

VIRTUAL AND AUGMENTED REALITY WITH APPLICATION TO CULTURAL
HERITAGE

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KÜLTÜREL MİRASA UYGULAMASI İLE SANAL VE ARTTIRILMIŞ
GERÇEKLİK

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ABSTRACT

VIRTUAL AND AUGMENTED REALITY WITH APPLICATION TO CULTURAL HERITAGE

In recent years, virtual and augmented reality have become more and more involved in our lives due to developing computer graphics technology. Reality solutions are used in a not only wide variety of known fields such as architecture, engineering, industrial design and gaming but also digital reconstruction of historical artifacts. However, traditional modeling techniques which are generally used today, must be improved with new drawing and modeling processes in digital reconstruction of ancient monuments and historical artifacts in order to obtain efficient satisfactory results. The process that tries to receive efficient results need more detailed research and optimization method in three-dimensional modeling. This work aims to create an efficient digital reconstruction process for reconstruction of ancient monuments and historical artifacts. Digital reconstruction of Classical Temple of Artemis in Ephesus (one of the seven wonders of the antique world) has been taken as a case study with the help of multiple graphics software. The utilitarian function of the state-of-the-art computer graphics technology is shown to be worthy of a place in the reconstruction of lost monuments of our cultural heritage.

Keywords: Computer Graphics, Volumetric Visualization, Virtual Reality, Digital Archaeology, Cultural Heritage

ÖZET

KÜLTÜREL MİRASA UYGULAMASI İLE SANAL VE ARTTIRILMIŞ GERÇEKLİK

Son yıllarda gelişen bilgisayar grafik teknolojisiyle birlikte sanal ve artırılmış gerçeklik hayatımıza daha fazla dahil oldu. Gerçeklik çözümleri sadece mimari, mühendislik, endüstriyel tasarım ve oyun gibi çok çeşitli bilinen alanlarda değil, aynı zamanda tarihi eserlerin dijital olarak yeniden yapılandırılmasında da kullanılmaktadır. Ancak günümüzde yaygın olarak kullanılan geleneksel modelleme tekniklerinin, verimli tatmin edici sonuçlar elde edebilmek için antik anıtların ve tarihi eserlerin dijital olarak yeniden yapılandırılmasında yeni çizim ve modelleme süreçleri ile geliştirilmesi gerekmektedir. Verimli sonuçlar almaya çalışan süreç, üç boyutlu modellemede daha detaylı araştırma ve optimizasyon yöntemlerine ihtiyaç duyar. Bu çalışma, antik anıtların ve tarihi eserlerin rekonstrüksiyonu için verimli bir dijital rekonstrüksiyon süreci oluşturmayı amaçlamaktadır. Efes'teki Klasik Artemis Tapınağı'nın (antik dünyanın yedi harikasından biri) dijital rekonstrüksiyonu vaka çalışması olarak alınmıştır. Son teknoloji bilgisayar grafik teknolojisinin faydacı işlevinin, kültürel mirasımızın kayıp anıtlarının rekonstrüksiyonunda bir yere layık olduğu gösterilmiştir.

Anahtar Kelimeler: Bilgisayar Grafikleri, Hacimsel Görselleştirme, Sanal Gerçeklik, Dijital Arkeoloji, Kültürel Miras

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LIST OF ABBREVIATIONS / SYMBOLS

2D	Two Dimension
3D	Three Dimension
4K Resolution	3840 x 2160 Display Resolution
8K Resolution	7680 x 4320 Display Resolution
CAD	Computer-aided Design
DWG	Drawing File Format
FBX	Filmbox File Format
FPS	Frames Per Second

1. INTRODUCTION

Cultural heritage is the past of societies and holds them together. The experiences of people have accumulated throughout history strengthen the sense of unity and togetherness. Exhibition of cultural heritage is important as it acts as a bridge between the past and the present.

Constantly developing digital technologies on computer graphics such as animation of three-dimensional models, real-time rendering and multimedia techniques demonstrated that virtual and augmented reality have created new ways to exhibit the cultural heritage. Today, it has become possible to virtually realize cultural heritage that have not survived or have been destroyed. It is important to carry these magnificent structures to the present with their first-day appearance to understand the history and past of humanity. Thanks to latest developments in three-dimensional volumetric visualization field, the technology is now available to resurrect the historical artifacts in birthplace of the cultural heritage. However, reference structures that have not survived today and very detailed three-dimensional volumetric visualizations have brought many difficulties in virtual realization of cultural heritage such as where to take reference when making three-dimensional modeling, how to proceed with the virtual realization process, which graphics software to use and how to optimize three-dimensional models.

This study mainly aims to develop the most efficient digital reconstruction process to be used in virtual realization of cultural heritage and optimize volumetric visualization of the three-dimensional models to be created in this process with the taking advantage of most advanced virtual and augmented reality software. Virtual reality part in this work can be defined as the three-dimensional modeling of historical artifacts that are part of the exhibiting cultural heritage. On the other hand, augmented reality is the display of three dimensional modeled historical artifacts in real places and conditions, which is another part of the exhibiting cultural heritage. In this work, the Classical Artemis Temple in Ephesus which was destroyed 2000 years ago will be virtually realized as a case study to analyze these processes.

How to visualize this wonder of the Classical Age? This conundrum has vexed many archaeologists, architects and artists since the commencement of the rediscovery of the Classical Age in the first years of the Renaissance. Reconstructions before the discovery of the temple in the 19th century were figments rather than resurrection of reality. Regrettably, neither the discovery of the temple, nor the excavations of the following 140 years sufficed to unlift the cover of mystery enwrapping the temple. Ahmet Denker in his study “Resonation of The Vitruvius’s Modular, Systematic Approach with The Computational Mindset of The Digital Age: 3D Modeling of The Ionian Temples of Aegean Turkey” states that by available historical data, one can digitally reconstruct the Classical Temple of Artemis in Ephesus one of the Ionian Temples in Turkey [1].

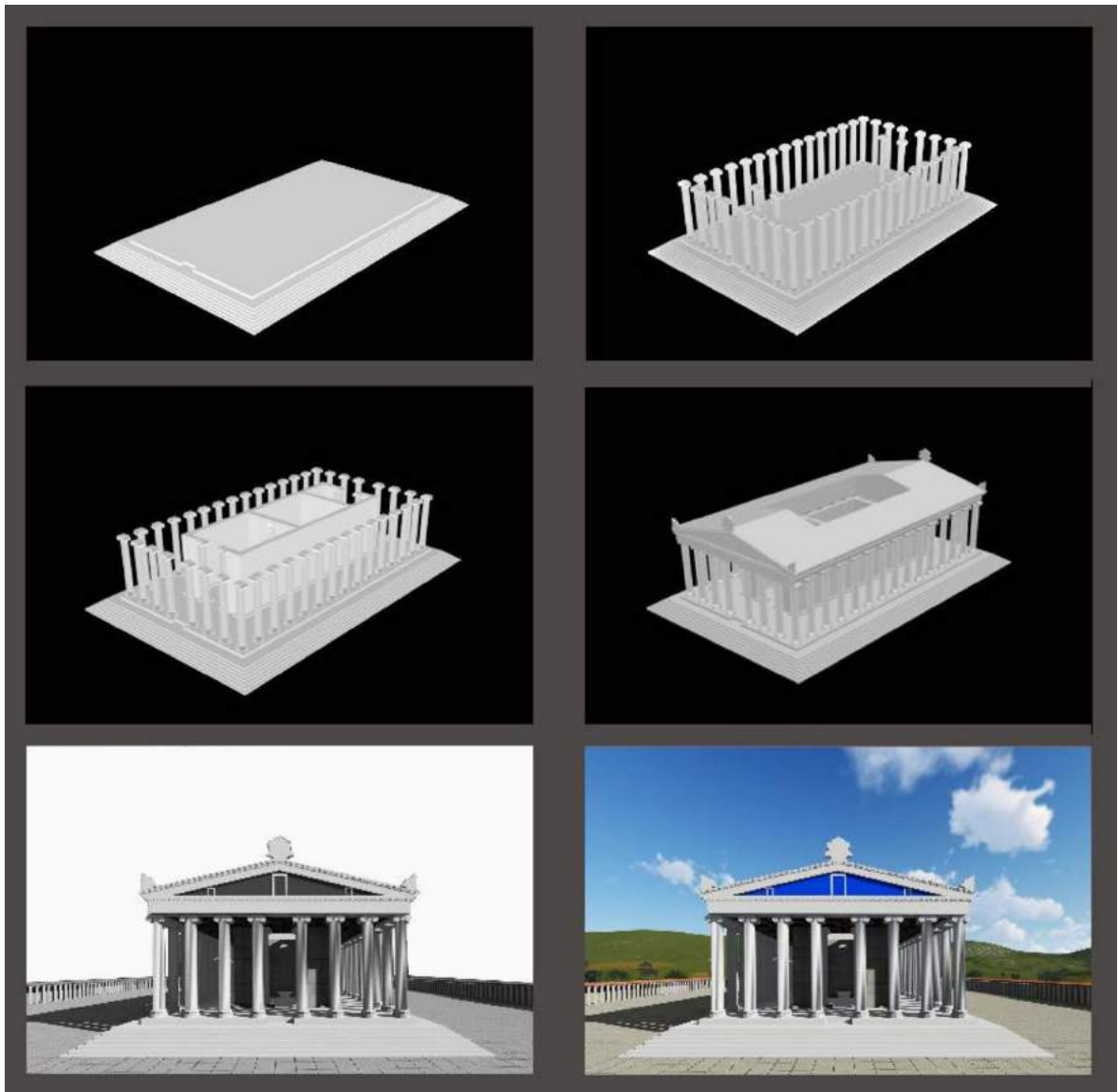


Figure 1.1. 3D Modeling of The Ionian Temples in Aegean Turkey [1]

Whatever necessary has been done archaeologically for the reconstruction problem of the Temple of Artemis in Ephesus, excavations of one and a half century have left no fragments awaiting discovery. Hundreds of monographs and books have been written about the found parts. The barriers hindering the reconstruction despite all of these efforts can only be removed with the advent of the cyber technology. New resources facilitated by cyber technology to the solution of the archaeological problems have recently been the focus of attention in the academic circles and Cyber Archaeology which merges archaeology with technology has gained acceptance as a new discipline. One of the prominent examples of this field is Ahmet Denker's article Virtual Reconstructing Palmira: Recreating Its Ancient Splendor in Digital Space, published in 2017 [2].



Figure 1.2. Virtual Reconstructing Palmira [2]

Similarly, this study undertakes the virtual realization of the Temple of Artemis in Ephesus with the aim of resurrecting the temple for today's visitors with a reality compared to that which was enjoyed by the visitors of the Classical Age. The work will also provide the facilities of visitor-temple interaction, interior and exterior promenading. The outcome of the project will open a window through which we can have a closer look to the antique world, and a wide-angle view of a wonder of the Classical Age as well as its unequalled "cosmos".

1.1. VIRTUAL REALIZATION

The 90's witnessed the emergence, discussion and popularization of Virtual-Archeology concepts and methods as a new discipline with P. Reilly's publication in 1991 titled "Towards a Virtual Archeology" [3]. The Virtual Archeology book, which presents the reconstructions of many famous historical relics revitalize in virtual reality, was published in 1995 under the editorship of Maurizio Forte [4]. Combining 3D geometric modeling and 3D computer graphics methods with mastery and skill was sufficient to achieve the results presented in these studies.

In the 2000s, the term "Virtual Archeology" had begun to gradually leave its place to the term "Cyber-Archeology". The book he edited 15 years after M. Forte's first book is called "Cyber-Archeology" [5] and includes important studies presented at congresses in this field in 2009-2010. Cyber-archeology enables the collection of much more data, much faster processing, classification and interpretation compared to previous disciplines, thus bringing a new cybernetic-oriented approach to visualization reconstruction problems. The distinctive feature of this opening for this study is the audience-temple interaction.



Figure 1.3. Forma Urbis Romae Project [6]

Cyber-archeology is a rapidly popular discipline and has opened the door to many important projects that will enable us to better understand our history. The Digital Michelangelo team at Stanford University carried out the Forma Urbis Romae project, which aims to digital reconstruct the map of ancient Rome from more than 1000 marble pieces [6].

The awareness created by the world community of the destruction of the great Buddha statues in the Bamiyan valley in Afghanistan caused researchers to focus on the problem of how to reconstruct these important monuments. In 2002, their digital reconstruction was carried out with the contribution of experts in computer graphics and computer vision [7].



Figure 1.4. Reconstruction of the Great Buddha of Bamiyan [7]

One of the most interesting cyber-reconstruction projects is the Rome Reborn project carried out by the University of Virginia [8], working interactively with Google Earth™, making it possible for the audience to see Rome through the eyes of the Romans in their most glorious days on the web [9].

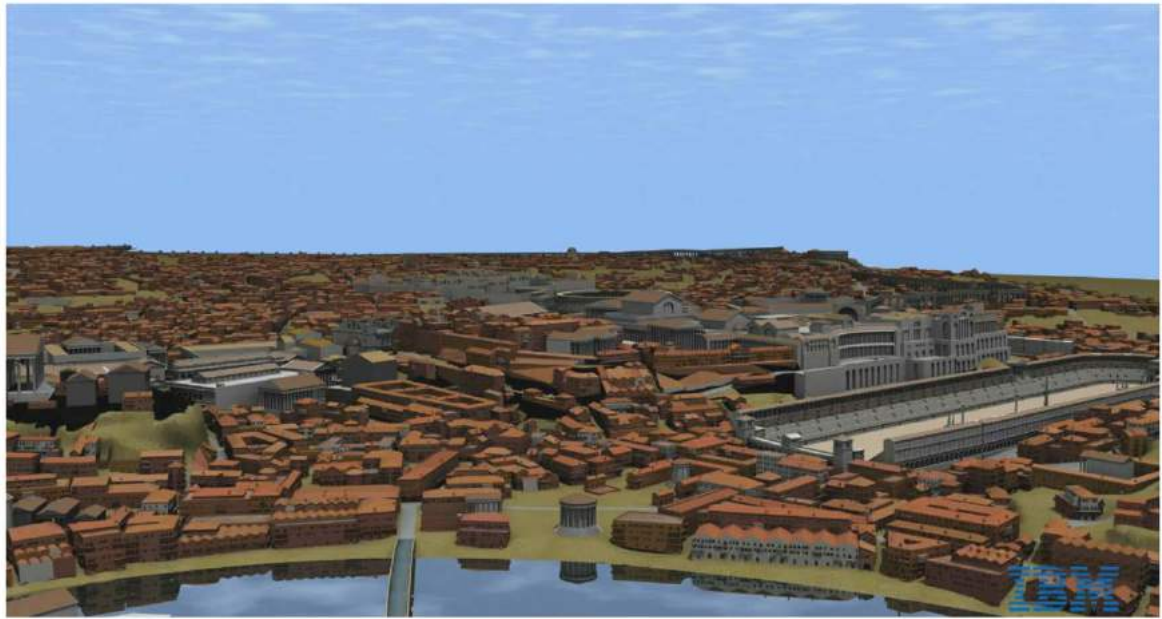


Figure 1.5. Rome Reborn 2.0 [8]

Rich historical heritage in Turkey has attracted the attention of foreign research teams working in the field of cyber archeology. Studies on Troy were published in 2004 by B. Brandau in the book *Troi: Wie es wirklich aussah* [10]. Berkeley University team is working on the digital reconstruction of Çatalhöyük. The digital reconstructions carried out by this team under the leadership of R. Tringham are included in books edited by M. Forte. In their work presented in Malta in 2009, the reconstruction of a Çatalhöyük house was discussed [11]. In 2004, a team from the Belgian Catholic University and the Swiss Federal Technical University carried out the digital reconstruction of the Antonine Fountain in the ancient city of Sagalassos near Burdur-Ağlasun [12]. In 2009, a team from Stanford University and the Austrian Academy of Sciences carried out the digital reconstruction of the octagon shaped mausoleum found in the ancient city of Ephesus [13].



Figure 1.6. Digital Reconstruction of the Antonine Fountain [12]

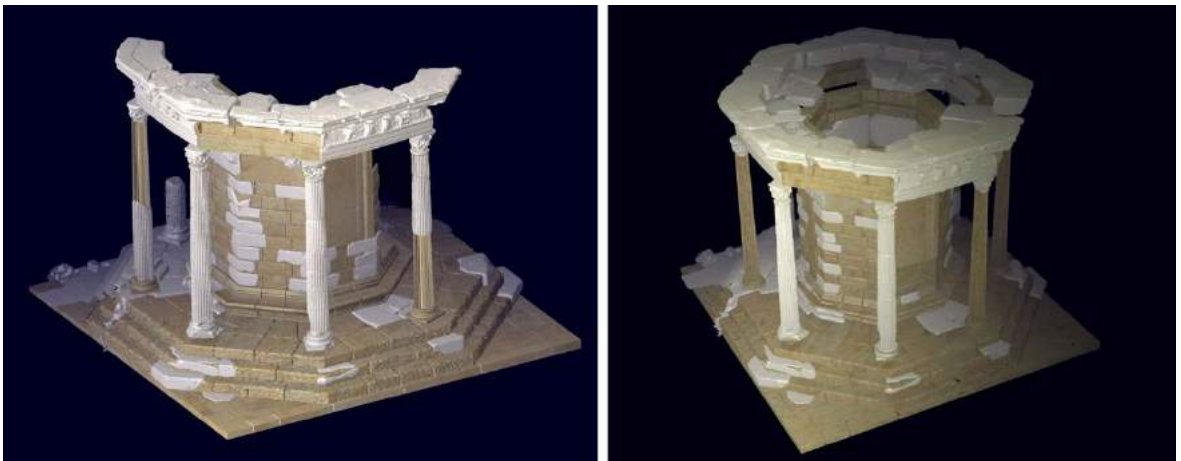


Figure 1.7. Digital Antostylosis of the Octagon in Ephesus [13]

The common feature of this study with the cyber reconstruction projects cited here is that all of them are included in the problem group considered as a three-dimensional puzzle (jigsaw puzzle). Bringing a large number of pieces together to rebuild very large monuments is a

human power problem. The solution of this problem is only possible by using computer graphics technologies. Goldberg et al presented this solution in their article published in 2004 [14].

A second factor that makes this problem much more difficult than normal puzzle problems is that the sum of the puzzle pieces only corresponds to a small proportion of the monument. This rate is less than 10% in Ephesus Artemision. In such cases, how to replace the missing parts is an issue that has been studied for the last 15 years.

The reconstruction problem of the temple of Artemis still remains a problem that has not been solved with scientific certainty, despite the fact that 150 years have passed since its discovery and hundreds of books and excavation reports, thousands of articles and statements have been published about it. Perhaps the most prominent among the genuine values that this study will create will be the solution to this problem.

Today, less than 10% of the temple remains. Restoring 100% of the remaining 10% of the marble fragments in the digital environment of the temple is like translating 100% of an antique book, only 10% of which remains. On the other hand, even 10% of the temple corresponds to more than a thousand broken marble pieces with a total weight of 60 tons. It is not possible to spread them on a floor, to relate them manually and with the naked eye, and to understand which main part they belong to. There is neither such a large ground nor the viewing capacity to see and synthesize such a large area.

The solution of this problem, which has not been solved until today due to the mentioned difficulties, will only be possible with the use of technology. There is only one previous example of solving a historical monument of this size using computer technologies: Forma Urbis Romae project [6]. In this project, the solution of the reconstruction problem was only possible by transforming the problem into a jigsaw puzzle. Almost all of the successful application examples of other jigsaw puzzle algorithms in the literature have focused on historical artifacts with much smaller scale and much lower rate of lost parts. The problem in this study is one of the largest and most difficult of its kind ever. If the problem is solved, it will have an important place in the archaeological literature as well as in the technological literature.

Removing the problem from the real museum environment and moving it to a computer environment where it can be solved in a virtual jigsaw problem requires the numerical storage of the geometric information of the pieces. In this problem where there are too many parts, collecting all the details with a laser scanner can be a long process that can take years. In order to accelerate this process, a method has been developed to extract the distinguishing features of objects by computerized image processing techniques and the minimum information corresponding to them has been scanned. This problem is a genuine problem that has not been adequately addressed due to the small size of the works in other examples in the literature.

The vast majority of people are aware of what 3D visualization is. Probably, these people passed through 3D corridors in 3D movies and amusement parks, entered 3D caves, where they met with ghostly 3D creatures, or rather they thought they were met. However, in such environments, not only the images but also the environment itself are synthetically created. In this study, the solution of another important problem that is still under investigation will be sought: blending the synthetic temple image with the natural environment image is another problem that is predicted to produce genuine value.

1.2. CLASSICAL TEMPLE OF ARTEMIS IN EPHEBUS

Ephesus Artemision has a long story, a lot has been written about it. Although the ruins of the temple have not been reached for many years, it has raised doubts whether it is a real or a legend, but the descriptions written in ancient books and included in Roman period coins during such periods are the most important reason why the lights of hope did not fade. The descriptions of the ancient writers and the depictions on the coins were so consistent in the details of the temple, and some details were shown in such detail that it was clear that this temple was real. Strabo wrote in his book *Geography* [15] that the temple was located outside the city in a grove between two streams and that its architect was the Cheirokeles, and his writings were accepted as an important proof of the existence of both the temple and the sacrificial altar.

The Artemision of Ephesus was the symbol of Ephesus and although it was destroyed 7 times, it was rebuilt each time by the Ephesians in a bigger and more magnificent way. It is the 8th and last temple, which is called the Classical Artemision because it belongs to the Classical period.

We learn the first architectural information about this temple from Pliny's *Natural History* [16] and Vitruvius's *Ten Books on Architecture* [17]. Pliny said that the dimensions of the temple were 225x425 feet and there were 127 columns, each 60 feet high. 36 of the columns were *columnae caelatae* (relief column). Vitruvius described the temple as a *dipteros* structure with 8 columns on the front and back sides and wrote that there was an opening in the ceiling.

The fact that Artemision was completely missing and not even the slightest trace of its foundation stones that should have been left behind had raised doubts as to whether it was truth or a legend? E. Falkener's book *Ephesus and Temple of Diana* [18], who conducted research in Ephesus in 1845, ends with the following words of his compatriot R. Chandler: "What happened to Diana temple? Could the wonder of the world disappear like a ghost without a trace? " Indeed, Artemision was the only temple among all the temples of the Classical Age that disappeared without the slightest trace. Without the reliefs on Roman-era coins and depictions of authors such as Pliny and Vitruvius, the temple would have been

believed to be the product of a dream.

Falkener's book caused John Turtle Wood to be interested in the subject, originally an engineer and another Englishman who came to Izmir for railway construction in 1863. Wood devoted his later years to the discovery of the temple and after seven years of effort, the temple, whose existence was disputed and doubted, was finally unearthed in the last days of 1869. John T. Wood continued his excavations until 1873. He described the 10-year excavation adventure that ended when the parts of the temple were moved to London in 1873, in his book *Discoveries at Ephesus* published in 1876 and presented a reconstruction drawing of the temple [19].

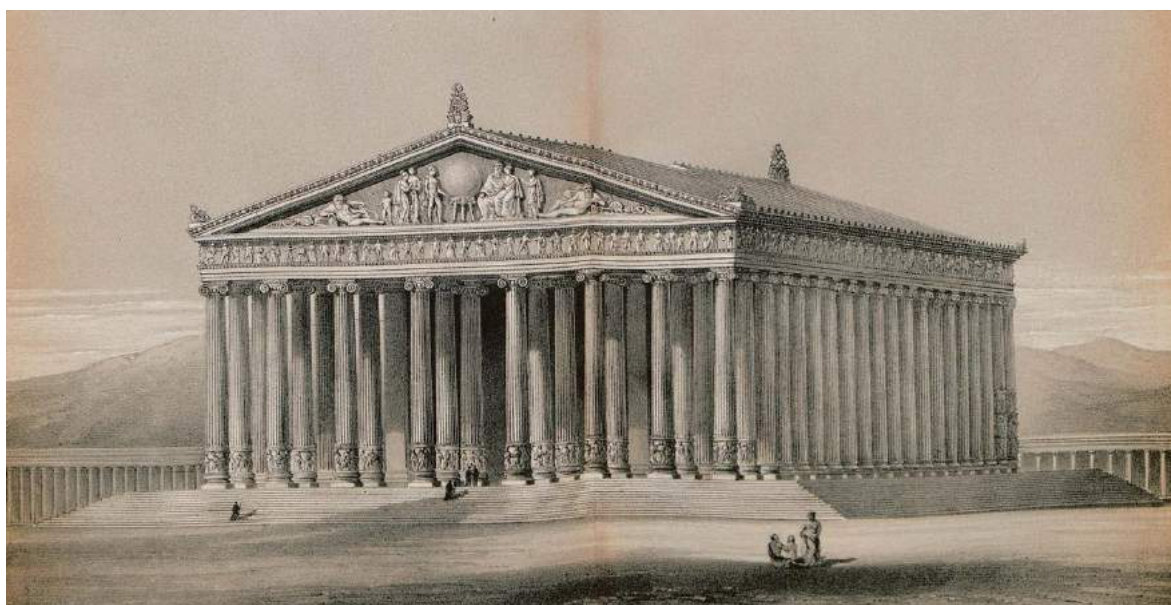


Figure 1.8. Proposed Reconstruction of The Temple of Artemis by Wood in 1876 [19]

D.G Hogarth and architect A. Henderson, who excavated in the center of the temple, created a sensation by finding the remains of the temples before the Archaic temple. Another important result of these excavations is that about 100 ancient coins were found. Among these were the oldest coins ever known. Hogarth's book, which includes the results of the early phase structures of the temple and information on the coins found, was published in 1908 under the name *Excavations at Ephesus* [20]. This book has served as an indisputable resource in the chronological ordering of the temple's phases for a century. The coins provide important clues about some details that have been lost due to the ruins being removed from

the foundation stones. The two-dimensional reconstruction drawing created by Bluma L. Trell using entirely coins in his book *The Temple of Artemis at Ephesos, Numismatic Notes and Monographs* [21] published in 1945 is still used by the British Museum today.

Among the marble pieces carried from the excavation site to the British Museum, many pieces of Ionic column heads, column columns, bases and drums, parapets and cornices were found. Since the temple was destroyed not by nature but by man and was looted as if it was a marble quarry for years, almost all but a few were found in small pieces. Ekrem Akurgal stated in his book *Ancient Civilizations and Ruins of Turkey* [22] that the reconstruction of the temple is possible based on these pieces in the British Museum.

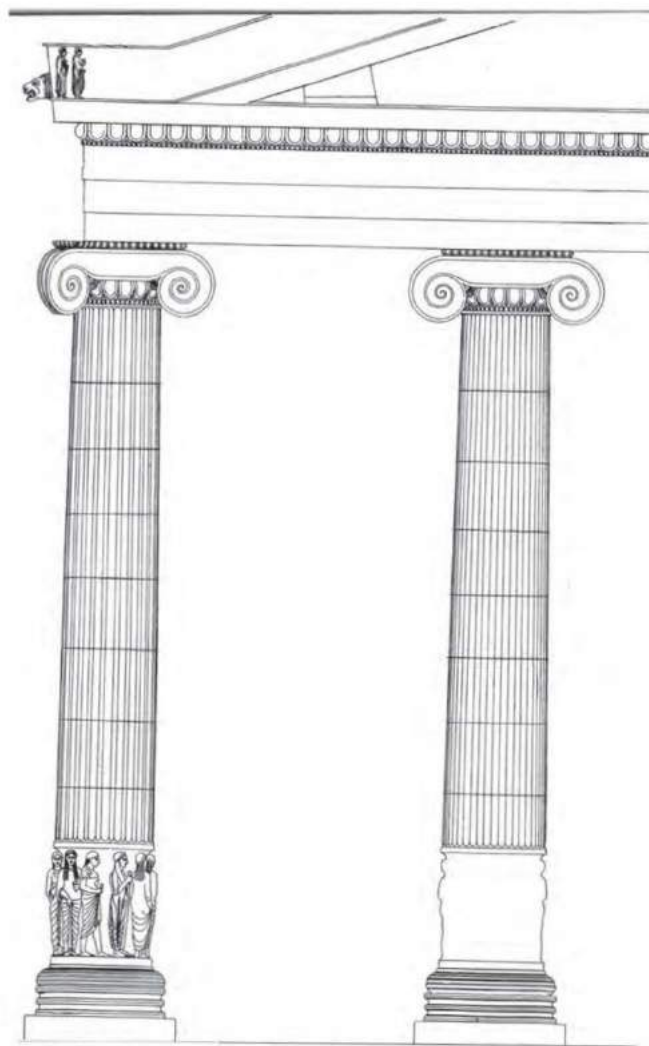


Figure 1.9. Sculptured Columns [22]

However, A.S. Murray who worked on these pieces, came to the conclusion after lengthy effort that being able to relate them to each other was not an easy task. It was left to A.S. Murray to assemble the small pieces, as Wood was not interested again after handing them over to the museum. After a long and painstaking work, Murray gave up the small pieces and turned to the smaller number of larger pieces, reconstructing a parapet that is today in the museum's warehouses but is not displayed and two separate Ionic column capitals from the Archaic period. A.S. Murray published these results in 1889 in the *Journal of Hellenic Studies* [23].

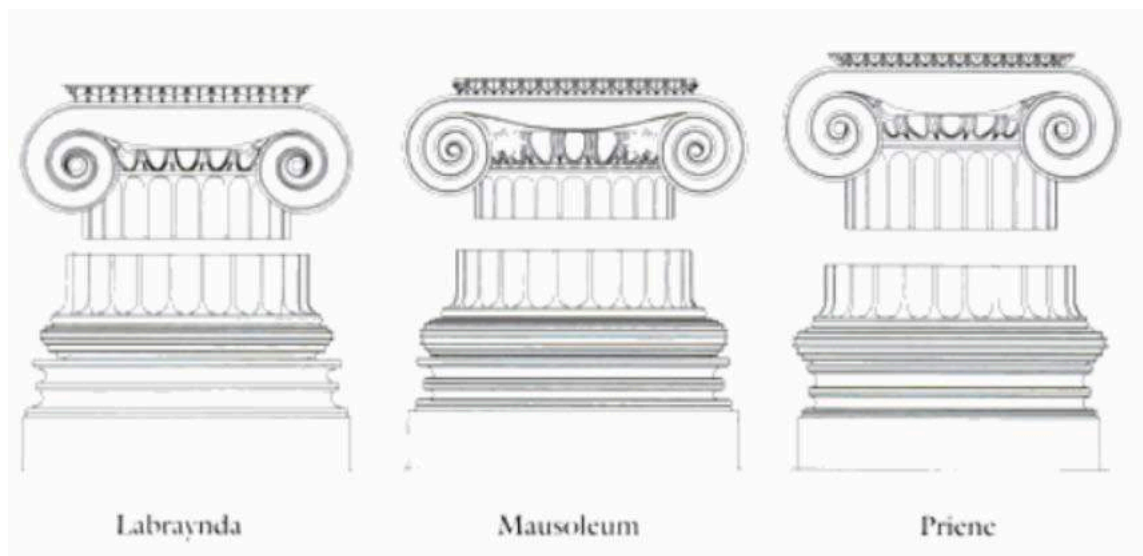


Figure 1.10. Ionic Columns [23]

The human-sized reliefs between the pieces were a sensational invention in archaeological circles. Wood was wrong to think that these were parts of the friezes. The puzzle was solved when Fergusson, who started to work on these pieces in 1884, discovered right-angled fittings, the reliefs belonged to cubic pedestals. These were the pedestals of the "columnae caelatae" (relief columns) referred to by Pliny. However, once again solving a problem created a new problem that awaited an answer. Cubic pedestals with relief were previously unseen temple elements, and how to relate them to the relief drums was a new question to answer. Murray placed the relief pedestals under the relief column drums, and the pedestal + drum pair under the obverse shafts [24]. Murray's construction was accepted and exhibited in the British Museum for a while.

But Murray, who needed additional height for the lengths of the pillars that stretched in this way, had radically placed them on a new flat that he created under the platform. Murray's reconstruction was severely criticized by Lethaby. Lethaby suggested important changes to this construction, saying that an order in which three separate columns were arranged on two separate high platforms constituted an order that was contrary to the Hellenist temple traditions. Lethaby lifted the relief column drums over the relief pedestals and placed the pedestals and drums on the platform. In Lethaby's arrangement, pedestal columns were at the front and drum columns behind them [25].

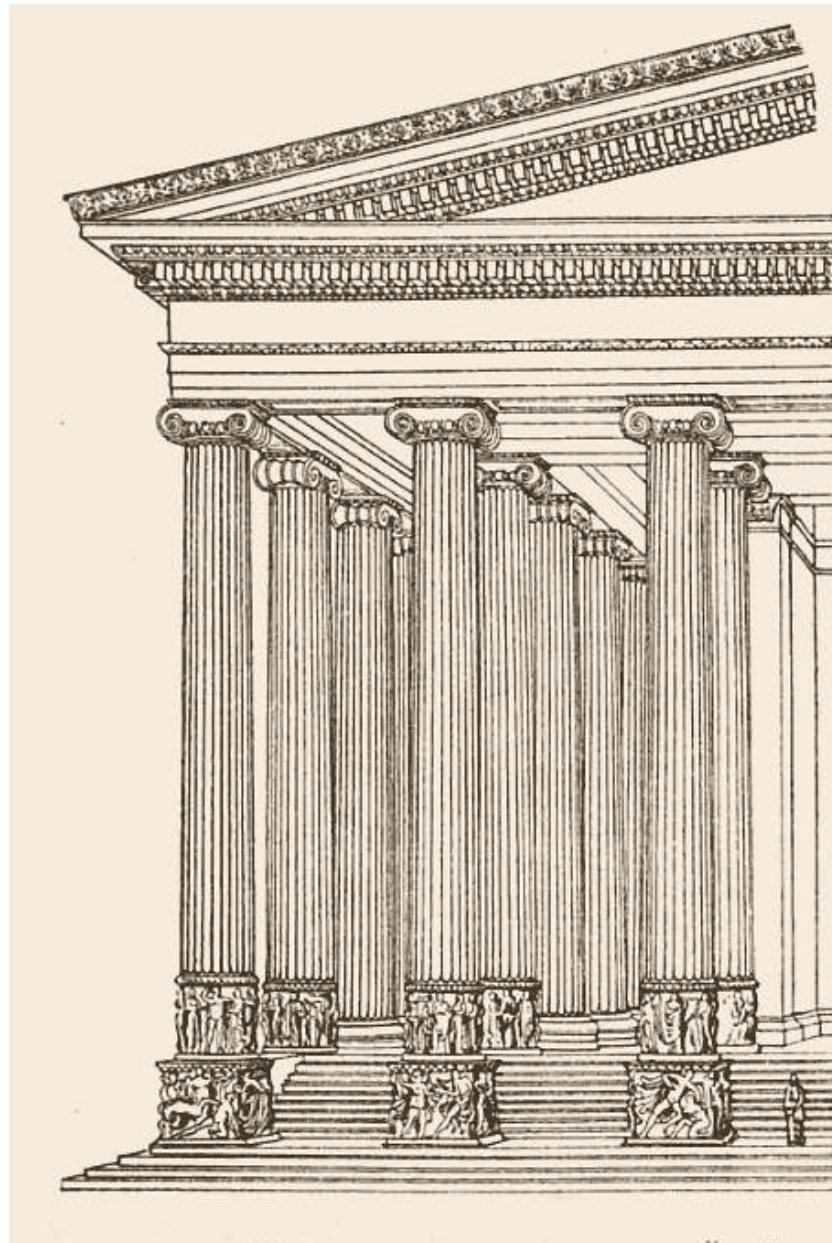


Figure 1.11. The Temple Façade Drawing by Lethaby [25]

Until the excavations of the temple of Artemis in Sardis were completed, the British Museum adopted the reconstruction of Murray. Excavations conducted by H. C. Butler were important in terms of the use of pedestals and drums in the Temple of Artemis, which was unearthed in Sardis and bears similarities to Classical Artemision. Butler's excavation results were published after his death [26]. Sardis excavation results showed that the drums were not placed on the pedestals. Pedestal and drum columns were arranged separately on the front, drum in the front and pedestal at the back. The British Museum, in the light of new information, lifted the relief drum from the pedestal and placed it on the platform of the exhibition space.

The temple excavations initiated by the British Museum in 1863 and continued intermittently after the temple was found and the parts were moved to England, were carried out by the Austrian Archeology Institute since 1965. The director of these excavations, Austrian architect Anton Bammer, published 2D architectural drawings of the temple as a result of his work on the ruins of the temple in 1968 at the British Museum [27]. In these drawings, Bammer re-opened the problem, which seemed to have closed after the Sardis findings, by placing the relief drums just below the column heads. This idea of Bammer stems from the fact that the cylindrical relief drums of the Apollon Smintheus temple located in the Troia region are located just below the column head.

Stefan Karwiese showed evidence of an Ephesus coin printed in the name of Caesar Maximus, which he included in his book *Introduction to Ancient Numismatics*, published in 1995, and stated that there are no signs of a drum under the column heads. Indeed, nothing is seen under the capitals of this coin, which depicts the facade of the temple in photographic resolution and illustrates the drums under the columns in detail [28].

In Bammer's article in the book of the same name, published in 2008 [29] due to the opening of the exhibition titled "Ephesus Artemision: The Sacred Space of a Goddess", Bammer mentions the problem of reconstruction and says: "..... Certain pieces of both [Archaic and Classical Temples] have certainly not survived. At the same time, the column heights of both temples are unclear. Therefore, there are many unknowns that prevent a reliable reconstruction of both temples. "

After the wonder of the world was destroyed by the Ostrogoths in 263 AD, its remains were used as a marble quarry, many parts that shed light on the history were dismantled for use in construction or burned in quarries. With the transfer of the last marble remains of the temple from Ephesus to London in 1873, there is nothing left for the present-day visitor to Ephesus to envision the true splendor of the temple.

Richard Stoneman describes this situation in his book *Land of the Lost Gods* as follows [30]:
“... the temple will never be seen in place again. A single standing column stands alone beside a green pond, a miserable reminder of the 127 columns that were once there. The Ephesians, who came to worship their Holy and Great Diana, were replaced by a stork family nesting on the column. Diana now resides at the British Museum. “

2. STEPS OF VIRTUAL REALIZATION PROCESS

The proposed process for the virtual realization of cultural heritage in Figure 2.1. consists of three main stages as structural information, digital reconstruction and scene design. In the structural information phase, a detailed literature search is made on selected cultural heritage. The digital reconstruction phase is divided into four parts as image editing, 2D drawing, 3D modeling and arrangement and optimization. At this phase, a usable three-dimensional model of the structure is created. Scene design, which is the final phase, consists of three stages as material editing, environment design and rendering. During the scene design phase, the environment and conditions are created for historical artifacts modeled in three-dimension.

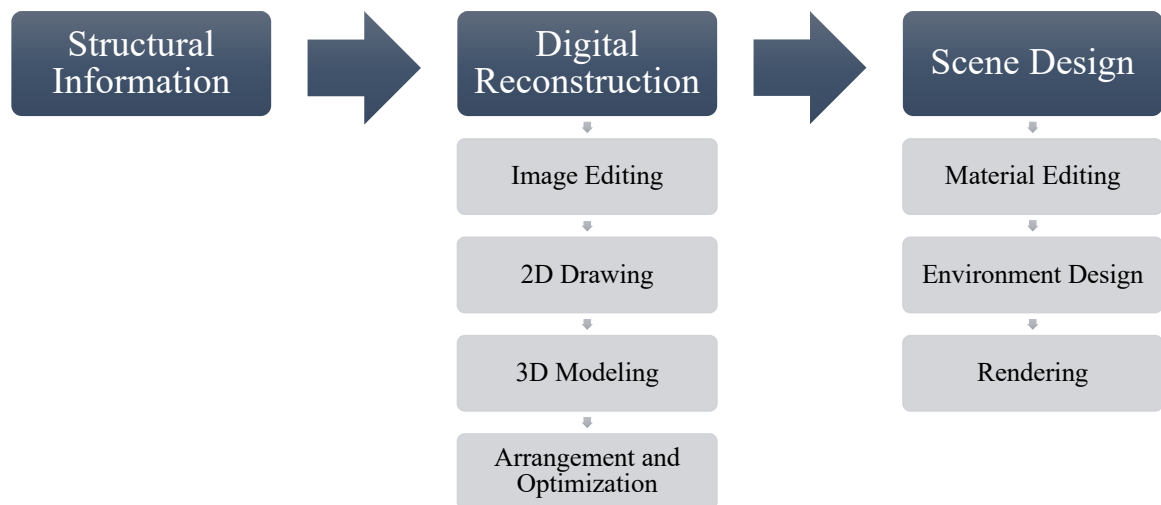


Figure 2.1. Steps of Virtual Realization Process

2.1. STRUCTURAL INFORMATION

Detailed scientific research is conducted on the cultural heritage which selected to be virtually realize at the structural information phase. This is the most important stage for virtual realization process because if the correct information about the cultural heritage cannot be obtained from the right sources, the reliability of the digital reconstruction is questioned. Thanks to this particular research, detailed drawings, visuals and plans about the historical artifact can be accessed. These information are usually obtained from the writings of the travelers of that period, historical inscriptions, archaeological excavations and even coins. Figure 2.2. shows an example of the Temple of Artemis at Ephesus drawings in the Metropolitan Museum of Art.



Figure 2.2. The Temple of Artemis Drawings in the Metropolitan Museum of Art

2.2. DIGITAL RECONSTRUCTION

The main purpose of the digital reconstruction process is to create a usable three-dimensional model of the cultural heritage by making use of the historical data such as plans, visuals and 2D Drawings obtained in the Structural Information phase. Various advanced computer graphics software is used while modeling the cultural heritage in three-dimension. This phase consists of Image Editing, 2D Drawing, 3D Modeling, and Arrangement and Optimization parts.

2.2.1. Image Editing

In order to be used in 2D Drawing and 3D modeling stages in the Image Editing stage, the visuals obtained at the Structural Information phase are sized in accordance with the plans, with the help of Adobe Photoshop raster graphics editor software. In addition, some visuals are edited with a white background and black and white to be used in 3D modeling of sculptures and reliefs. Figure 2.3. shows an example of this editing. Black and white and white background images are only needed at the 3D Modeling stage.

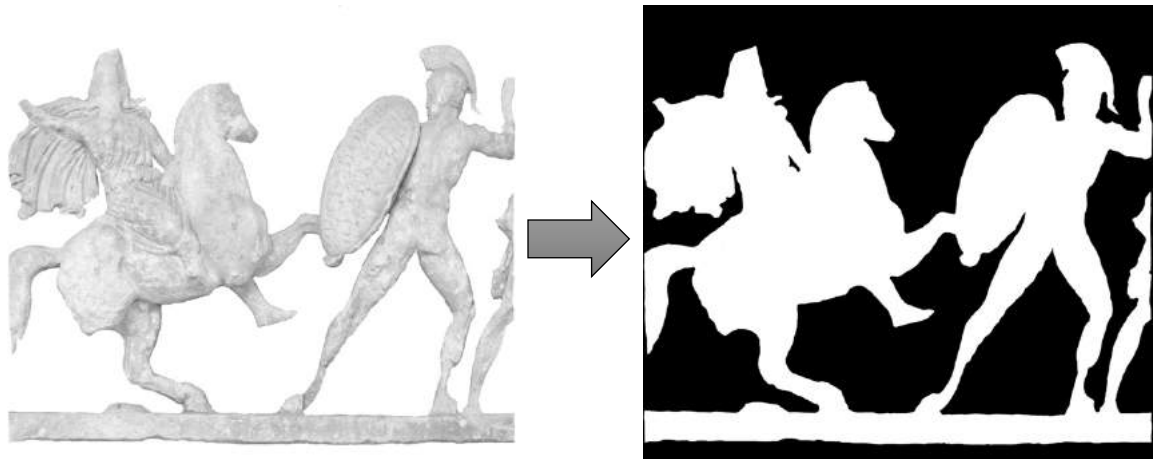


Figure 2.3. Converting Image to Black and White

2.2.2. 2D Drawing

In the 2D Drawing stage, Autodesk AutoCAD, one of the powerful CAD software is used to make 2D drawings from the edited visuals during the Image Editing stage and the

collected historical data such as plans during the Structural Information Phase. The reason to use cad software is to create real scale drawings to be used in the 3D Modeling stage. The edited image is imported in the software. Lines and points are drawn to create a 2D drawing on the imported image to form the visual. Figure 2.4. shows a 2D column head drawing drawn from the imported column head visual editing. These drawings obtained from the edited images are saved for later use in the 3D Modeling stage.

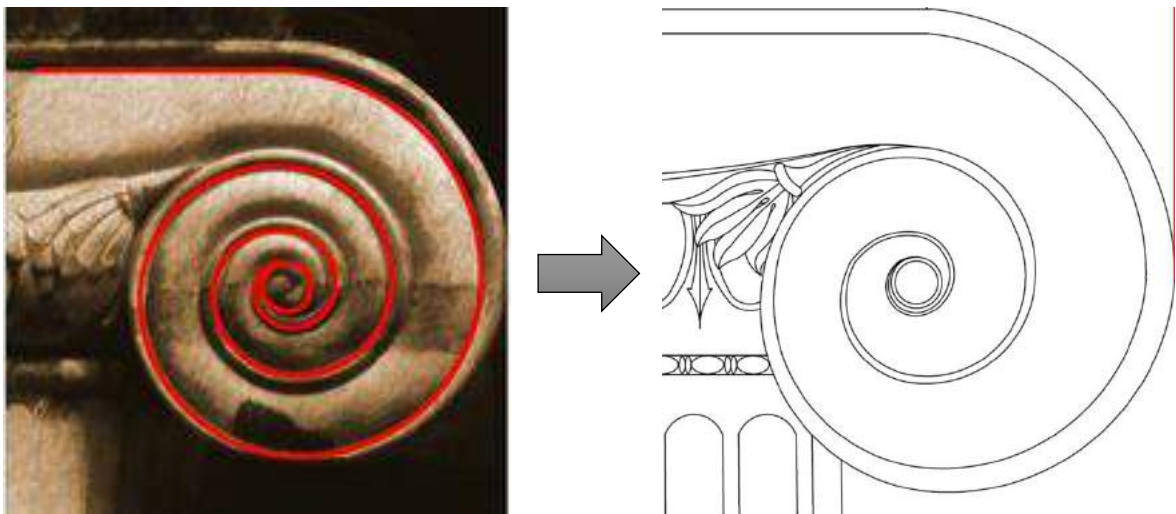


Figure 2.4. 2D Drawing on Edited Image

2.2.3. 3D Modeling

3D models mainly consist of polygons and vertexes. These vertexes and polygons combine in three dimensions to create a model. 3ds Max modeling software, which is a product of Autodesk like AutoCAD, is used to create historical artifact models in the 3D Modeling stage. The compatibility of the graphics software used in 2D Drawing and 3D Modeling stages is very important. For this reason, products of the same software manufacturer are preferred. Scaled drawings and edited visuals formed in the 2D Drawing and Image editing stages are imported to create 3D model of structure by using various commands in 3ds Max modeling software. In addition, simple models are created by using the object creation commands in the 3ds Max modeling software based on the historical data and plans obtained at the Structural Information phase. An example of these models is shown in Figure 2.5.

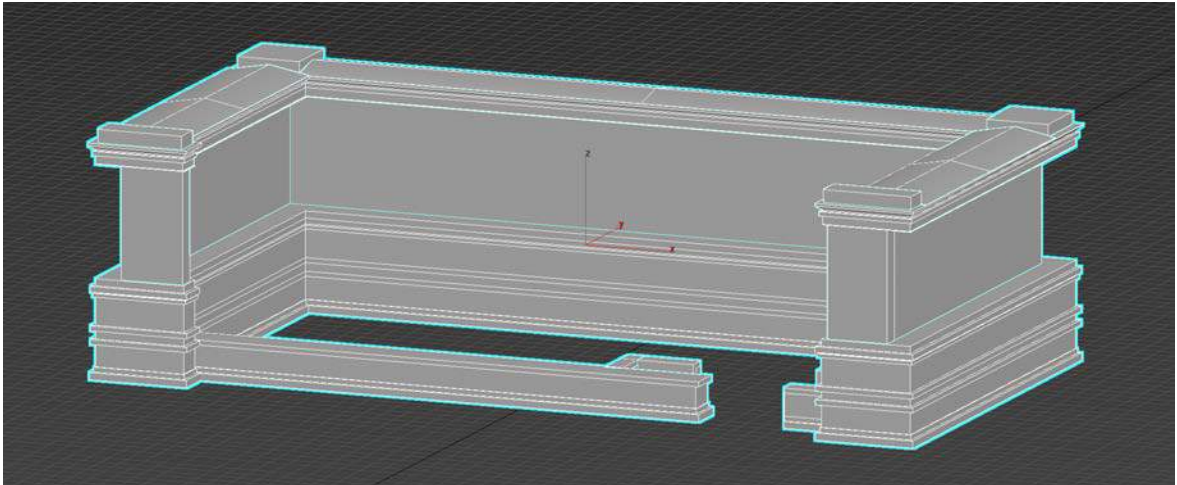


Figure 2.5. 3D Model of The Altar

2.2.4. Arrangement and Optimization

The Arrangement and Optimization stage is very important to ensure the usability of the 3D model. At this stage, historical artifacts that are modeled in three dimensions are brought together in 3ds Max modeling software. The details of the created models are directly proportional to the number of polygons. Depending on the details of the three-dimensional models, the graphics processing power of the computer used is limited. The graphics processing power of each computer varies according to its configuration. However, after the three-dimensional model is arranged, the screen refresh rate should be over 20 FPS in 3ds Max Performance Mode for efficient operation. If the screen refresh rate is below 20 FPS, the number of polygons of the model should be reduced using various commands such as “MultiRes Modifier”. Figure 2.3. shows an example of 3D models arrangement.

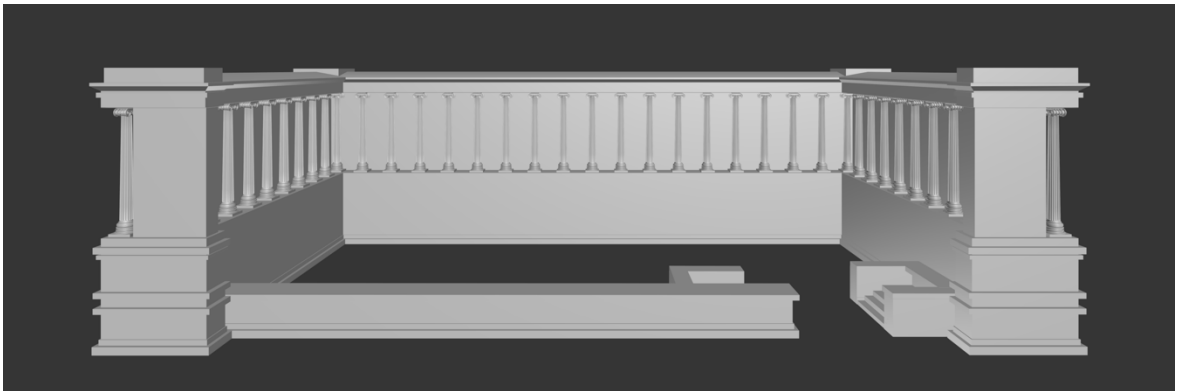


Figure 2.6. Arrangement of 3D Models

2.3. SCENE DESIGN

Scene Design phase includes three stages as Material Editing, Environment Design and Rendering. At this phase, 3D historical artifact models created in the Digital Reconstruction phase are visualized in accordance with their environment and conditions thanks to the information obtained in the Structural Information phase. Lumion, one of the advanced rendering software, is used for this visualization at all stages. The cultural heritage modeled in 3ds Max software are exported in FBX file format, then imported in Lumion software and passes the above-mentioned stages for visualization. Figure 2.7. shows an example of a rendered model whose visualization has been completed.



Figure 2.7. Scene Design on Lumion

2.3.1. Material Editing

At the stage of material editing, color and texture assignments are made to the polygons of 3D models in accordance with the obtained structural information. In order for these assignments to be made correctly, cultural heritage must have a standard texture while modeling during the Digital Reconstruction phase in 3ds Max software before exported FBX file format. In the Lumion software material editing section, adjustments are made such as the size, color, relief rate, light settings and aging of the material used. Figure 2.8. shows a model with edited material on Lumion software.



Figure 2.8. Material Editing on Lumion

2.3.2. Environment Design



Figure 2.9. Environment Design on Lumion

In the environmental design phase, after detailed research on the environment where the cultural heritage is located, the height map of the terrain is downloaded according to its

coordinates and location, then imported in the Lumion software. The sea, streams, trees and other environmental factors are accurately placed in the Lumion software according to their location, historical data and height map data of the terrain. Effects such as wind speed, wave direction and length, the color of the tree leaves, and the length of the grass can be added to the created environment design in Lumion software terrain editing section. Figure 2.9. displays a scene with an environmental design created in the Lumion software.

2.3.3. Rendering

Rendering Stage is the most important stage of Scene Design phase. This stage aims to generate image or animation from the color and texture assigned model and the created environmental design with the help of various lighting settings and effects on Lumion software. The generated image is a frame and while the animation is generated, one second consists of 30 frames. This generation can be challenging for computers while trying to produce detailed quality output. The main reason for using Lumion software as 3D rendering software in Scene Design phase is the success in advanced image generation and image processing speed. Lumion software generates advanced image from a detailed scene with 12 FPS frame rate, 245 million 3D points and 1550 trees/plants in 20 minutes at 8K resolution. Figure 2.10. represents a column drum as the output of the rendering process.



Figure 2.10. Rendering on Lumion

3. CASE STUDY – CLASSICAL TEMPLE OF ARTEMIS IN EPHEBUS

Arguably no other temple in the world has affected mankind so much as the Temple of Artemis in Ephesus by its mystery, inaccessibility, obscurity and exclusivity. Destroyed seven times yet to be rebuilt each time with greater magnificence and splendor than the former. The eighth temple (Classical Temple of Artemis) which is the subject of this case study was the most glamorous of all; it was one and the most stupendous of the seven wonders of the world. Classical Temple of Artemis had taken a number of scientists, archeologists, travelers, architects and artists into its grip for centuries.

No other temple of the Classical Age had vanished like it without leaving any trace; had it not been to the prints of the temple on the Roman coins, and the descriptions of the ancient authors like Pliny and Vitruvius, one would believe the world wonder was a figment of the imagination [16,17]. On the last day of 1869, after seven years of effort, the temple which was so long lost, so long sought for, and almost despaired of was finally found by the English engineer J.T. Wood.

Yet, today's visitor to Ephesus is encountered with a frustrating scenery. Because, in 1873, after ten years of excavations, 60 tons of marble fragments remaining from the temple were transported from Ephesus to London and nothing was left to today's visitor to conjure up its original magnificence.

Richard Stoneman in his book *Land of the Lost Gods* writes about this as follows [30]: “.... but the temple itself will never stand again. The one re-erected column stands in a green pool, a forlorn reminder of the 127 columns there once were. Atop it nests a family of storks, the only inhabitants now who have replaced the Ephesian worshippers of Great Diana. Diana dwells now in the British Museum.”

Contrary to “.... but the temple itself will never stand again.” prophecy of the author, thanks to latest developments in three-dimensional volumetric visualization field, the technology is now available to resurrect the Temple of Artemis in Ephesus, the birthplace of the goddess.

The subject of this case study is, with the advent of the latest technologies on computer graphics field and the developed virtual realization process in chapter two, to resurrect the most splendid shrine of our historical heritage with a virtual reality comparable to what the Ephesians of the Classical Age used to see.

In figure 3.1., the 2D drawing of the Artemis Temple created with CAD software, one of the advanced computer graphics technologies, is shown as an example.

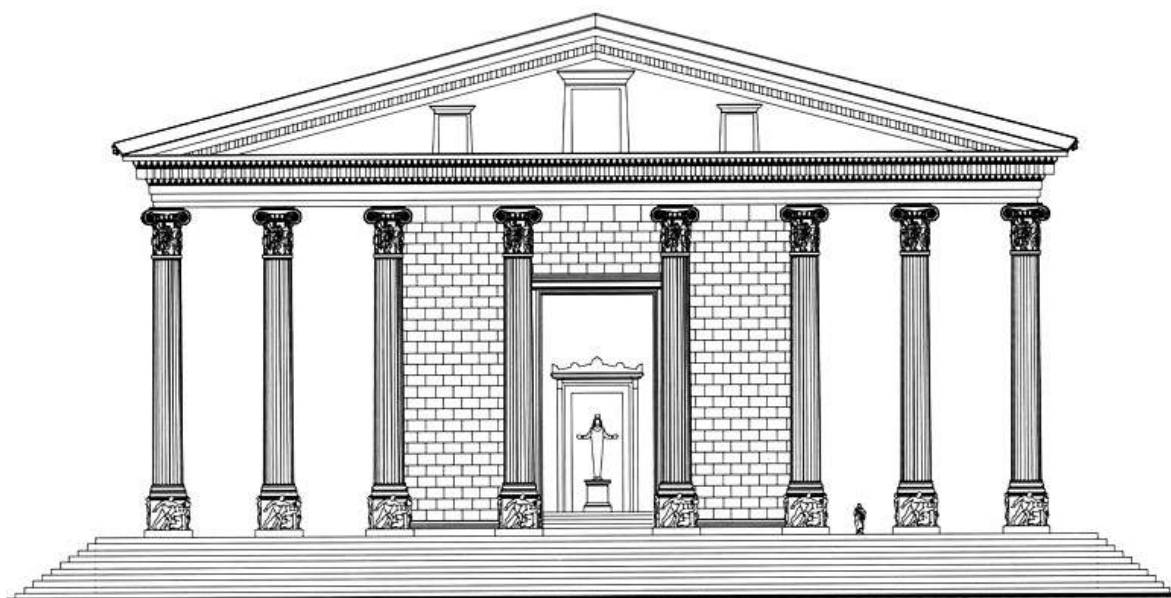


Figure 3.1. Temple of Artemis 2D Drawing

3.1. STRUCTURAL INFORMATION

Based on the literature research in Chapter 1.2., the structural information of the Temple of Artemis was obtained from various articles and books. In addition, various drawings and images of the remains that have survived to the present day of the temple of Artemis for use in 2D drawings and 3D modeling were obtained as a result of detailed structural information research.

The dimensions of the Classical Artemis Temple, which one of the Ionian Temples in Turkey to be modeled in three dimensions are shown in Table 3.1. [1]. Classical Temple of Artemis is 111.48 meters long, 51.44 meter wide and has 10 steps leading to the temple. The temple has a row of 8x27 columns, and the height of the columns is 17.65 meter, and the diameter is 1.84 meters.

Temple Attributes	Temple of Artemis Leukophryne (Case Study)	New Temple of Artemis at Ephesus (Classical)	Temple of Athena Polias at Priene	New Temple of Apollo at Didyma	Temple of Artemis at Sardis	Smintheion in Troas	Temple of Dionysos at Teos	Temple of Aphrodite at Aphrodisias
Date	220 BC	356 BC	345 BC	333 BC	300-275 BC	Mid 3 rd Century B.C.	190 BC	Late 1 st Century B.C.
Architect(s)	Hermogenes	Cheriokrates	Paeonius	Paeonius	?	?	Hermogenes	?
Peristyle type	Pseudo-dipteral	Dipteral	Peripheral	Dipteral	Pseudo-dipteral	Pseudo-dipteral	Peripheral	Pseudo-dipteral
Portico Style	Octastyle	Octastyle	Hexastyte	Decastyle	Octastyle	Octastyle	Hexastyle	Octastyle
Stylobate L	57.89 m	111.48 m	37.17 m	111.55 m	97.94 m	47.88 m	19.9 m	8.5 m
Stylobate W	31.6 m	51.44 m	19.53 m	49.6 m	45.51 m	30.82 m	32.57 m	31 m
Stairs type	All sides	All sides	All sides	All sides	All sides	All sides	All sides	All sides
Number of steps	7	10	3	14	6	10	11(front) 5(sides)	4
Column Height	13.10 m	17.65 m	11.40 m	19.5 m	17.8 m	10.096 m	8.806 m	9.288 m
Array of Columns	8 x 15	8x27	6 x 11	10 x 21	8 x 20	8 x 14	6x11	8x13
Column Diameter	1.485 m	1.840 m	1.425	2.022 m	2.094 m	1.289 m	1.036 m	2.176 m

Table 3.1. Temple Attributes of The Ionian Temples in Turkey [1]

The Temple of Artemis plan taken from Vitruvius's book “Ten books on architecture”, is shown in Figure 3.2. [17]. In the 3ds Max modeling software, the plan of the temple is assigned as a texture on a plane drawn according to the dimensions of the temple. 127 columns, 2 separate steps, walls and altar are positioned in the modeling software according to the scale in this plan.

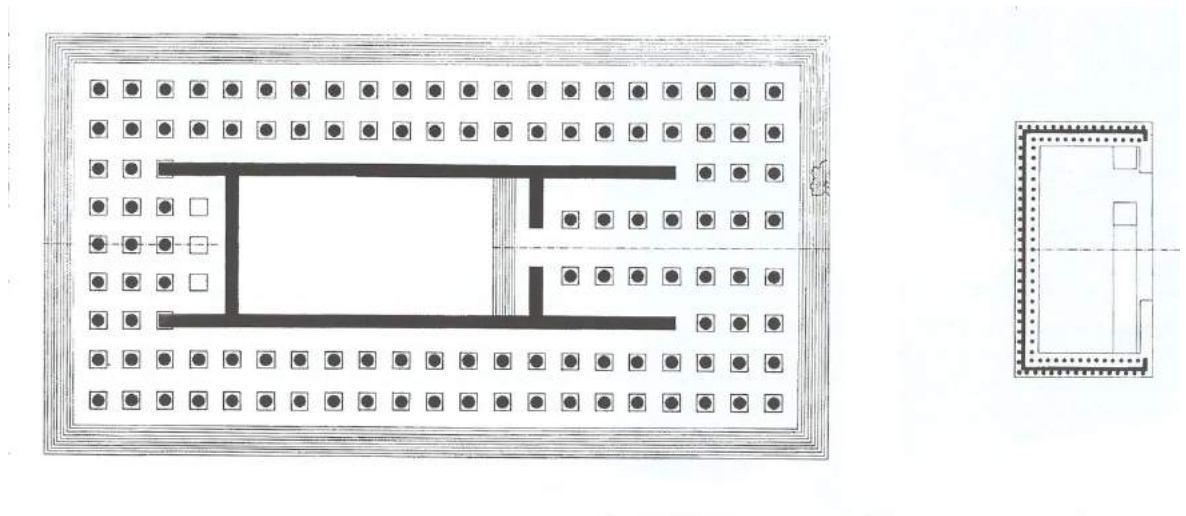


Figure 3.2. Temple of Artemis Plan [17]

3.2. MODELING

In the Modelling section, the structural parts that make up the Temple of Artemis will be modeled in 3ds Max Software with the historical data obtained at the structural information phase. These structural parts to be modeled are divided into 3 sections as "Walls, Stairs and Roof", "Columns" and "Reliefs and Statues" according to modeling methods.

In addition, the three-dimensional models created will be arranged and optimized at last part. Figure 3.3. shows the 3D model of the Artemis Temple that will emerge as a result of these stages.

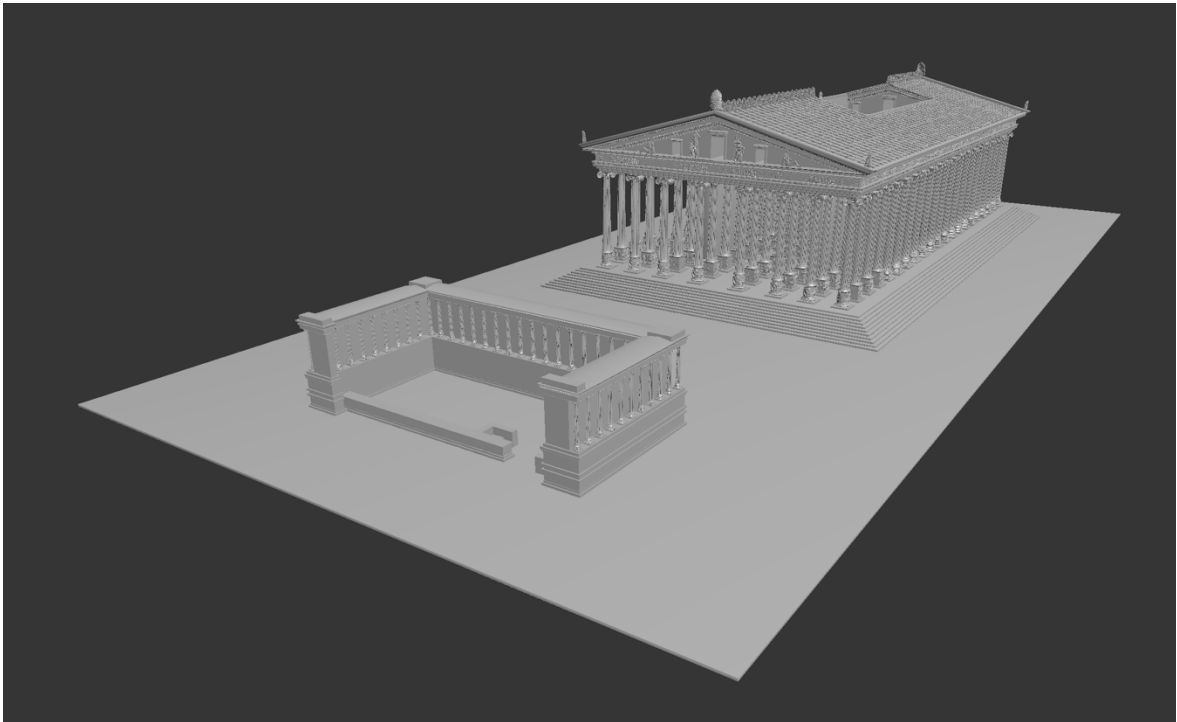


Figure 3.3. 3D Model of The Temple of Artemis (without material mapping)

3.2.1. Walls, Stairs and Roof

At this stage, firstly the chamfer boxes are created according to the measurements in the temple plan to form the walls, stairs and roof. The generated chamfer boxes are converted to editable poly in order to make changes on the models. The model is created by adhering to the 2D drawings and scale of Artemis Temple with polygon addition or subtraction

methods.

2D CAD front view drawings drawn in the AutoCAD software during the modeling phase of the roof and walls are taken as a reference. On the stairs, the plan of the temple is taken as a reference. Figure 3.4. shows the structural parts created by these methods.

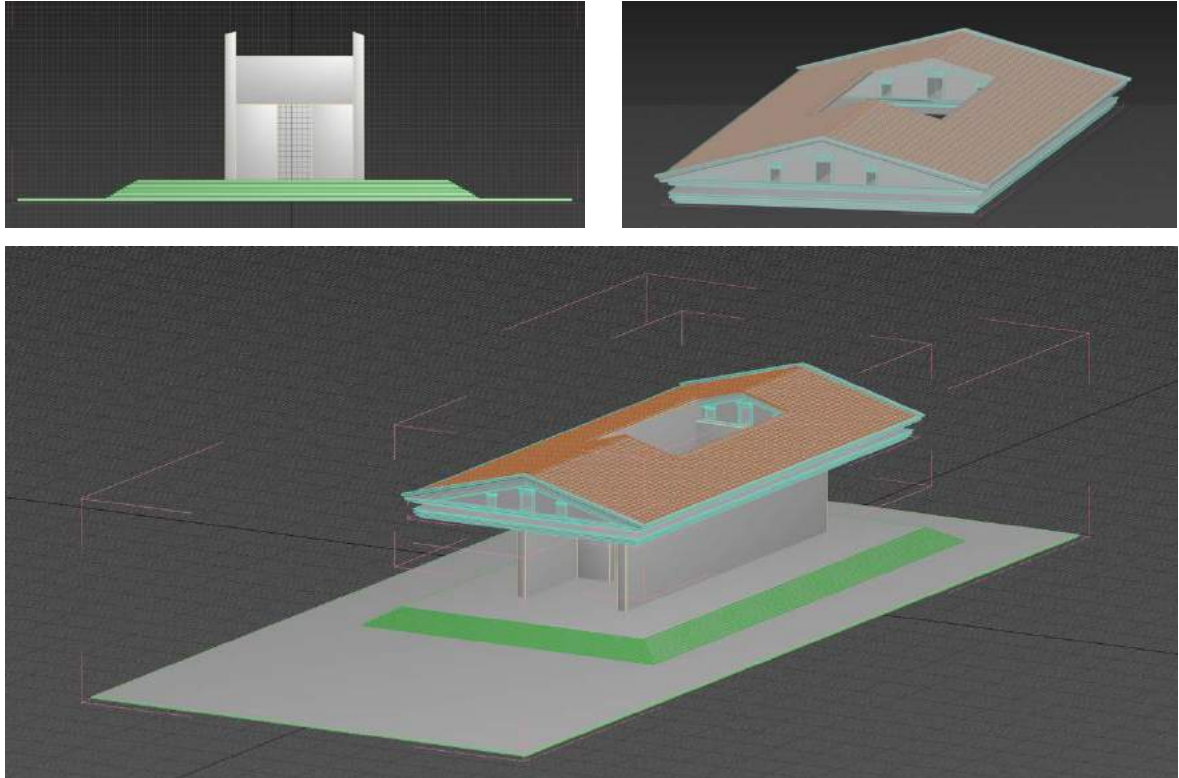


Figure 3.4. Modeling of Walls, Stairs and Roof

3.2.2. Columns

The Temple of Artemis has 6 different columns shown in Figure 3.5.. 5 of these columns are Ionic and one is Corinthian. The modeling of the columns is completed in 3 stages as head, body and drum shown below. These column pieces are combined after going through individual modeling steps to form the columns.

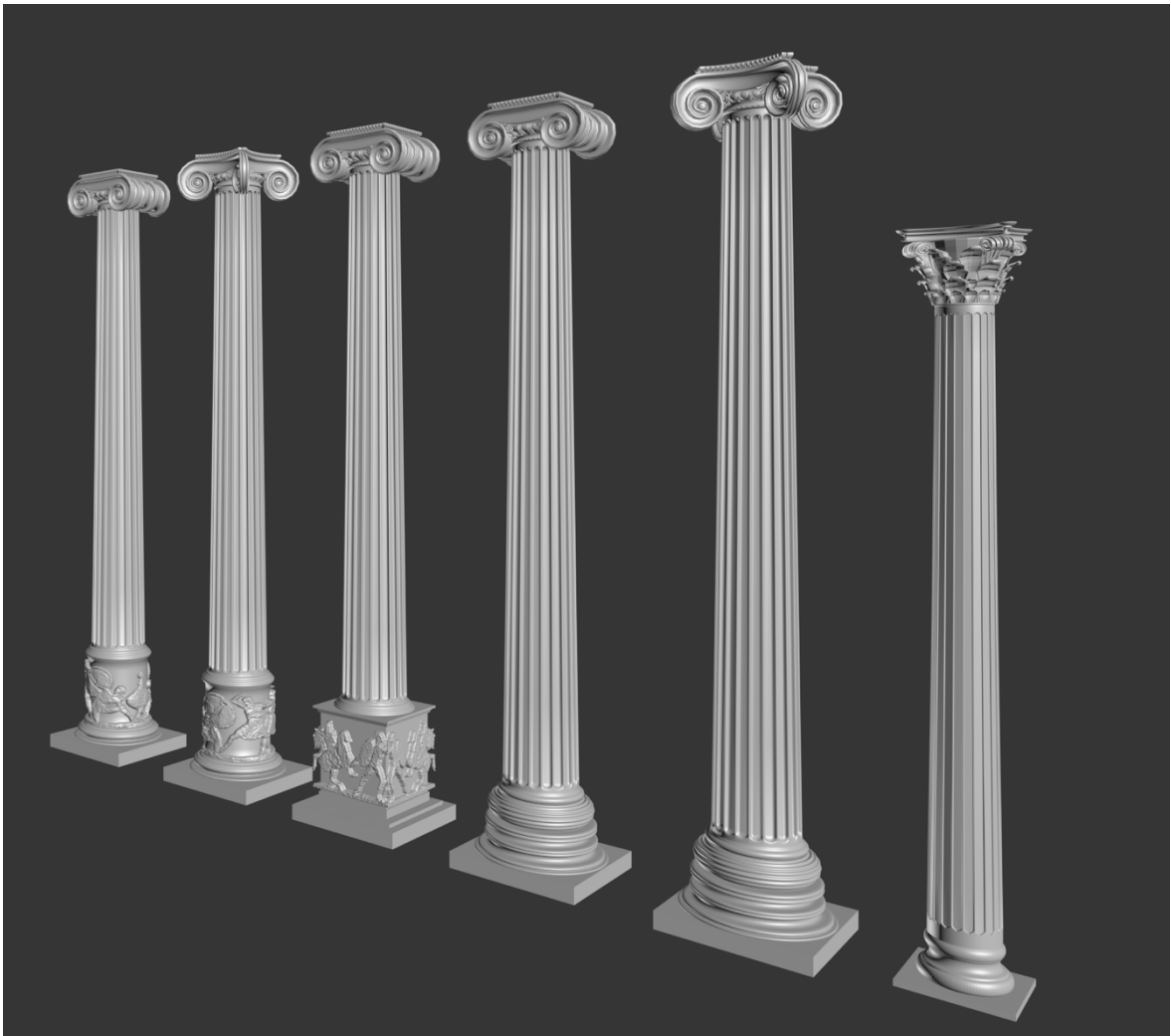


Figure 3.5. Columns of The Temple of Artemis

The columns in the Temple of Artemis have 3 different column heads as Ionic, Corner Ionic and Corinthian. The 2D cad drawing drawn with reference to the images of the temple is imported into the 3ds Max software. A chamfer box is created on the imported CAD drawing. The chamfer box is generated into editable poly, then polygon addition and removal methods are applied, and the polygons and vertexes are moved to make the chamfer box take the shape in the drawing.

The volume is given to the model by using the "Bevel" command. Corner column heads are bent at the desired angle using the "Bend" command. This process for the front face of the column head is created symmetrically on the backside using the "Mirror" command. The "Mirror" command is applied to all 4 sides for corner column heads. The side faces of the

column heads are arranged by moving the polygons and vertexes with reference to the visuals of the temple. Figure 3.6. shows the column head modeling process.

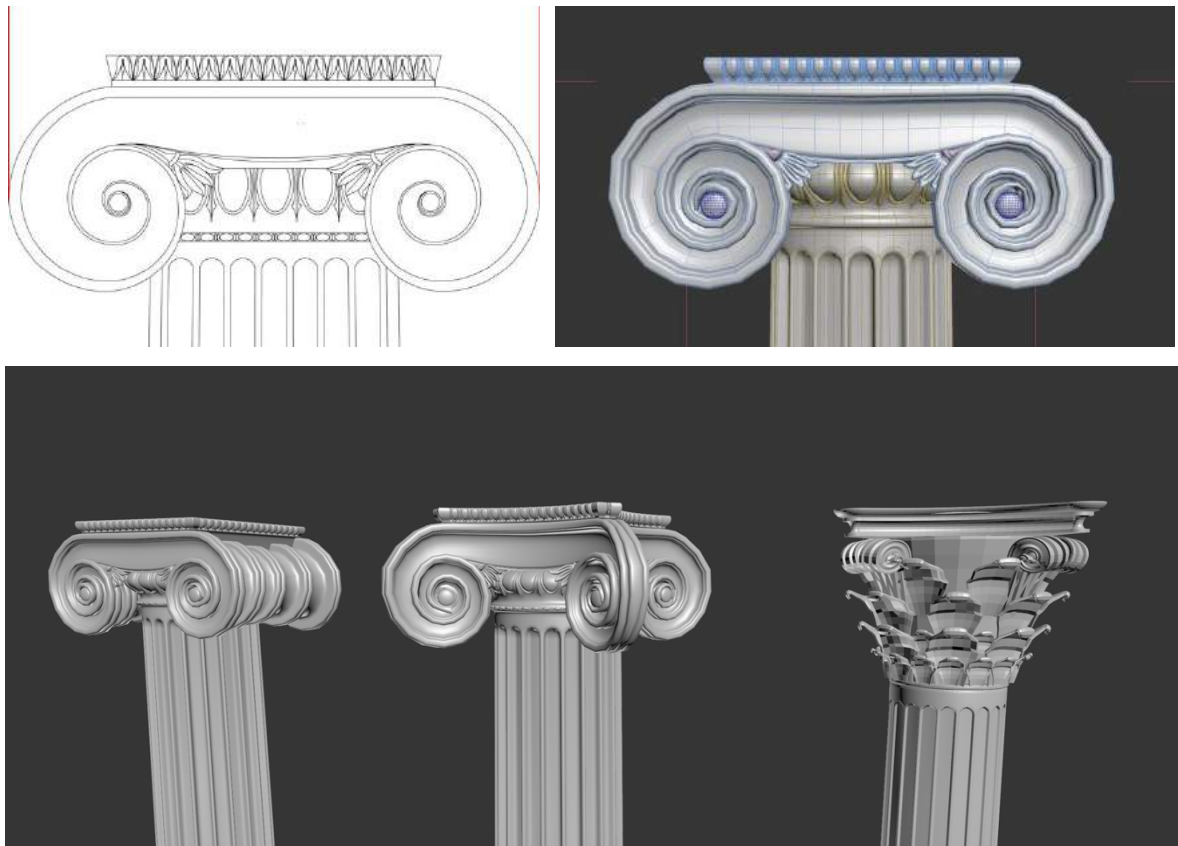


Figure 3.6. Ionic Capitals

Column bodies are created with the same modeling technique, even though their lengths or widths are different. 2D CAD drawing drawn in AutoCAD software with reference to the Temple of Artemis visuals is imported in 3ds Max software. A chamfer box is formed on the column body drawing and converted into poly. The polygons and vertexes of this chamfer box are moved to take the shape of the column body groove. The volume is given to the model by using the "Bevel" command.

The resulting model is turned 360 degrees using the "Array" command and the column body is created. The column body model created is scaled according to the column type to be used. Figure 3.7. represents the column body modeling phase.

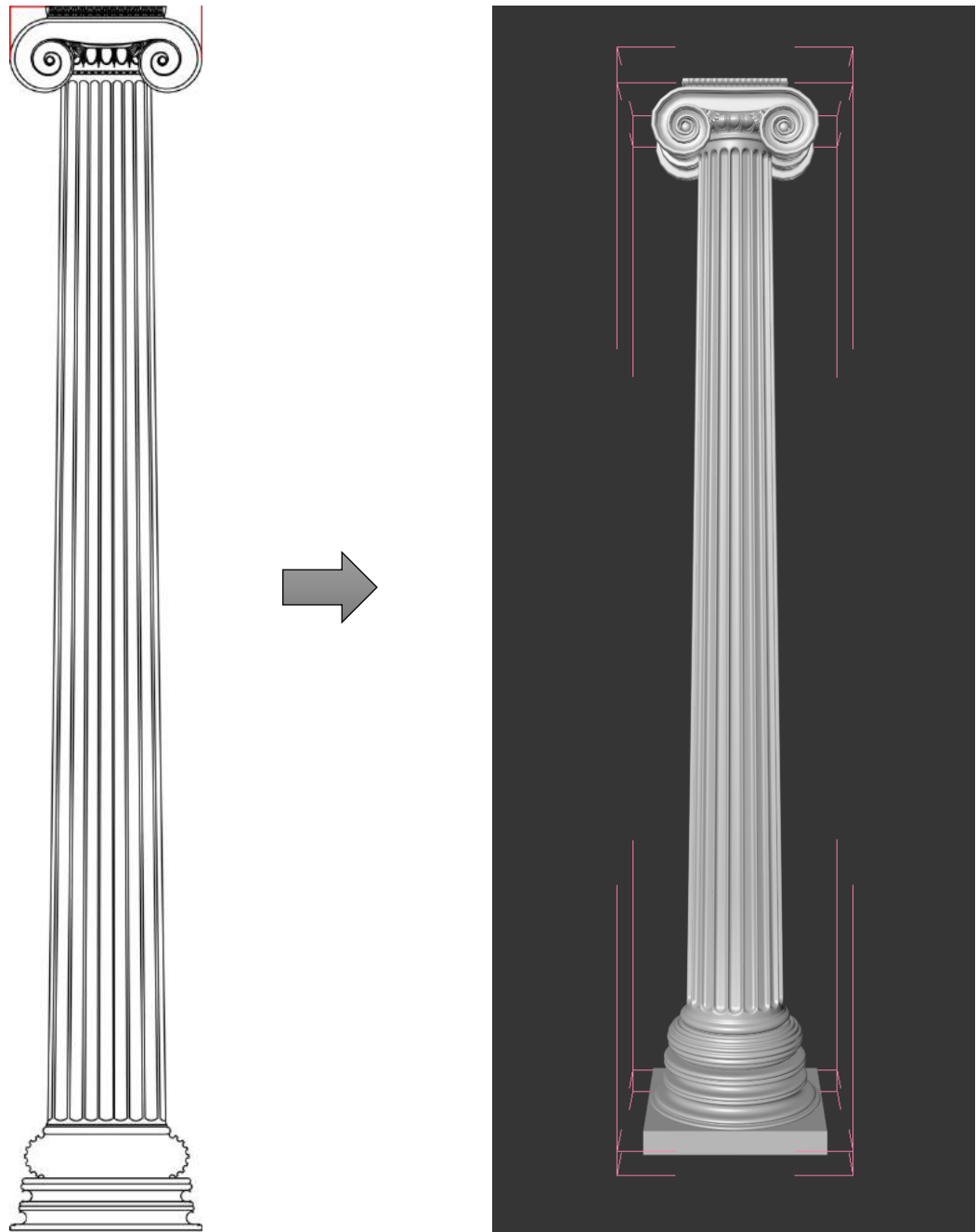


Figure 3.7. Ionic Column

Columns have three different column drums as shown in Figure 3.8.. Two of them are sculptured and one is classical column drum. In classical column drum modeling, 2D CAD drawing is taken as reference and its steps are the same as column body modeling stage. Sculpted drums are modeled with the method shown at the stage of reliefs and statues. The modeling phase of the columns is completed by combining the drums formed with the body and head, which are other parts of the columns.

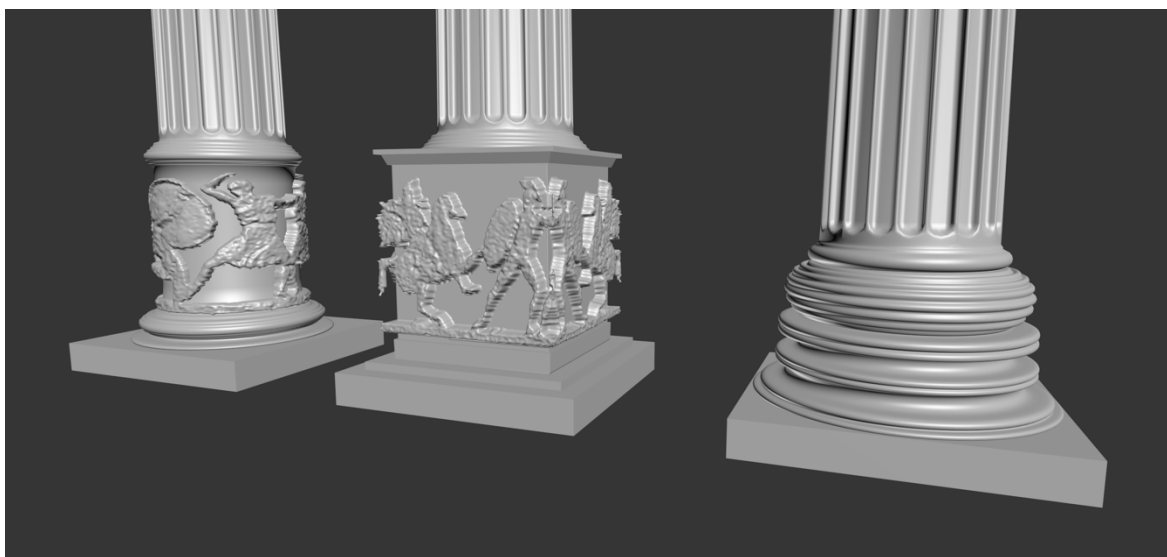


Figure 3.8. Three Different Column Bases

3.2.3. Reliefs and Statues

The Temple of Artemis has various sculptures and reliefs used in different places and for different purposes. These reliefs and statues are shown together in Figure 3.9.. Historical data, visuals and drawings are taken as references for the positions of the reliefs and statues used. The modeling stage of all reliefs and sculptures is the same.



Figure 3.9. Reliefs and Statues

Visuals of reliefs and sculptures to be modeled are transferred to Adobe Photoshop software. The dimensions of the images in the software are adjusted by reference to the drawings of the temple. Copies of the images with black and white and white backgrounds are created and then imported into 3ds Max software.

In 3ds Max software, a plane is created according to the dimensions of the visual and converted to editable poly. The more polygons in the created plane, the more detailed the model will be. The created plane is assigned a black and white visual imported as texture, and the volume is given using the “Displace” modifier. Then, the created model is assigned a white background visual imported as texture and volume is given once again with the “Displace” modifier to create the details. Using these methods, the modeling of the front of the relief or statue is completed, and then using the “Mirror” command to create a symmetrical copy of the back face of the model. Finally, the created models are combined, and the modeling phase of the statue or relief is completed. Figure 3.10. shows the stages of modeling the relief.

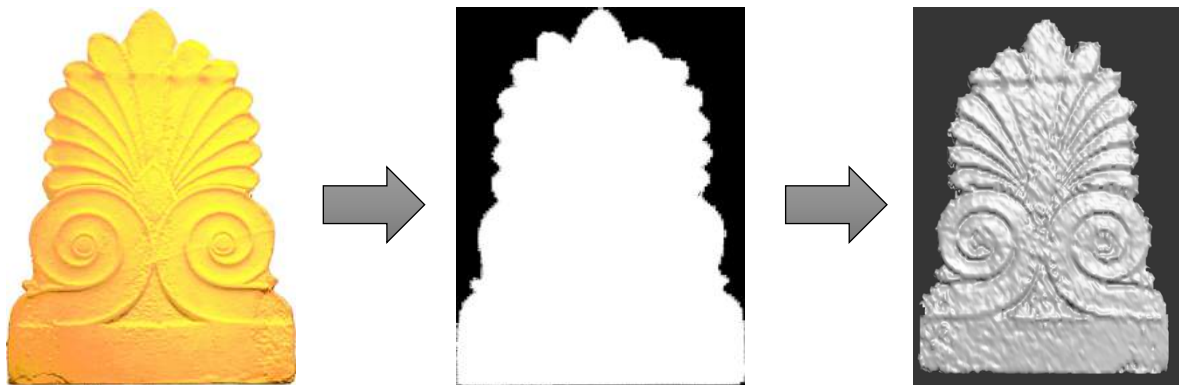


Figure 3.10. Modeling Stages of Acroterion

3.2.4. Arrangement and Optimization

In 3ds Max software, 3D models made in different files are merged in a single file at this stage. Figure 3.11. shows the merged 3D models of the Artemis Temple. The reason why the models are created in different files is to make the software work more efficiently. These detailed models with too many polygons cause the software to run slowly. After the model is merged, necessary polygon reduction processes are made in order to work efficiently.



Figure 3.11. Arrangement of 3D Models

The three-dimensional model of the assembled Artemis Temple has more than 150 million polygons, and the screen refresh rate of the scene is 8 FPS. As explained in Chapter 2.2.4, the screen refresh rate of the scene should be above 20 FPS. The number of polygons of the Artemis Temple 3D model is reduced by using the “MultiRes” modifier in 3D models with more than necessary polygons without distorting the view. Thus, as seen in Figure 3.12., the number of polygons of the 3D model of the Artemis Temple was reduced from 150 million to 54 million, and the screen refresh rate of the stage was increased from 8 FPS to 23 FPS.

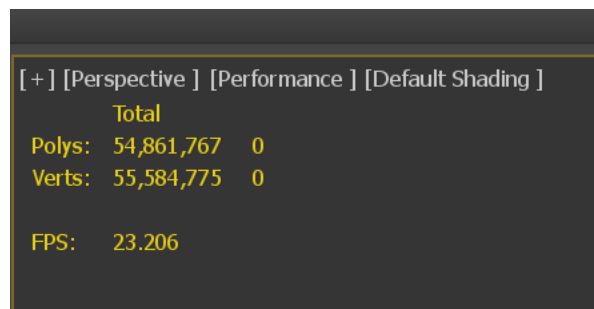


Figure 3.12. Optimization of 3D Models

3.3. SCENE DESIGN

During the Scene Design phase, the visualization of the 3D Artemis Temple model is achieved through various stages such as Material Editing, Environment Design and Rendering. Lumion software is used in all stages of scene design. The textures of the 3D model of the Artemis Temple created in the 3ds Max software in the previous phase are converted to standard map texture using the “Conversor” plugin. After that, this model is exported in FBX file format and imported into the Lumion software for visualization. Figure 3.13. shows an example of a rendered Artemis Temple model whose visualization has been completed.



Figure 3.13. Scene Design of The Temple of Artemis

3.3.1. Material Editing

At this stage, the materials of the 3D Artemis Temple model imported in FBX format are assigned with reference to the historical data and visuals obtained in Chapter 3.1. When assigning materials, materials are selected and sized in accordance with the original structures.

Aging of the materials, taking into account the age of the Temple of Artemis, is done with the "Weathering" option. Depending on the material selections, reflection, colorization and relief settings are adjusted in the material editing section as shown in Figure 3.14..

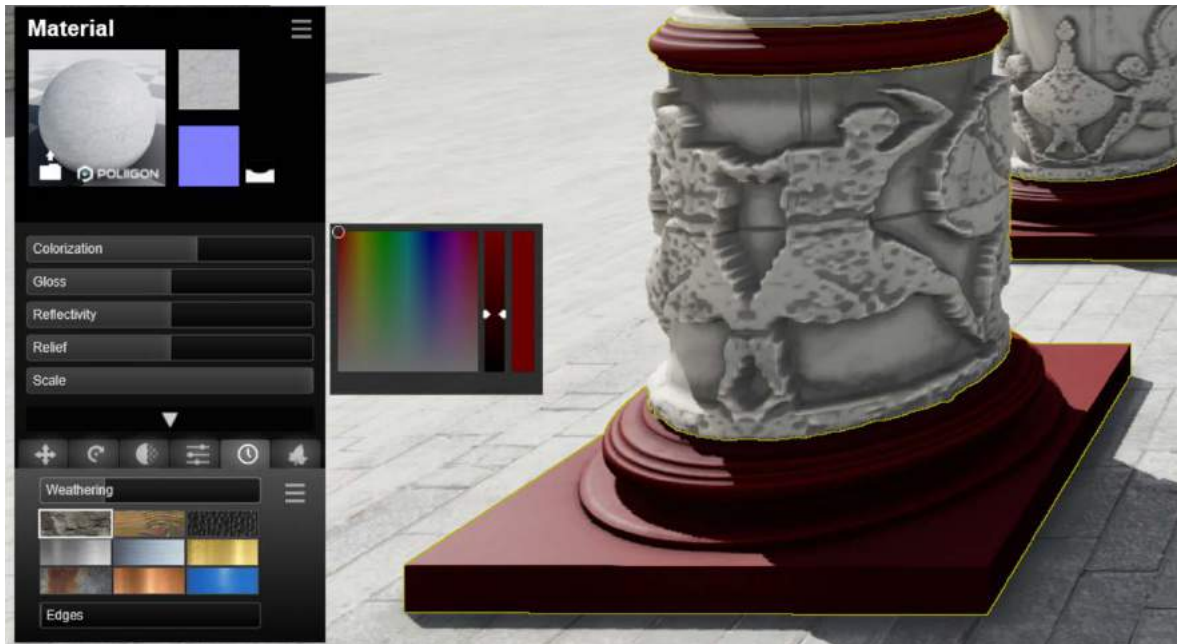


Figure 3.14. Material Editing of 3D Models

3.3.2. Environment Design

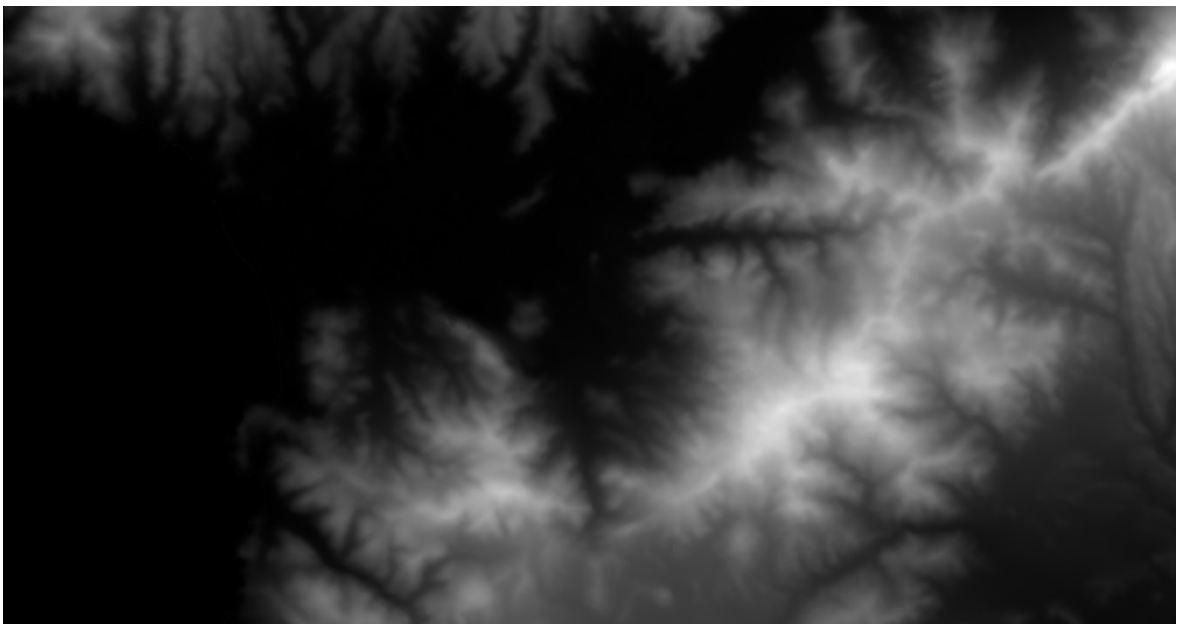


Figure 3.15. Height Map of Ephesus Terrain

First of all, at this stage, the location of the Artemis Temple in Ephesus is determined according to the historical research and the height map of the terrain shown in Figure 3.15. above is downloaded according to the location. Then the downloaded terrain height map is imported into the Lumion software to create the terrain of the Artemis temple in Ephesus.

In addition, the sea, streams, flora and other environmental factors are accurately placed in the Lumion software according to their location, historical data and height map data of the Ephesus terrain. Effects such as wind speed, wave direction and length, the color of the tree leaves, and the length of the grass are added to the created environment design of Artemis Temple terrain in Ephesus in Lumion software terrain editing section. Figure 3.16. displays a scene of Artemis Temple terrain in Ephesus with an environmental design created in the Lumion software.



Figure 3.16. Environment Design

3.3.3. Rendering

In Rendering stage, image or animation are generated from the color and texture assigned the Temple of Artemis 3D model and the created environmental design of Ephesus terrain with the help of various lighting settings and effects on Lumion software.

The render settings of the scene are made as shown in Figure 3.17.. Basic render settings are selected as "Realistic". The sun is adjusted according to the location of the Temple of Artemis. In shading and reflecting options, quality settings are increased so that the output can reach the maximum reality.

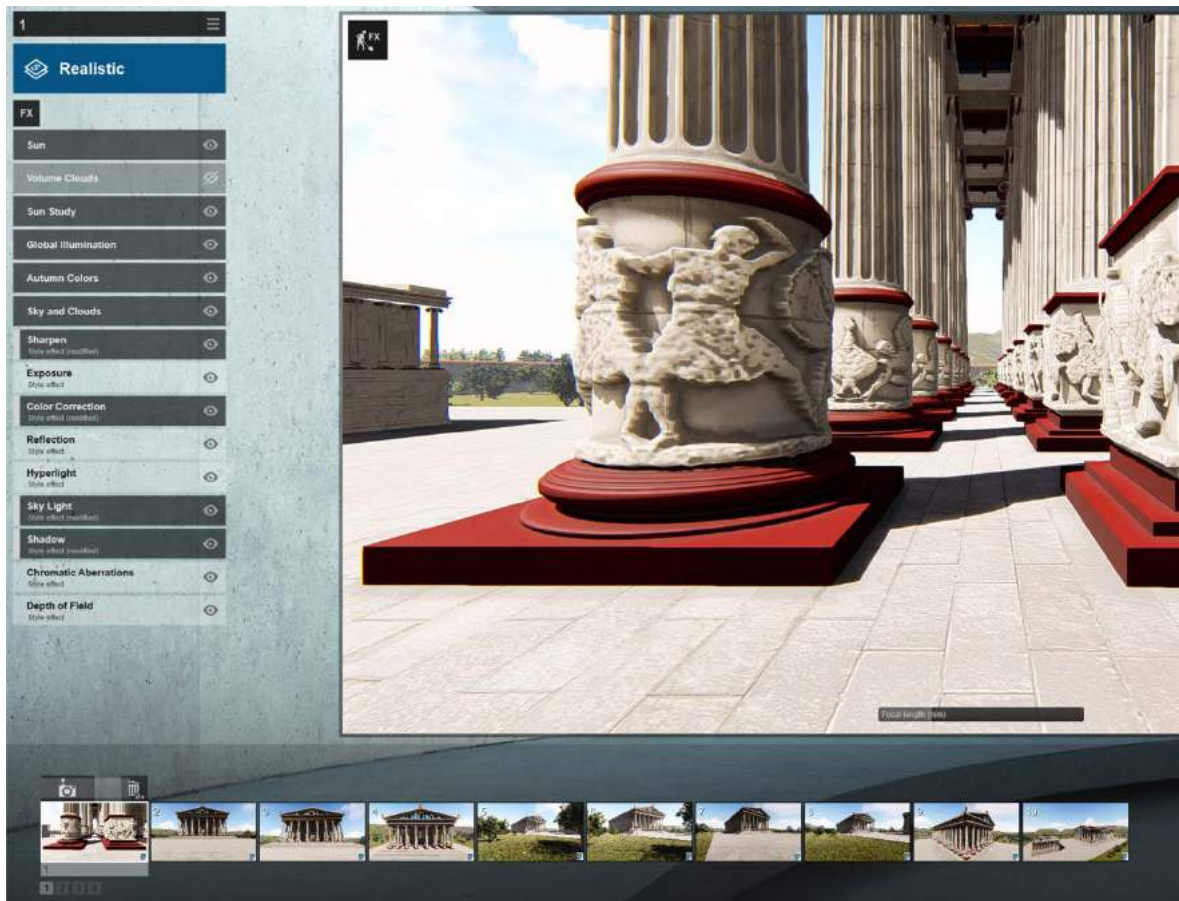


Figure 3.17. Rendering Settings

In render photos settings as shown in Figure 3.18., selected scenes of Artemis Temple are added at the photo set step with a maximum of 10 scenes to create an image, and output is taken at poster as 8K resolution.

Similarly, between the scenes selected in the animation settings, the animation is created according to the time set as a result of the movement of the camera from one scene to another. The maximum resolution in the animation phase is 4K.

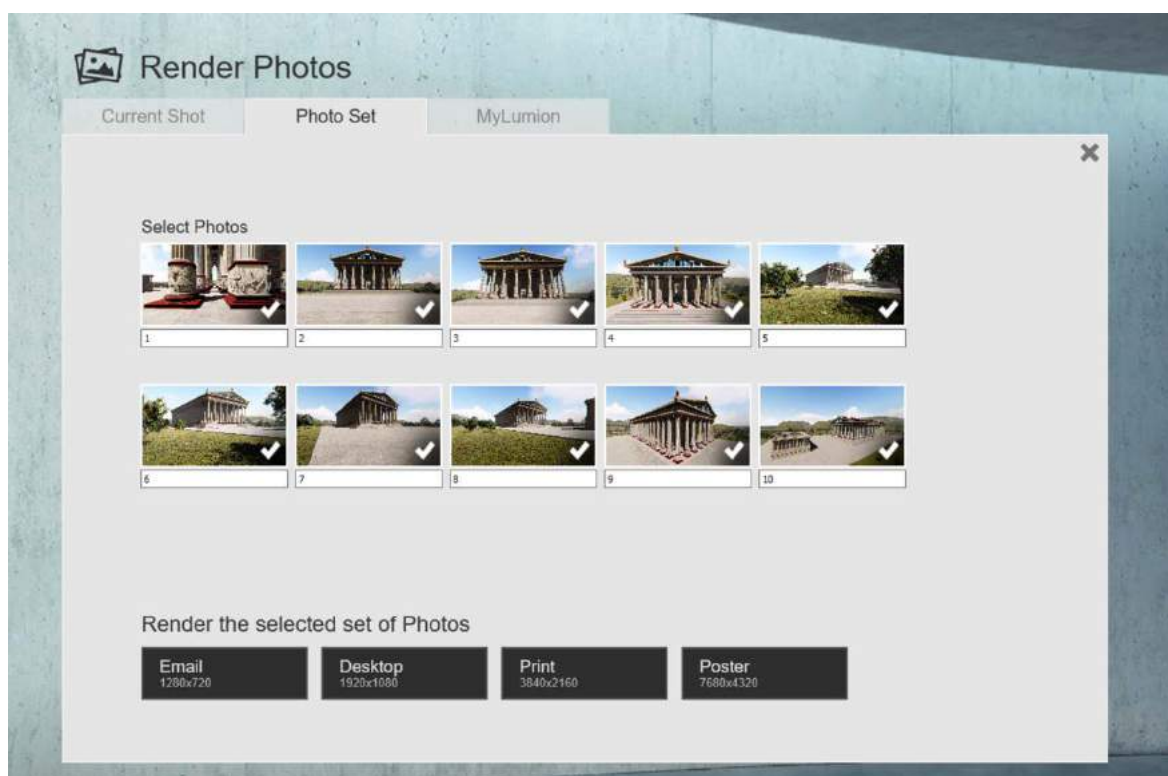


Figure 3.18. Rendering Quality Settings

In Figures 3.19 to 3.25 show renderings of the temple of Artemis taken from different angles and views.



Figure 3.19. Front Far View of The Temple of Artemis

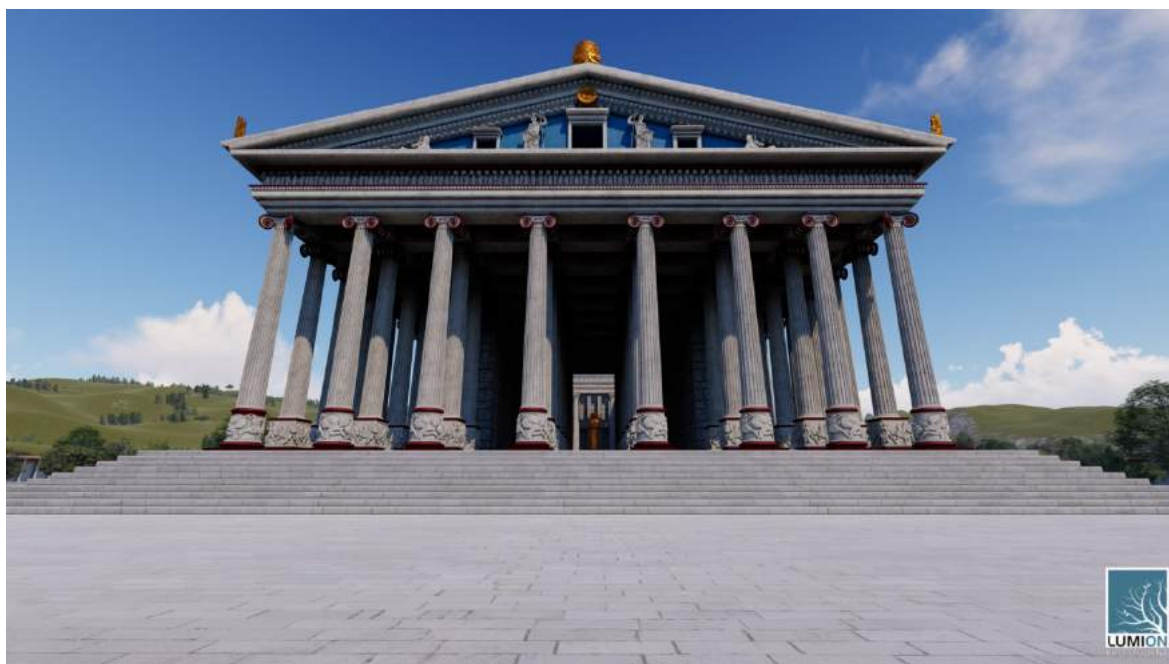


Figure 3.20. Front Eye Level View of The Temple of Artemis



Figure 3.21. Front View of The Temple of Artemis



Figure 3.22. Side Eye Level View of The Temple of Artemis



Figure 3.23. Side View of The Temple of Artemis



Figure 3.24. Side Far View of The Temple of Artemis



Figure 3.25. Back View of The Temple of Artemis

In order to obtain a 360 panoramic view for use in virtual reality glasses, the target device is selected as “GearVR / Oculus” and the output quality as maximum in 360 panoramas settings. Figure 3.26 shows a 360 panoramic render of the Artemis Temple.



Figure 3.26. 360 Panoramic View of The Temple of Artemis

The “Clip Plane” option is used to render the section rendering of the Temple of Artemis. The added “Clip Plane” is placed at the desired angle, and then the scene is rendered. As a result, an output is obtained as seen in Figure 3.27..

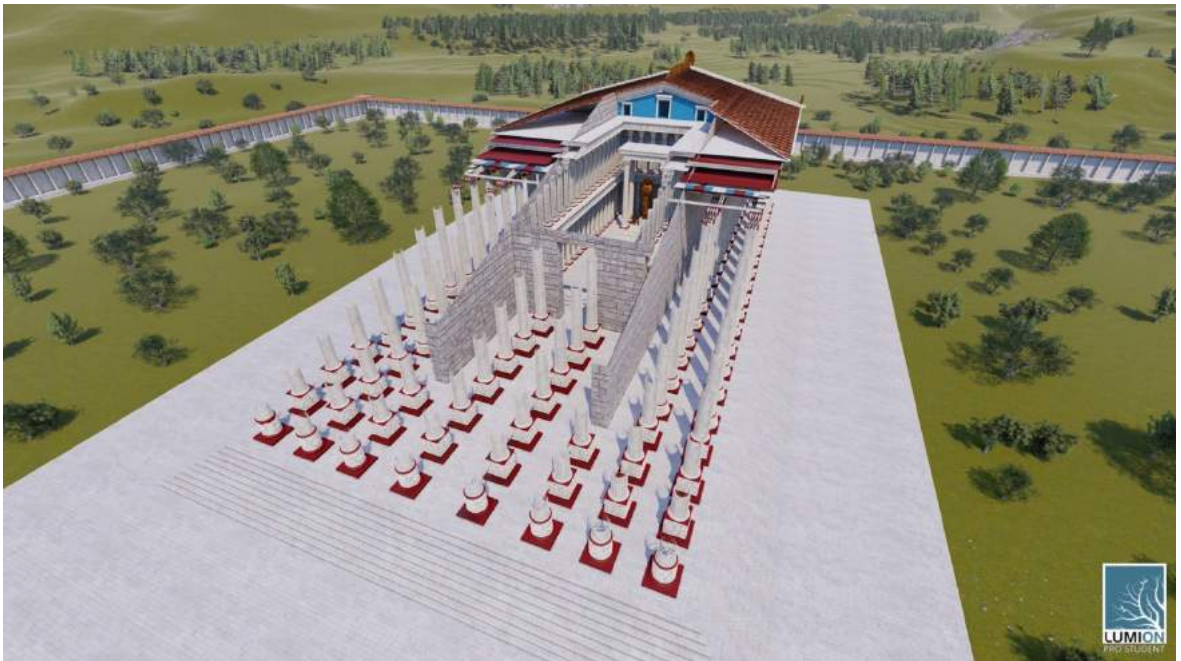


Figure 3.27. Section View of The Temple of Artemis

4. CONCLUSION AND FUTURE WORK

In this study, an efficient digital reconstruction process that will be used in the virtual realization of cultural heritage is developed with digital technologies. The volumetric visualization of the three-dimensional models created in this process has been optimized using the most advanced virtual and augmented reality software.

Thanks to latest developments in three-dimensional volumetric visualization field such as animation of three-dimensional models, real-time rendering and multimedia techniques, it become possible to resurrect the historical artifacts in birthplace of the cultural heritage with the virtual realization process developed.

Reference structures that have not survived today and very detailed three-dimensional volumetric visualizations have brought many difficulties in virtual realization of cultural heritage. Problems such as where to take reference when making three-dimensional modeling, how to proceed with the virtual realization process, which graphics software to use, how to optimize three-dimensional models, polygon reduction methods and the incompatibility caused by different software usage, which are among the difficulties encountered with the developed virtual realization process, have been solved effectively. In addition, computer crash problems experienced during detailed modeling have been solved by completing the modeling in different files and combining them into a single file, and by applying polygon reduction processes that are made considering the screen refresh rates.

The virtual realization of the Temple of Artemis in Ephesus which was destroyed 2000 years ago as a case study has been successfully completed using this developed virtual realization process. It is important to carry this magnificent structure to the present with its first-day appearance to understand the history and past of humanity.

In the future work, it will be ensured that the cultural heritages of which virtual realization are made will be displayed in their current location and in real environment with virtual reality glasses. In this way, the interaction between the historical artifact and the audience will be increased as much as possible.

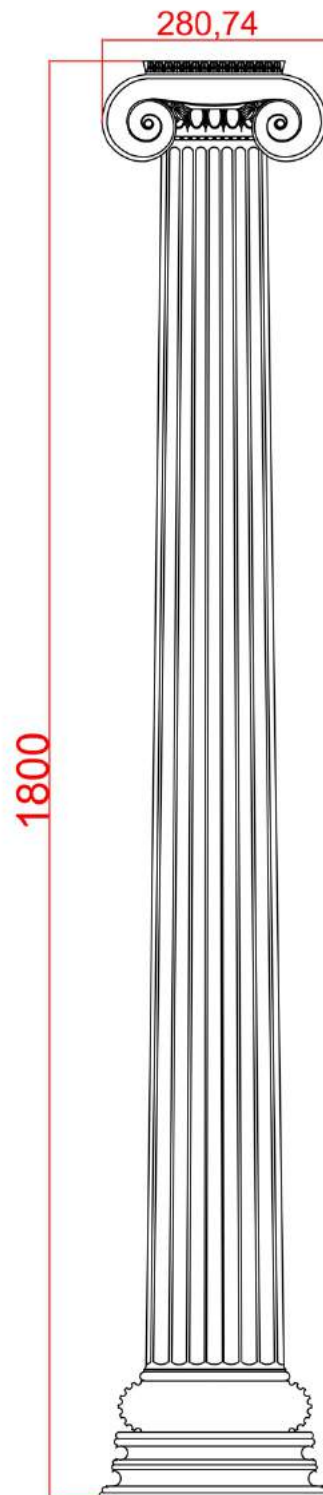
APPENDIX A: 2D Drawings

Figure A.1. 2D Drawing of Column

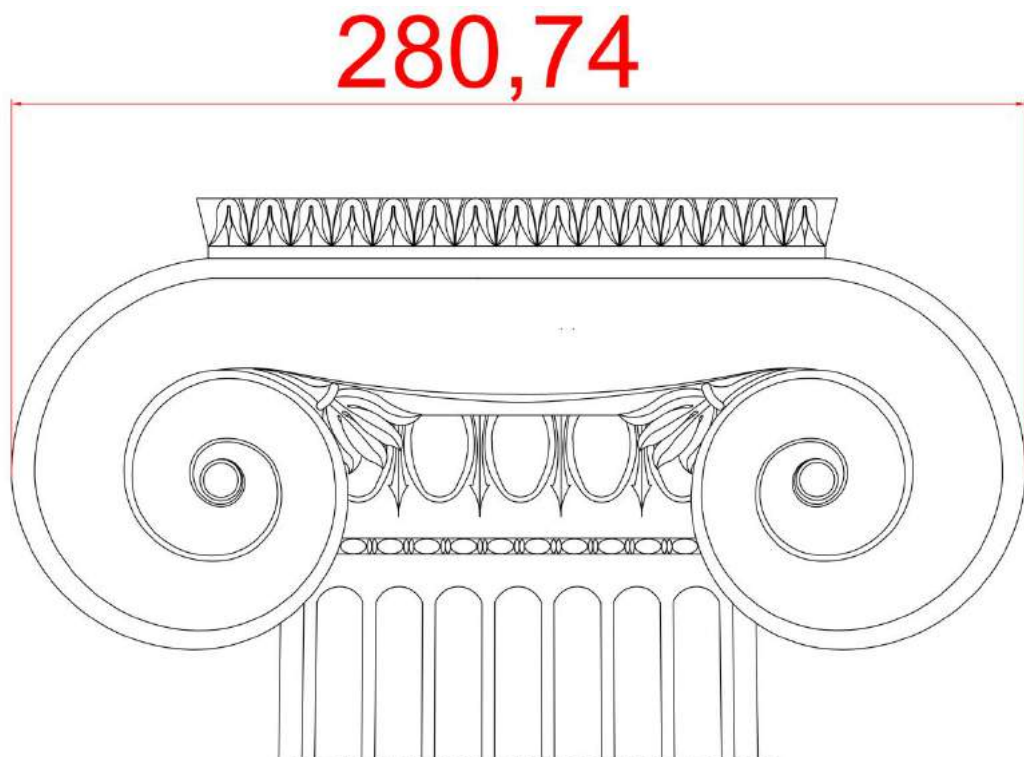


Figure A.2. 2D Drawing of Column Head

APPENDIX B: 3D Models

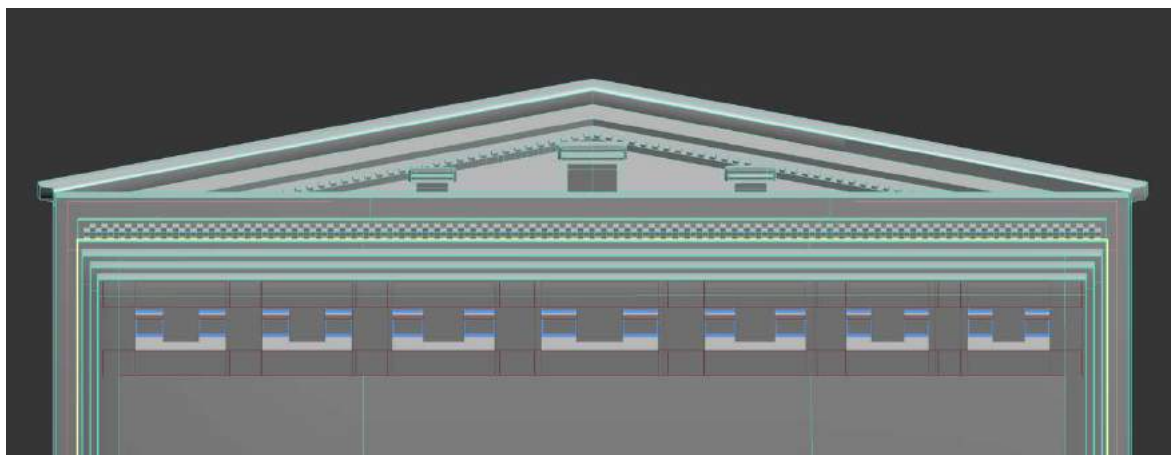


Figure B.1. 3D Model of The Temple of Artemis Ceiling

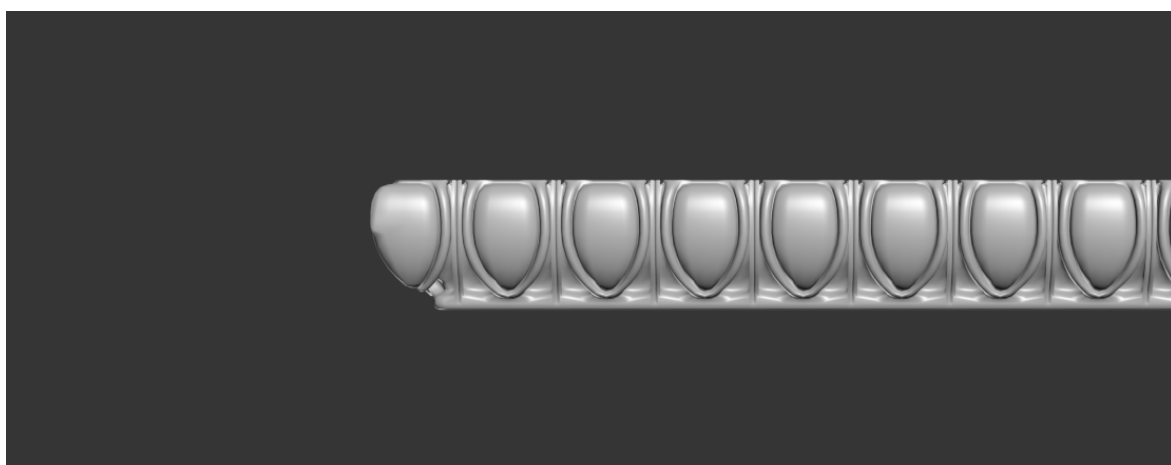


Figure B.2. 3D Model of The Temple of Artemis Decoration

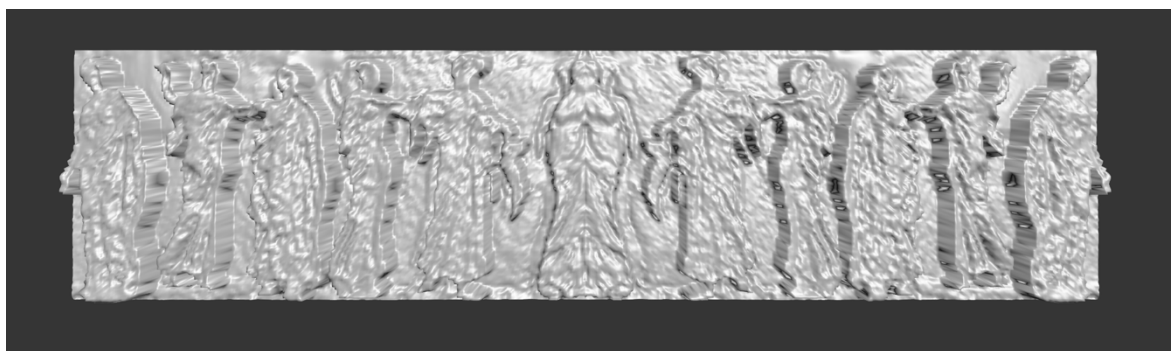


Figure B.3. 3D Model of The Temple of Artemis Reliefs

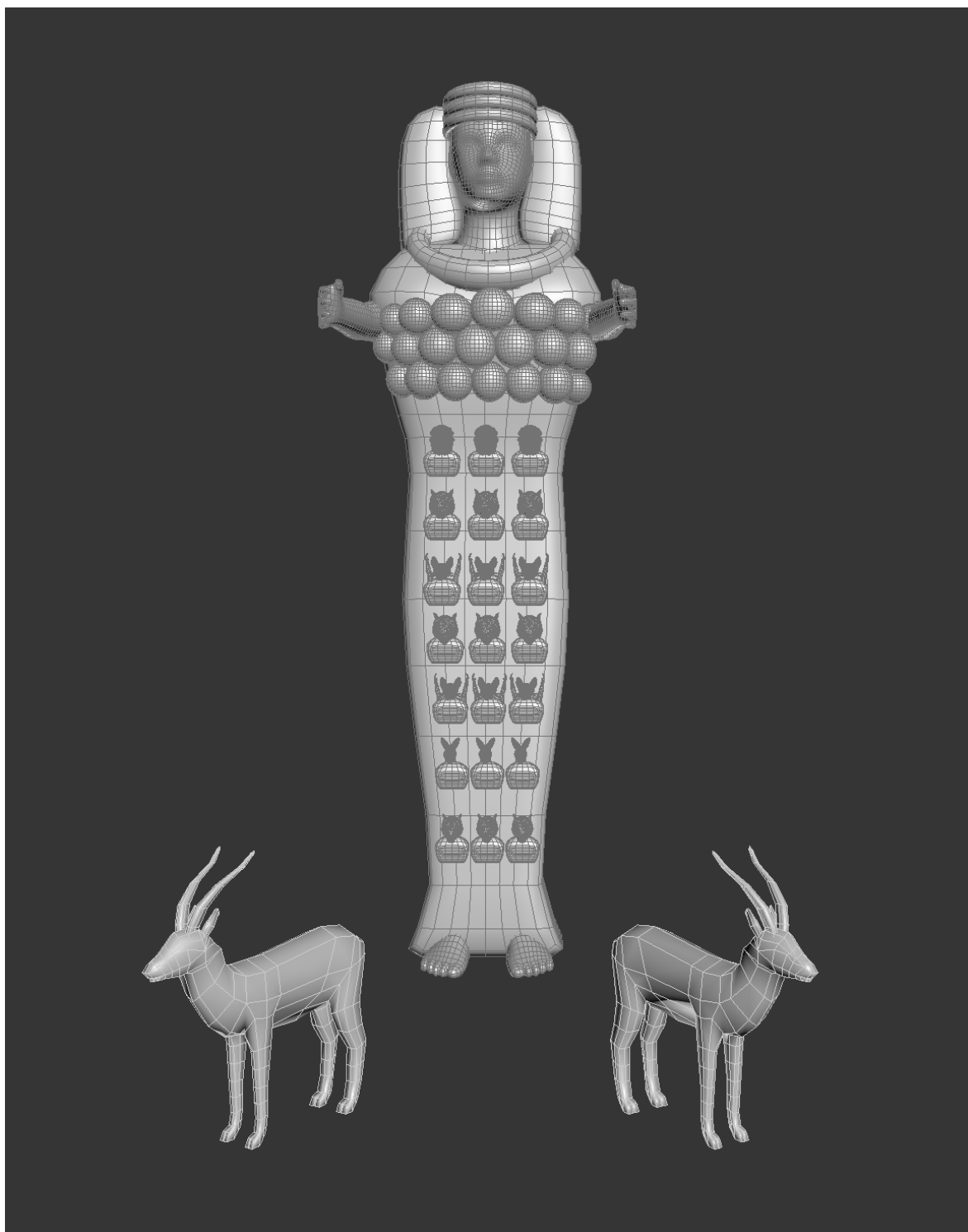


Figure B.4. 3D Model of Artemis Statue

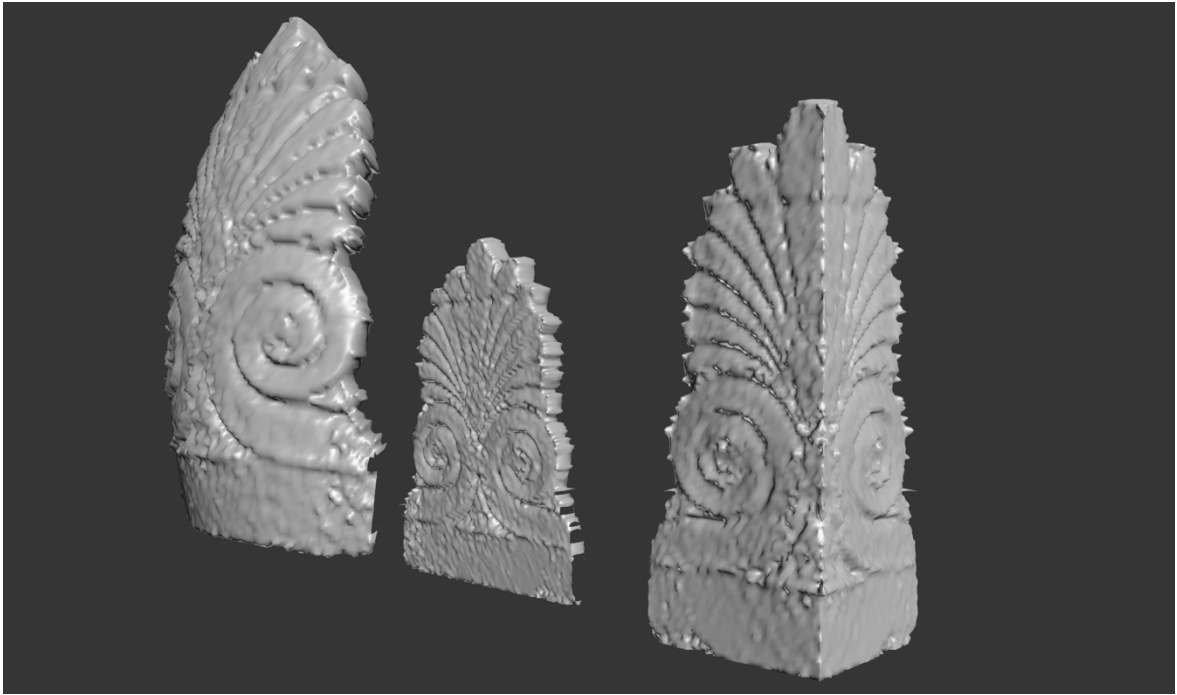


Figure B.5. 3D Model of The Temple of Artemis Roof Decorations



Figure B.6. 3D model of The Temple of Artemis Roof Section

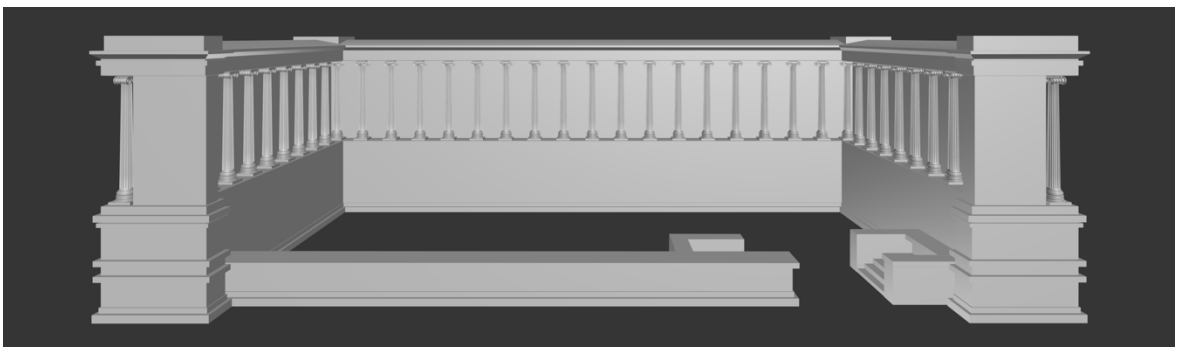


Figure B.7. 3D Model of Altar

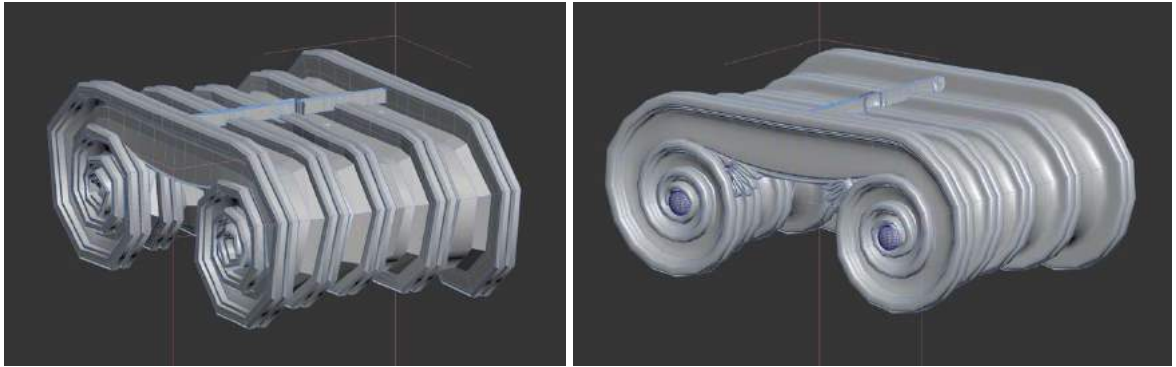


Figure B.8. 3D Model of Column Head

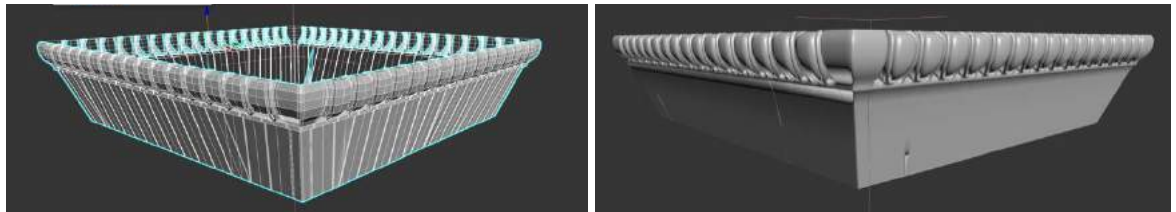


Figure B.9. 3D Model of Column Decoration

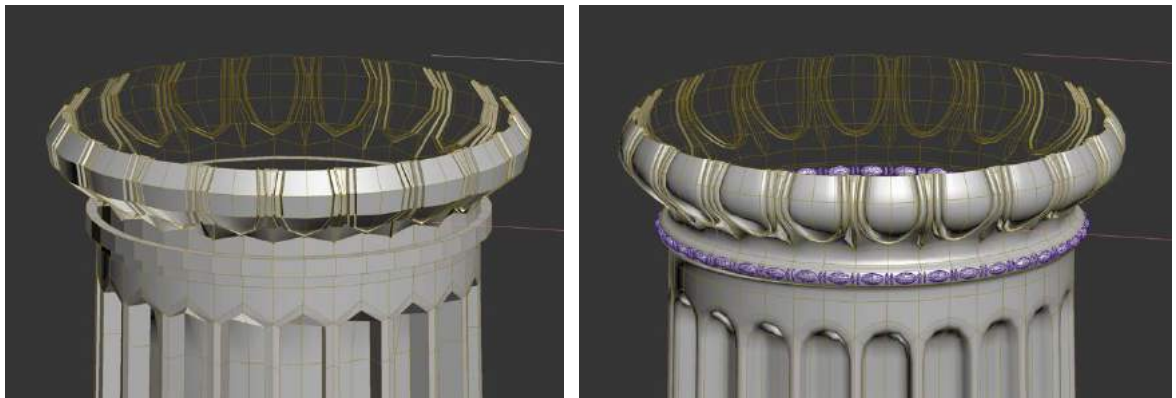


Figure B.10. 3D Model of Column Body

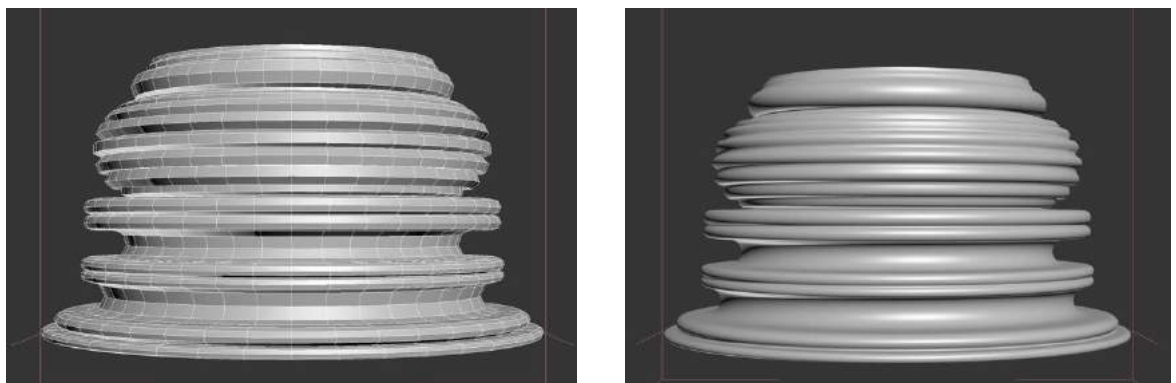


Figure B.11. 3D Model of Column Drums

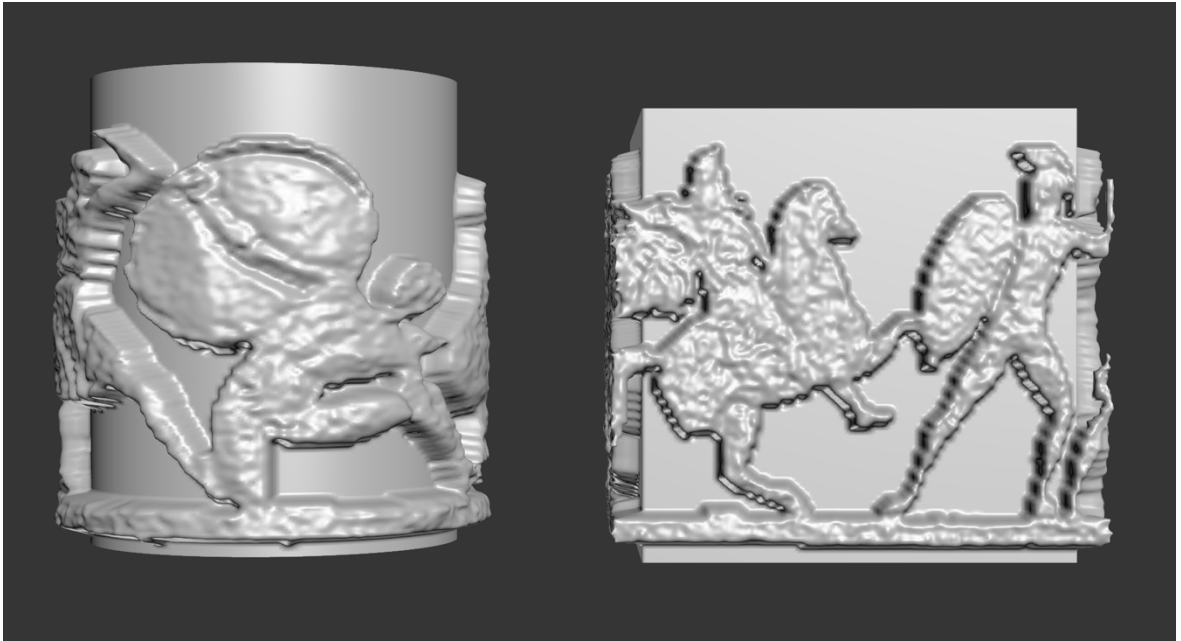


Figure B.12. 3D Model of Sculptured Column Drums



Figure B.13. Inside View of The Temple of Artemis 3D Model



Figure B.14. Front View of The Temple of Artemis 3D Model

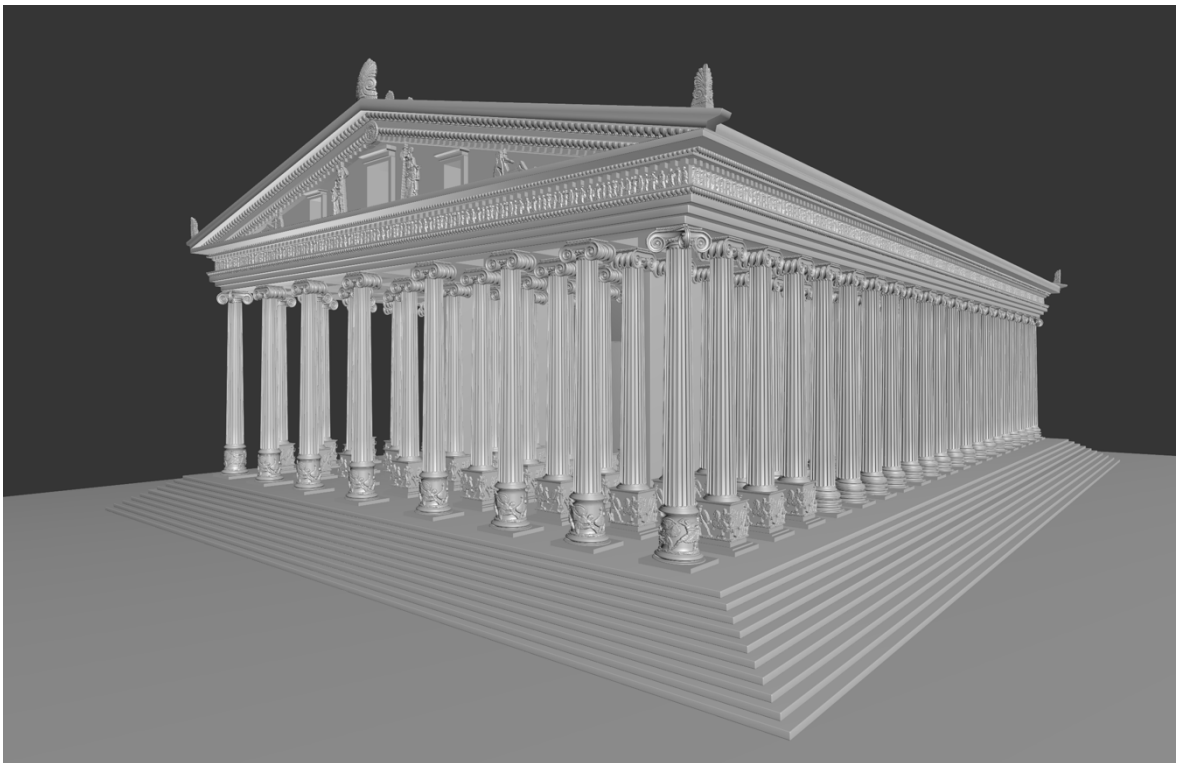


Figure B.15. Front Side View of The Temple of Artemis 3D Model

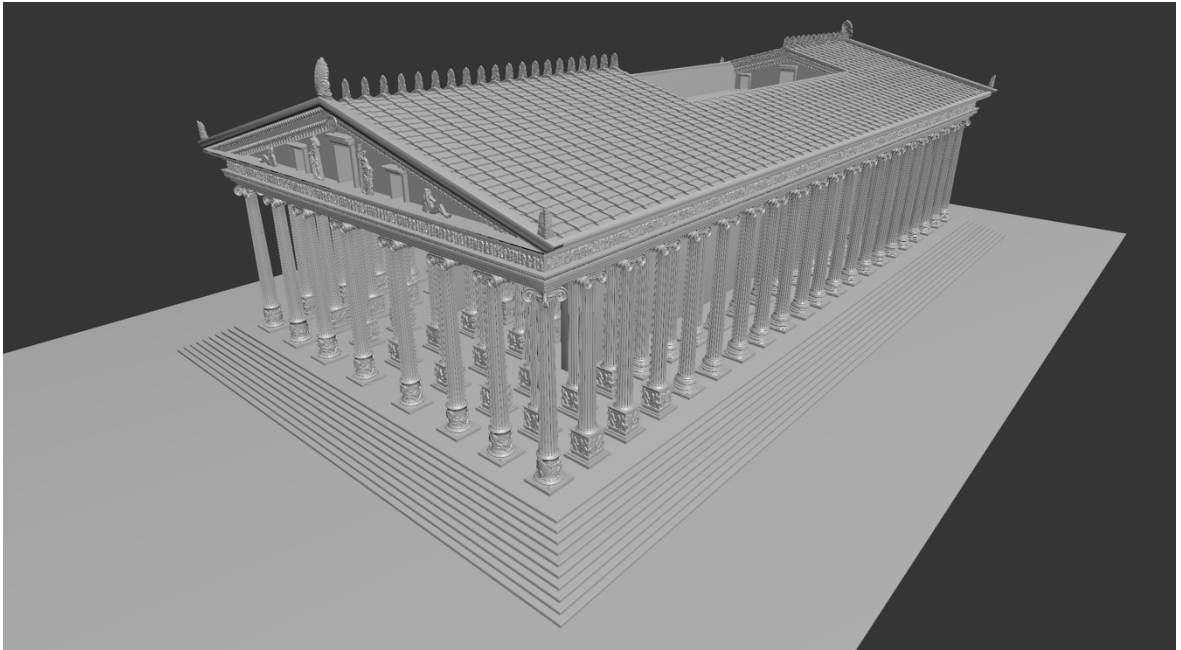


Figure B.16. Front Top Side View of The Temple of Artemis 3D Model

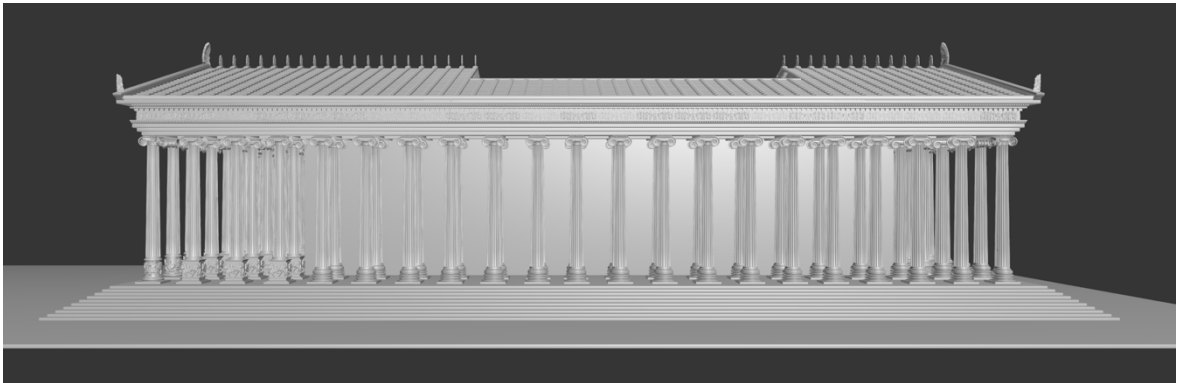


Figure B.17. Side View of The Temple of Artemis 3D Model

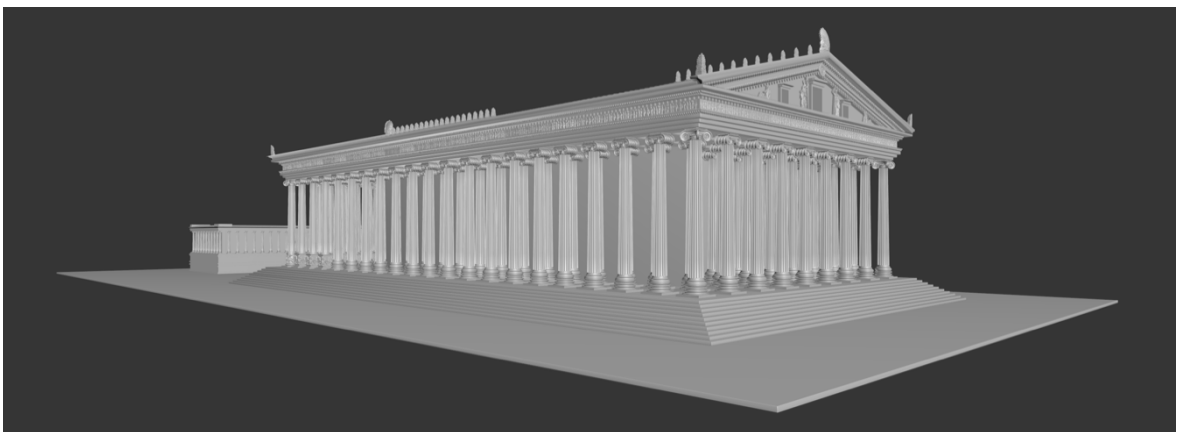


Figure B.18. Back Side View of The Temple of Artemis 3D Model

APPENDIX C: Renders



Figure C.1. Column Heads of The Temple of Artemis



Figure C.2. Column Drums and Column Body of The Temple of Artemis



Figure C.3. Sculptured Column Drums and Column Body of The Temple of Artemis



Figure C.4. Columns of The Temple of Artemis



Figure C.5. Ceiling Decoration and Columns of The Temple of Artemis



Figure C.6. Sculptured Columns Body of The Temple of Artemis



Figure C.7. Reliefs and Column Heads of The Temple of Artemis



Figure C.8. Reliefs and Sculptured Columns of The Temple of Artemis



Figure C.9. Roof Section of The Temple of Artemis



Figure C.10. Front Far View of The Temple of Artemis



Figure C.11. Altar and Main Temple Front View of The Temple of Artemis



Figure C.12. Altar and Main Temple Side View of The Temple of Artemis



Figure C.13. Side View of The Temple of Artemis



Figure C.14. Inside View of The Temple of Artemis



Figure C.15. Front Top View of The Temple of Artemis

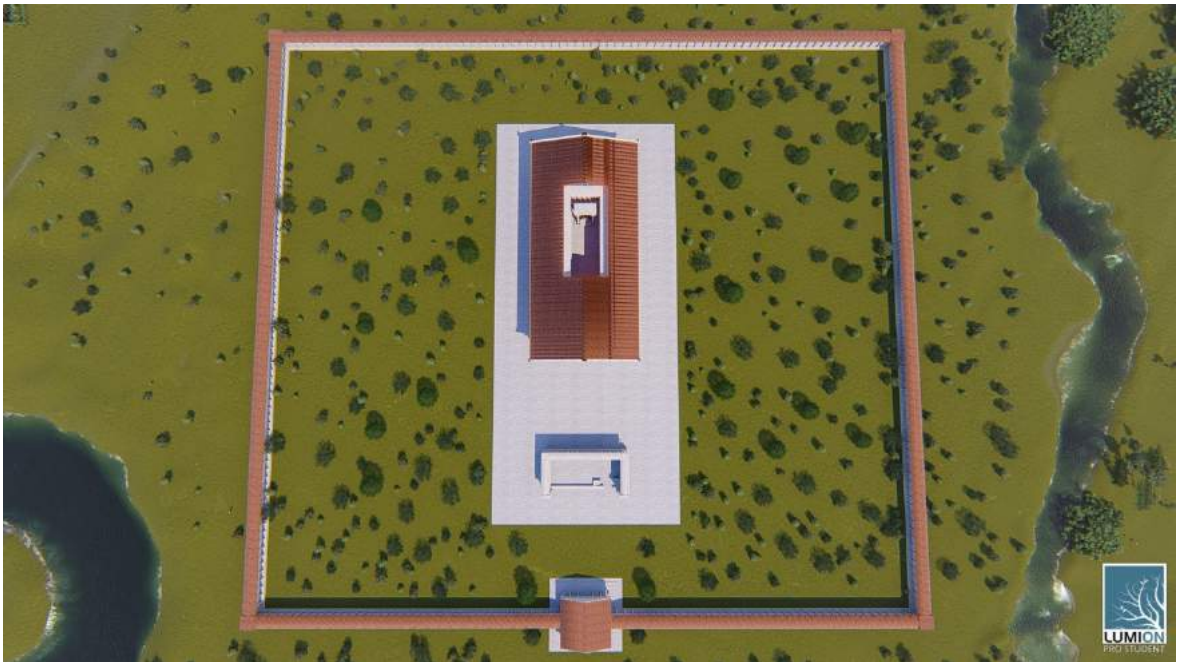


Figure C.16. Top View of The Temple of Artemis

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