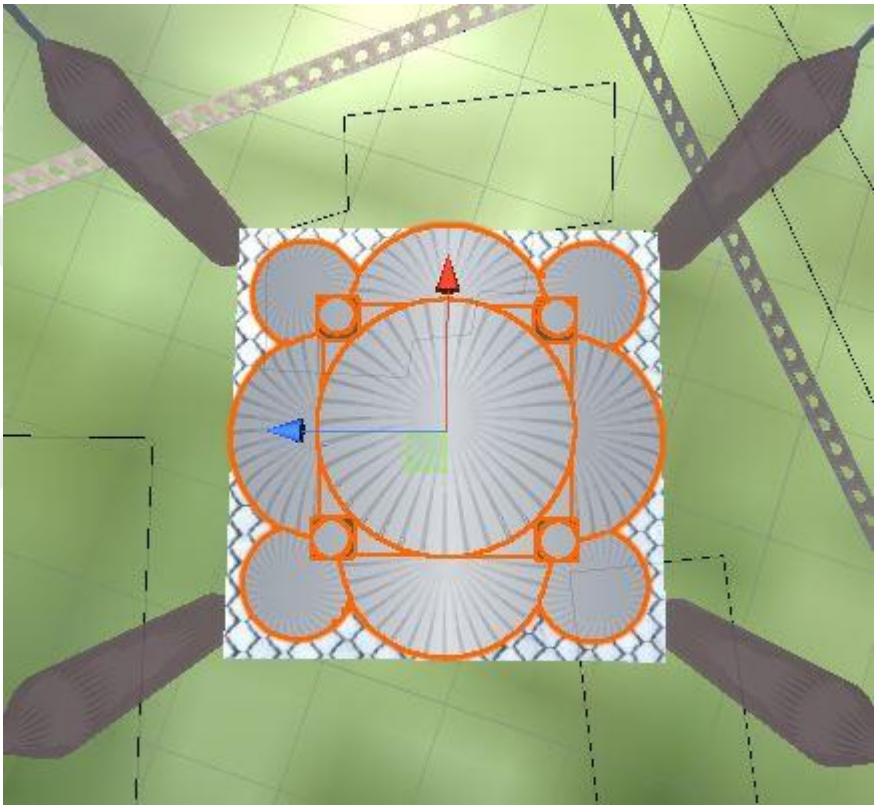


Figure 3.21 Default sized domes

Figure 3.22 shows two examples of dome sizes differently.

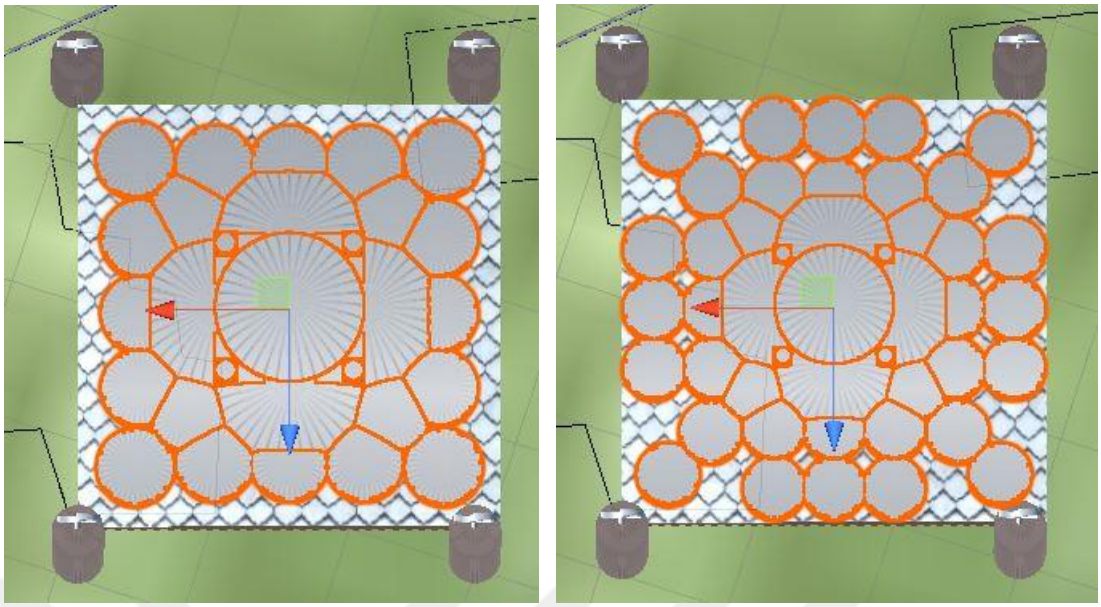


Figure 3.22 Mosques with different sized domes

A detailed view of the removable dome windows and cubic structures is shown in Figure 3.23.

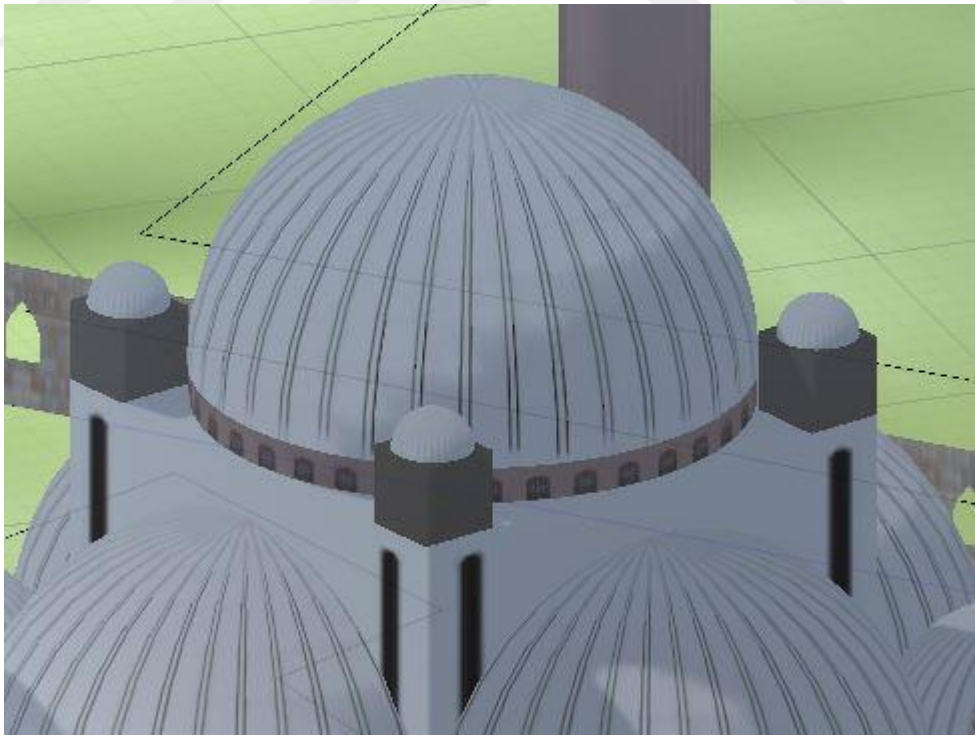


Figure 3.23 Domes with windows and cubic structures

3.3.4.3 Minarets

The minaret of the mosque, which is modeled in classical style, consists of 3 parameters. The parameters are as shown in Figure 3.24.

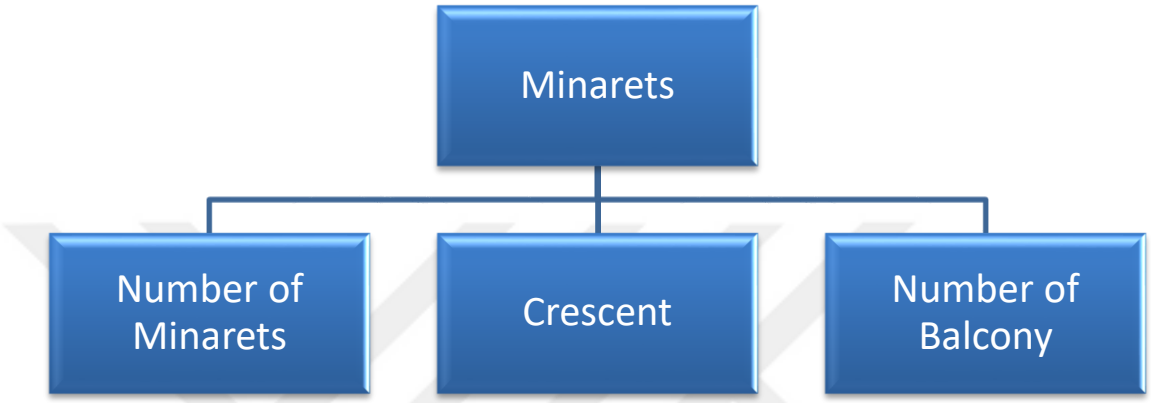


Figure 3.24 Minaret parameters

Based on the data set by the Presidency of Religious Affairs, a minaret and a balcony shall be found in the mosques designated as a small place of worship, and a second minaret and a second balcony may be permitted in the mosques designated as medium and large places of worship. These minarets are located at the four corners of the mosque, to the right and left of the Qibla direction. For classic style, between 1 and 4 minarets can be modeled. In this context, the medium size sample shown in Figure 3.25 shows two and four minarets according to the parameter taken from the user.

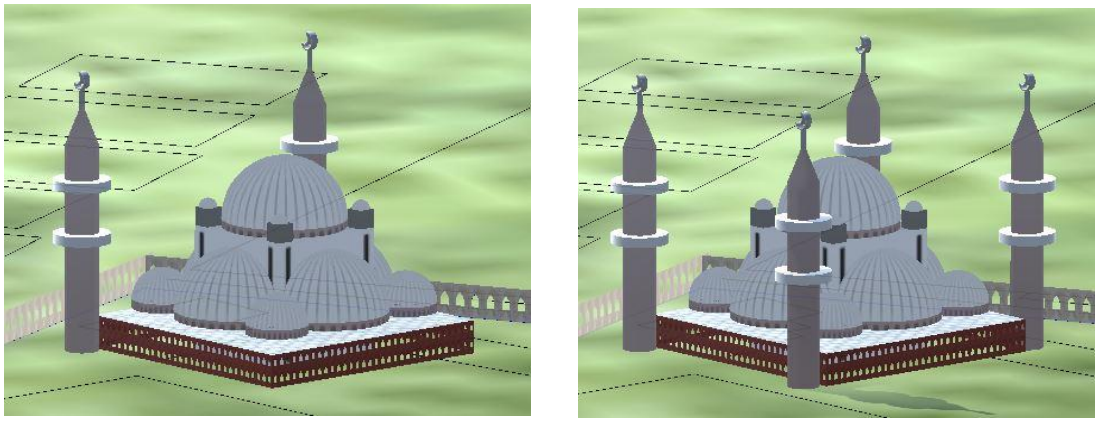


Figure 3.25 Mosques with two and four minarets

In our other example, which is a small place of worship, a modern style mosque model has a single minaret and two balconies (Figure 3.26).

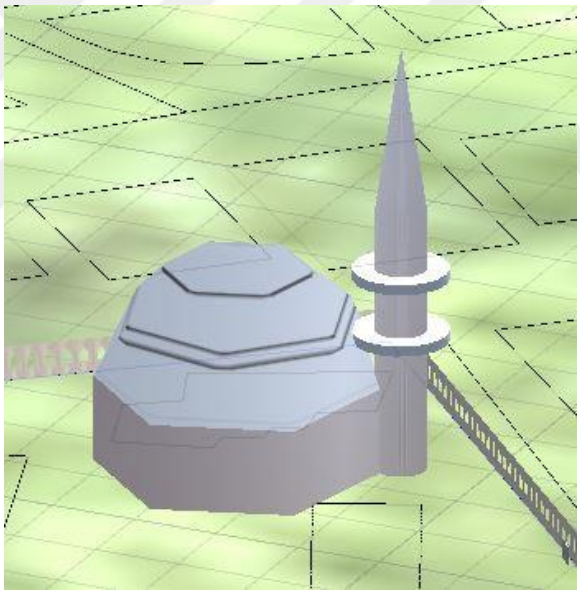


Figure 3.26 The modern style mosque has a single minaret

The balcony and the crescent, which are the details of the minaret, can also be added and removed according to the information received from the user. Figure 3.27 shows a crescent-shaped view of the minaret with two balconies.

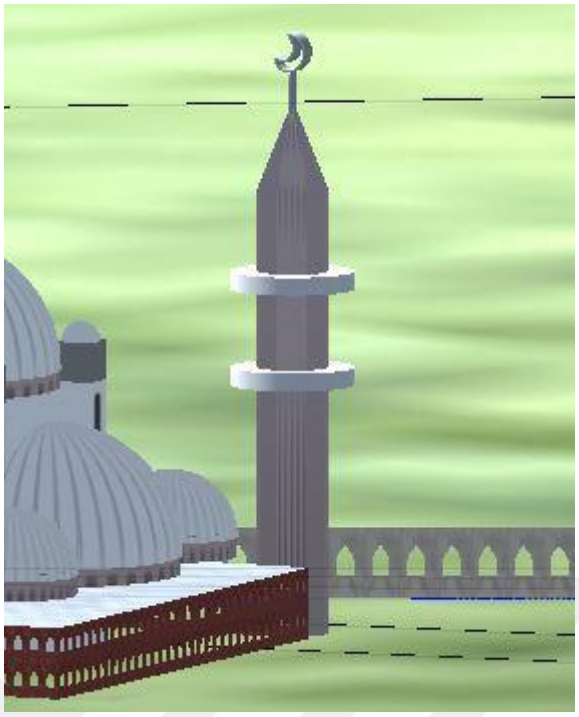


Figure 3.27 View of the minaret with two balconies and a crescent

3.3.4.4 Inner Garden

Within the boundaries of our outer boundaries, there is a courtyard part which can be included in the modeling after the masjid part of the mosque is modeled. The courtyard also consists of garden walls, garden domes and fountains (Figure 3.28).

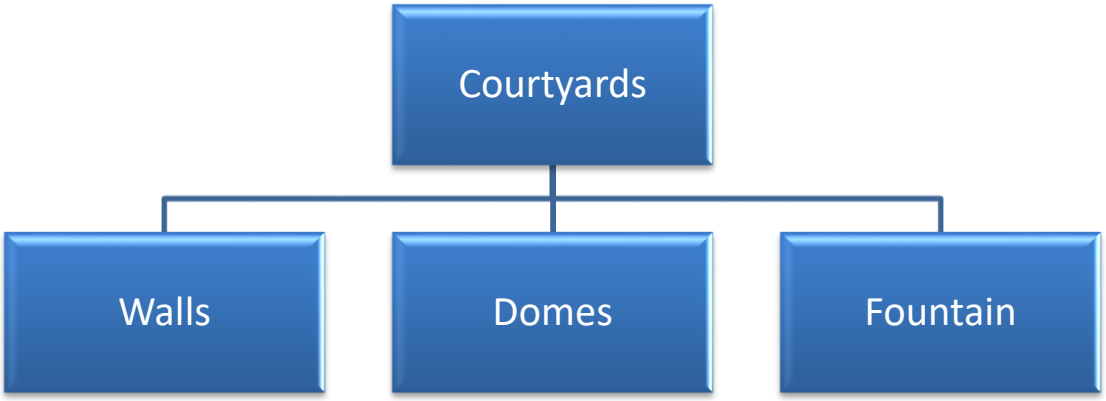


Figure 3.28 Inner garden parameters

In Figure 3.29, the example of the inner garden is shown with walls, domes, and fountain.

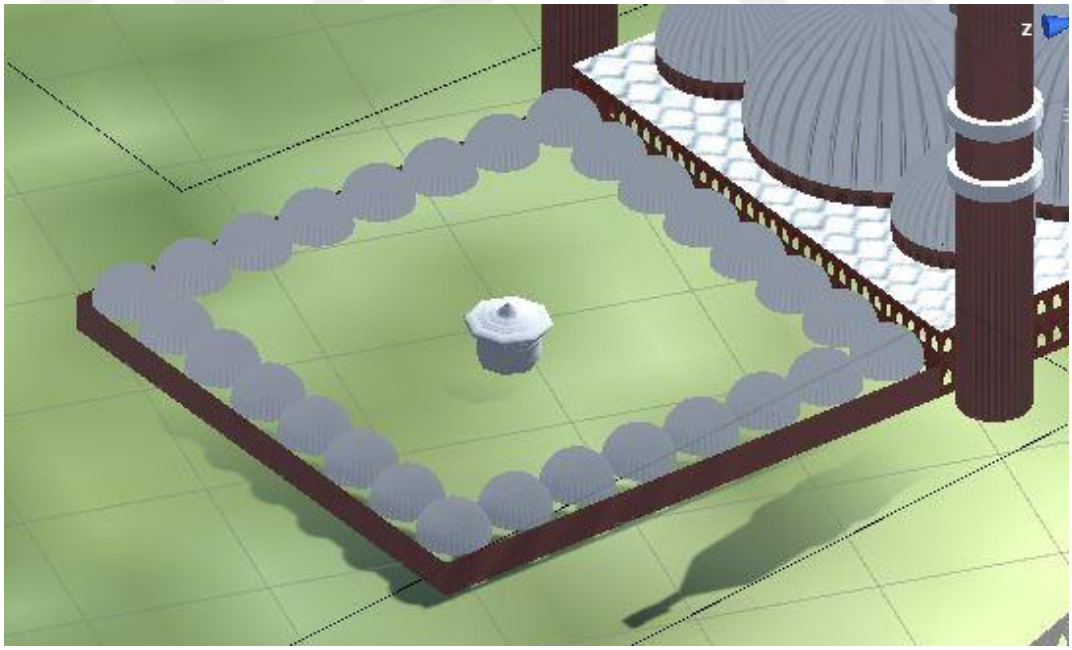


Figure 3.29 Inner garden with fountain

3.3.4.5 Outer Garden

Within the given area information, a garden wall surrounding the boundaries of the area can be added. The shape of the garden can be modeled in accordance with the desired wall model in such a way as to follow the edges of the area exactly.

Examples from different areas are shown in Figure 3.30.

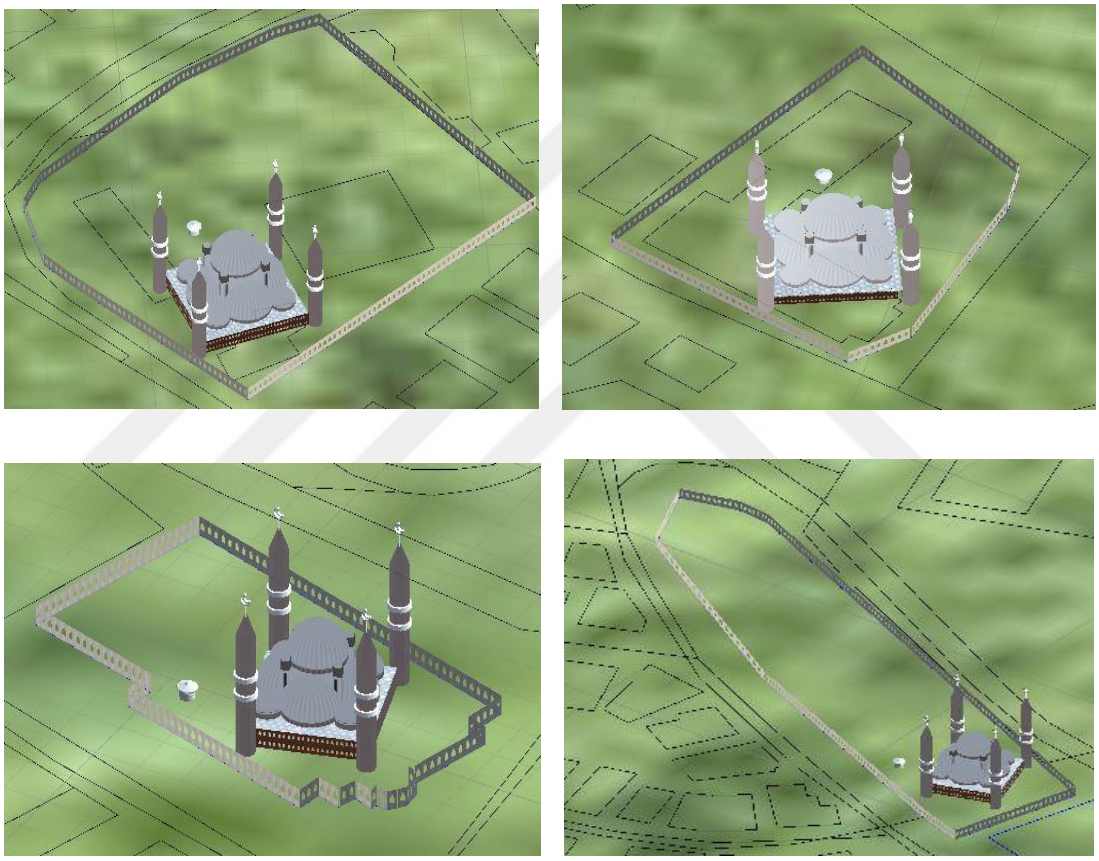


Figure 3.30 Examples of different areas that surrounding a garden wall

CHAPTER 4

RESULTS AND FUTURE WORKS

In this study, a method has been presented to automatically model mosques. The mosque, which has a very important place in the Islamic world for centuries, still maintains its existence and importance. Although it differs in architectural styles and rules in different regions and ages, it continues to retain its basic purpose. The reason we chose the mosque structure as the main subject of our modeling is that the mosques are of great importance for architecture as well as for carrying a cultural value. The characteristics of the mosques allow us to model it in a parametrical way.

The procedural modeling techniques commonly used in architecture are also suitable for the modeling of mosques that represent a high level of architecture. The procedural modeling techniques used in building facades, buildings at different levels of detail and the construction of virtual cities provide a very suitable basis for modeling mosques with high detail levels with these procedural modeling techniques.

Over time, there are significant changes in the characteristics of mosques in various societies. Therefore, in this study, we first identified the Ottoman / Mimar Sinan style mosque models, which are commonly seen in our country, as an example. Examples of Ottoman / Mimar Sinan style mosques, as well as the basic features of mosques, also contain a number of characteristics. Based on these characteristics of the sample mosques, the parameters used in the application were determined. The hierarchical representation of the parameters in the study is shown in Figure 4.1.

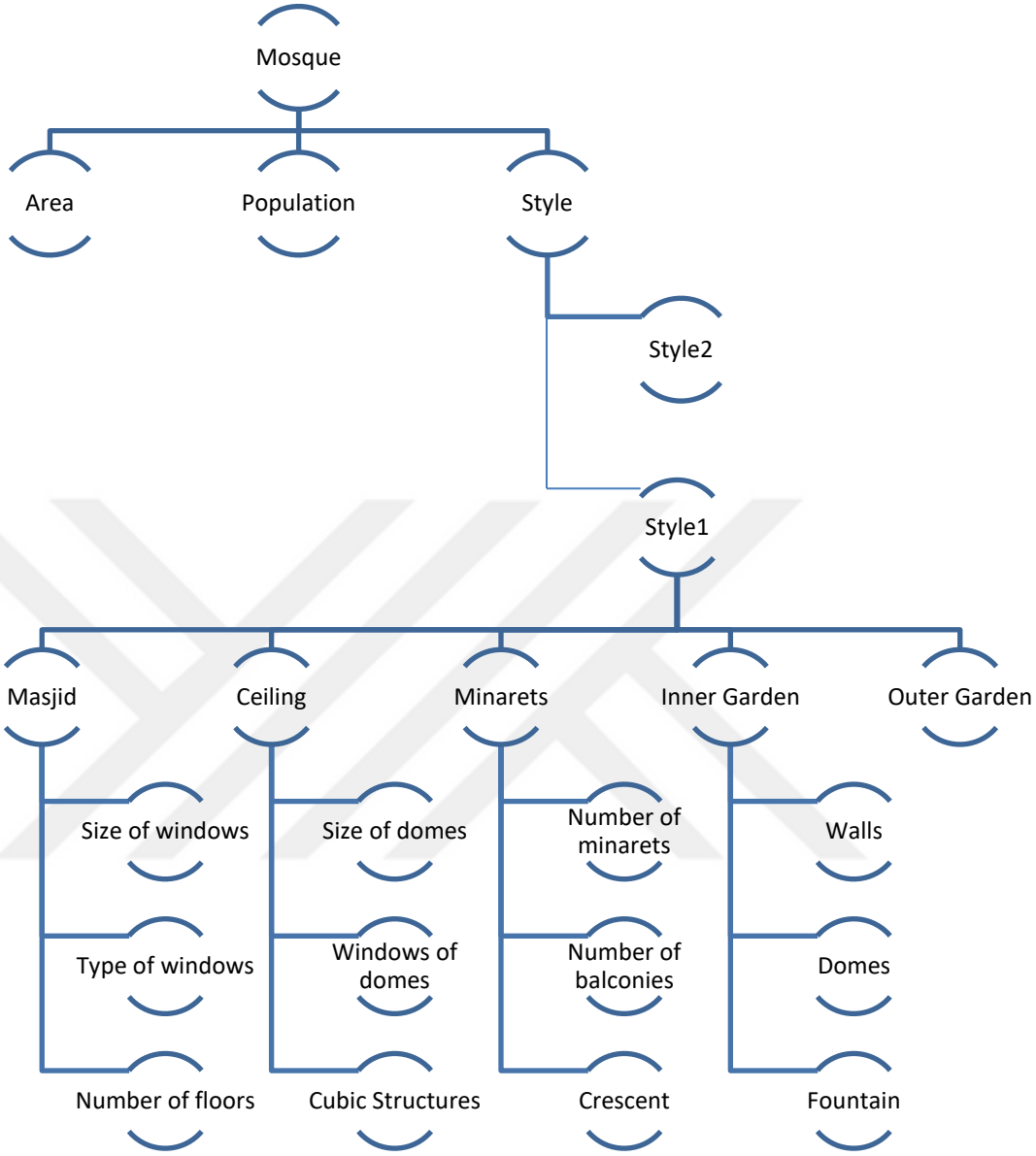


Figure 4.1 Hierarchical representation of the parameters

The developed application automatically modeled the desired mosque according to the parameters obtained from the user. One advantage of our study is that the parameters specified in the application have a hierarchical order. There are two stages in practice. In the first stage, in accordance with the rules determined according to the knowledge of the area, population information, and style, other parameters which are the characteristic features of the mosque model are determined and the desired mosque model is created automatically. Another feature that makes the study useful is that the parameters in the second stage can intervene at any time. The fact that the user does not require any technical infrastructure while changing these parameters is an important feature of our application.

If we evaluate the study in terms of abstraction, parametric control and flexibility of the successful procedural techniques mentioned in 2.1 Procedural Techniques Research section, our approach has been taken that the minimal information required for the production of the model. Parameter control is provided to prevent unwanted situations by restrictions created by the developer. Finally, a flexible working area is provided to the user by changing the parameters of the study if necessary. Figure 4.2 and Figure 4.3 show examples with different parameters.

The study aims to identify rules and architectural elements according to different styles and to develop the system to be more inclusive. In this context, it is envisaged to develop the parameters and rules that we have determined on the model of the Ottoman / Mimar Sinan mosque. In the future, it is planned to model higher detail levels with procedural modeling techniques to improve the model. The ability to produce models at different levels of detail is important for systems in which the level of detail to be used according to the features of the equipment or application in which the imaging is performed is determined automatically.

After this work, our more comprehensive aim is to develop a system that can be modeled automatically with the whole of mosques, buildings, roads, and other cities. Such a system has the potential to make significant contributions in areas such as games, simulations, and virtual reality that require three-dimensional content.

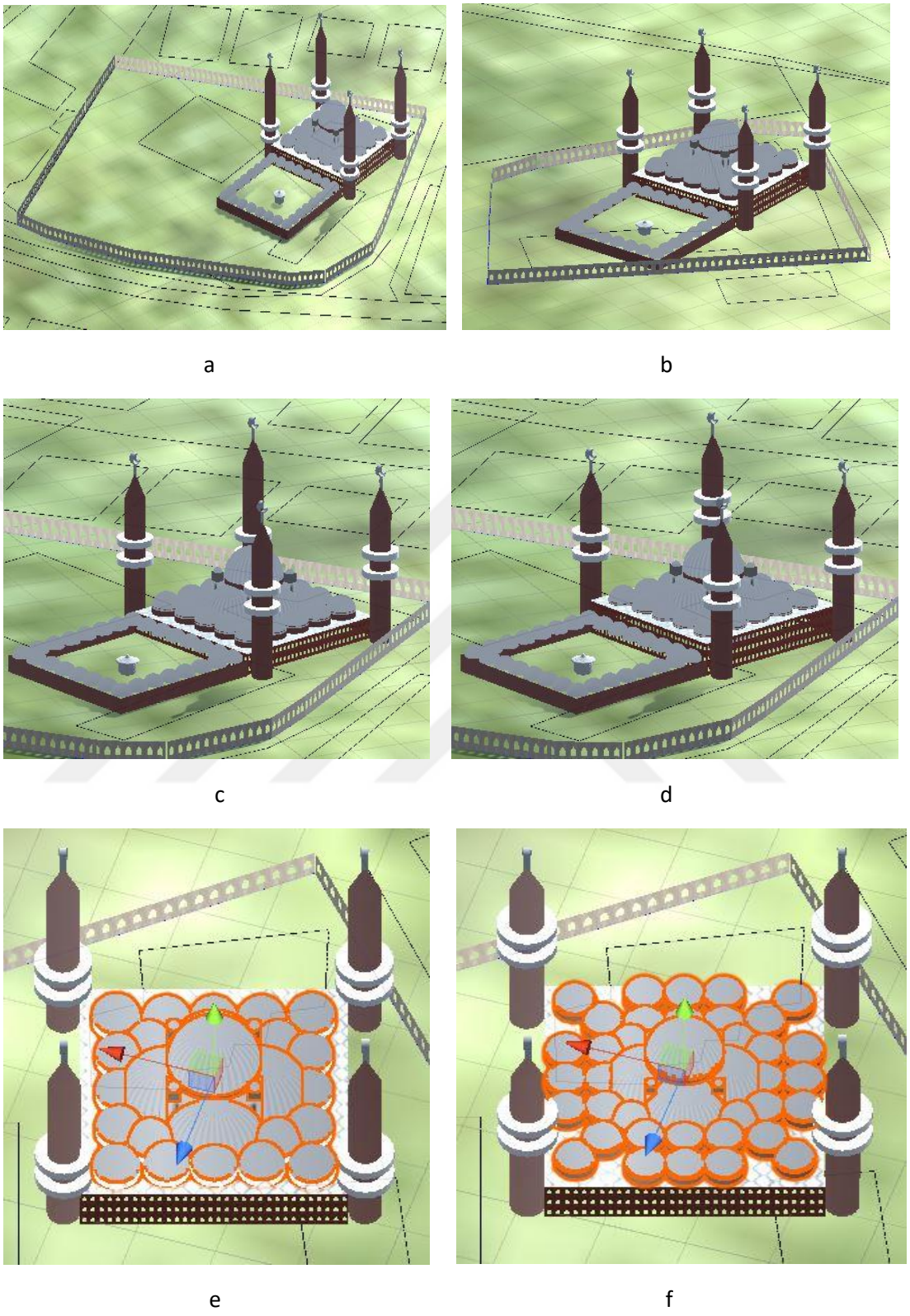


Figure 4.2 Example of different parameters

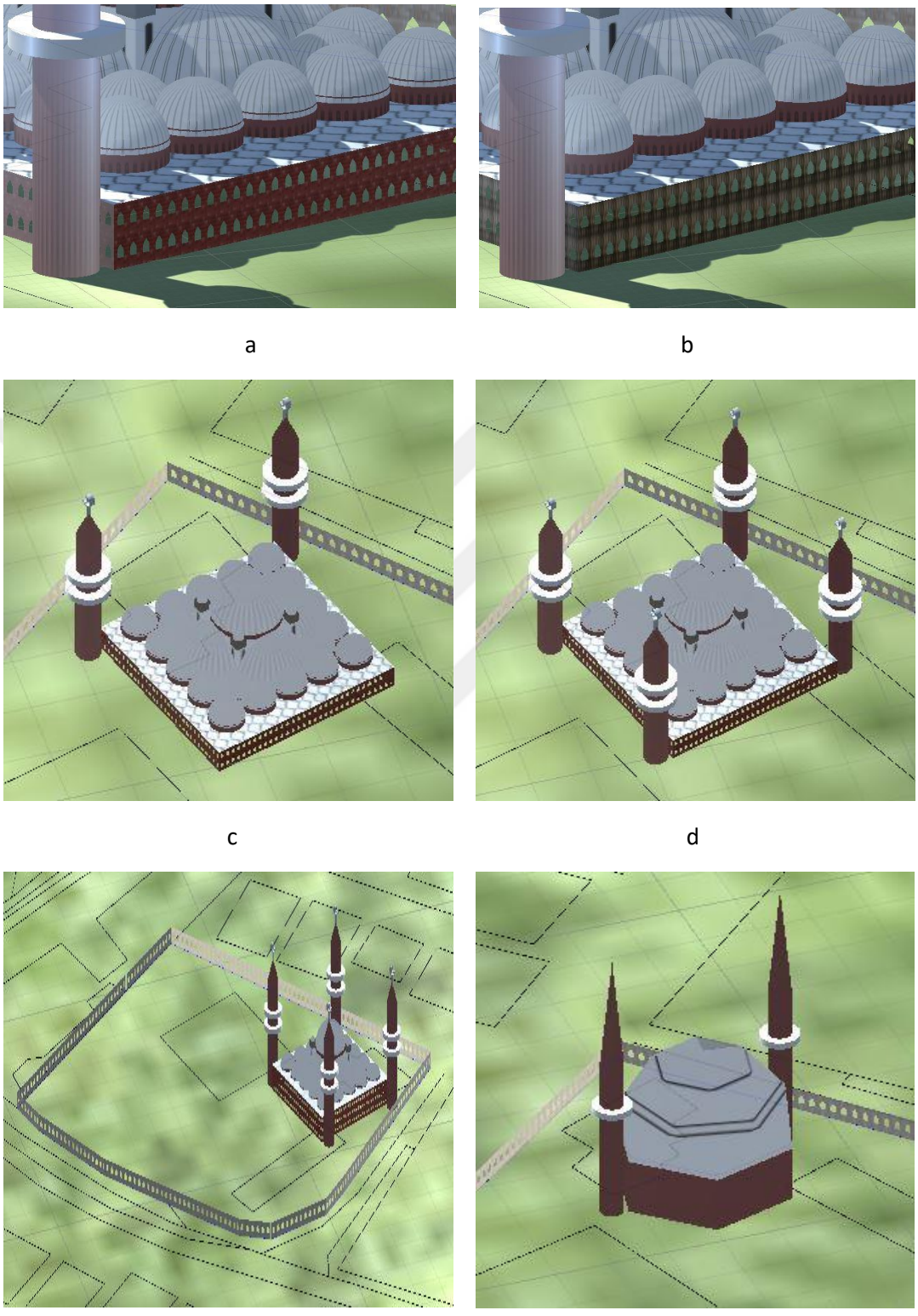


Figure 4.3 Example of different parameters

REFERENCES

[1] Bokeloh, M., Wand, M., & Seidel, H. P. A connection between partial symmetry and inverse procedural modeling. In ACM Transactions on Graphics (TOG) (Vol. 29, No. 4, p. 104). ACM. (2010, July).

[2] Schwarz, M., & Müller, P. Advanced procedural modeling of architecture. ACM Transactions on Graphics (TOG), 34(4), 107. (2015).

[3] Prusinkiewicz, P., Hammel, M., Hanan, J., & Mech, R. L-systems: from the theory to visual models of plants. In Proceedings of the 2nd CSIRO Symposium on Computational Challenges in Life Sciences (Vol. 3, pp. 1-32). Melbourne: CSIRO Publishing. (1996, February).

[4] Prusinkiewicz, P., & Lindenmayer, A. The algorithmic beauty of plants. Springer Science & Business Media. (2012).

[5] Perlin, K. An image synthesizer. ACM Siggraph Computer Graphics, 19(3), 287-296. (1985).

[6] Prusinkiewicz, P., & Lindenmayer, A. The algorithmic beauty of plants. Springer Science & Business Media. (2012).

[7] Ebert, D. S., Musgrave, F. K., Peachey, D., Perlin, K., & Worley, S. Texturing & modeling: a procedural approach. Morgan Kaufmann. (2003).

[8] Kelly, G., & McCabe, H. A survey of procedural techniques for city generation. The ITB Journal, 7(2), 5. (2006).

[9] Kelly, G., & McCabe, H. An interactive system for procedural city generation. Institute of Technology Blanchardstown, 25. (2008).

[10] Mandelbrot, B. B. The fractal geometry of nature (Vol. 1). New York: WH Freeman. (1982).

[11] Linden, W., & Schachinger E. Fractals - Computer simulations. http://itp.tugraz.at/LV/wvl/Comp_Simulationen. Last accessed: 10 Sep 2007. 2002.

[12] Barnsley, M. F. Fractals everywhere. Academic, New York. 1993.

[13] Perlin, K. Making Noise. Based on a talk presented at GDCHardCore (Dec 9, 1999). (2006).

[14] Hart, E. 3d textures and pixel shaders. Direct3D ShaderX, 428. (2002).

[15] Sensible Software. Shoot'Em-Up Construction Kit (SEUCK). Published by Outlaw. 1987.

[16] Planetside. Terragen is a scenery generator capable of photorealistic results. http://www.planetside.co.uk/terragen. Last accessed: 10 Aug 2006. 2004.

[17] Suveg, I., & Vosselman, G. Reconstruction of 3D building models from aerial images and maps. ISPRS Journal of Photogrammetry and remote sensing, 58(3-4), 202-224. (2004).

[18] Vosselman, G., & Dijkman, S. 3D building model reconstruction from point clouds and ground plans. International archives of photogrammetry remote sensing and spatial information sciences, 34(3/W4), 37-44. (2001).

[19] Demir, N., & Baltsavias, E. Automated modeling of 3D building roofs using image and LiDAR data. In Proceedings of the XXII Congress of the International Society for Photogrammetry, Remote Sensing, Melbourne, Australia (Vol. 25). (2012, August).

[20] Biljecki, F., Ledoux, H., & Stoter, J. GENERATION OF MULTI-LOD 3D CITY MODELS IN CITYGML WITH THE PROCEDURAL MODELLING ENGINE RANDOM3DCITY. ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences, 3(4). (2016)

[21] Rosser, J., Morley, J., & Smith, G. Modelling of building interiors with mobile phone sensor data. ISPRS International Journal of Geo-Information, 4(2), 989-1012. (2015).

[22] Biljecki, F., Ledoux, H., Stoter, J., & Vosselman, G. The variants of an LOD of a 3D building model and their influence on spatial analyses. ISPRS Journal of Photogrammetry and Remote Sensing, 116, 42-54. (2016).

[23] Donkers, S., Ledoux, H., Zhao, J., & Stoter, J. Automatic conversion of IFC datasets to geometrically and semantically correct CityGML LOD3 buildings. Transactions in GIS, 20(4), 547-569. (2016).

[24] Stilla, U., Soergel, U., & Thoennessen, U. Potential and limits of InSAR data for building reconstruction in built-up areas. ISPRS Journal of photogrammetry and remote sensing, 58(1-2), 113-123. (2003).

[25] Müller, P., Wonka, P., Haegler, S., Ulmer, A., & Van Gool, L. Procedural modeling of buildings. In Acm Transactions On Graphics (Tog) (Vol. 25, No. 3, pp. 614-623). ACM. (2006, July).

[26] Biljecki, F., Ledoux, H., Stoter, J., & Zhao, J. Formalisation of the level of detail in 3D city modelling. Computers, Environment and Urban Systems, 48, 1-15. (2014).

[27] Biljecki, F., Ledoux, H., & Stoter, J. An improved LOD specification for 3D building models. Computers, Environment and Urban Systems, 59, 25-37. (2016).

[28] Smelik, R. M., Tutenel, T., Bidarra, R., & Benes, B. A survey on procedural modelling for virtual worlds. In Computer Graphics Forum (Vol. 33, No. 6, pp. 31-50). (2014, September).

[29] Müller, P., Wonka, P., Haegler, S., Ulmer, A., & Van Gool, L. Procedural modeling of buildings. In Acm Transactions On Graphics (Tog) (Vol. 25, No. 3, pp. 614-623). ACM. (2006, July).

[30] Wonka, P., Wimmer, M., Sillion, F., & Ribarsky, W. Instant architecture (Vol. 22, No. 3, pp. 669-677). ACM. (2003).

[31] Edelsbrunner, J., Havemann, S., Sourin, A., & Fellner, D. W. Procedural modeling of architecture with round geometry. Computers & graphics, 64, 14-25. (2017).

[32] Tepavčević, B., & Stojaković, V. Procedural modeling in architecture based on statistical and fuzzy inference. Automation in Construction, 35, 329-337. (2013).

[33] Kelly, G., & McCabe, H. Citygen: An interactive system for procedural city generation. In Fifth International Conference on Game Design and Technology (pp. 8-16). (2007).

[34] Lyu, X., Han, Q., & de Vries, B. Procedural modeling of urban layout: population, land use, and road network. Transportation research procedia, 25, 3337-3346. (2017).

[35] Aybars, U. Ğ. U. R., Hangül, E., KALAYCI, T. E., & AYDIN, D. Üç Boyutlu Binaların Web Üzerinde Otomatik Olarak JOGL ile Modellenmesi.

[36] Merrell, P., & Manocha, D. Model synthesis: A general procedural modeling algorithm. IEEE transactions on visualization and computer graphics, 17(6), 715-728. (2011).

[37] Finkenzeller, D., & Bender, J. Semantic representation of complex building structures. In Computer Graphics and Visualization (CGV 2008)-IADIS Multi Conference on Computer Science and Information Systems, Amsterdam, The Netherlands. (2008, July).

[38] Rogla, O., Pelechano, N., & Patow, G. Procedural Crowd Generation for Semantically Augmented Virtual Cities. arXiv preprint arXiv:1811.10036. (2018).

[39] Murphy, M. Structural simulations and conservation analysis-historic building information model (HBIM) (Doctoral dissertation, Dublin Institute of Technology). (2015).

[40] Demir, İ., & Aliaga, D. G. Guided proceduralization: Optimizing geometry processing and grammar extraction for architectural models. Computers & Graphics. (2018).

[41] Frank, E., & Olsson, N. Procedural city generation using Perlin noise. (2017).

[42] Cami Mimarisinin Gelişimi. (n.d.). Retrieved January 1, 2019, from http://milacamiprojeleri.com/makaleler.html

[43] Kılınç, S. (Ed) *Osmanlı Mimarisi* (1st ed.). Çamlıca. 2011

[44] T.C. Başbakanlık Diyanet İşleri Başkanlığı (2017). Retrieved February 11, 2018, from https://www.diyanet.gov.tr/tr-TR/Kurumsal/Detay//6/diyanet-isleribaskanligi-istatistikleri

[45] Cantay, T. *Süleymaniye Camii*. Eren Yayıncılık.

[46] Son Cemaat Yeri (n.d.). Retrieved January 1, 2019 from http://e-wiki.org/tr/images/Son_cemaat_yeri

[47] Lagae, A., Lefebvre, S., Cook, R., DeRose, T., Drettakis, G., Ebert, D. S., ... & Zwicker, M. A survey of procedural noise functions. In Computer Graphics Forum (Vol. 29, No. 8, pp. 2579-2600). Oxford, UK: Blackwell Publishing Ltd. (2010, December).

[48] Biagioli, A. *Understanding Perlin Noise.* Retrieved February 3, 2019, from https://flafla2.github.io/2014/08/09/perlinnoise.html. August 9, 2014

CURRICULUM VITAE

PERSONAL INFORMATION



Name Surname : Elif YAYLA
Date of Birth : 1992
E-mail : eyayla@ybu.edu.tr

EDUCATION

High School : Open High School / ANKARA (2006-2010)
(88.5/100)
Bachelor : Gazi University / Ankara (2010-2015)
(3.68/4.0)
Master Degree : Ankara Yıldırım Beyazıt University / (2016-continued)
(3.86/4.0)

WORK EXPERIENCE

Research Assist. : Ankara Yıldırım Beyazıt University / (2016-continued)

TOPICS OF INTEREST

- Procedural Modeling
- Unity