Preserving Heritage Sites of Dhaka City Using 3D Modeling and Virtual Reality Technology

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Bachelor of Computer Science and Engineering

Under the Supervision of

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Declaration

We hereby affirm that the work done for this thesis is based on results attained from our own work. All of the tools and materials used in this text have been properly acknowledged. This thesis, neither in whole nor in part, has been previously submitted to any other University or Institute for the award of any degree or diploma.

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We would also like to express our gratitude and gratefulness to our beloved family and friends. We are indebted to all of the participants who helped us directly, or indirectly in completing our research work.

Finally, and this goes without saying, we want to say a special thank you to BRAC University for enabling us to conduct this research and providing us with the right support and tools to do so.

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List of Acronyms

CMS	Content Management System
CSS	Cascading Style Sheets
HTML	Hypertext Markup Language
VR	Virtual Reality
3D	Three-Dimensional

Abstract

This thesis presents a model that is aimed at preserving heritage sites of Dhaka by implementing 3D modeling and Virtual Reality technologies. The proposed model consists of reconstructed 3D models of historical establishments, a Virtual Reality application and a digital archive of the aforementioned 3D models. To implement the proposed model, three dimensional reconstructions of few prominent heritage sites are created by using 3ds Max. Then the 3D models are implemented in a VR environment so that users can explore the heritage sites and finally to preserve the 3D models, a digital archive has been created to store the 3D renderings of the heritage sites. The website shows 3D animation of the heritage sites of Dhaka such as the historic buildings of Lalbagh Fort, which include The Tomb of Pori Bibi, The Diwan-i-Aam and the Mosque, the structure of Shahid Minar and the model of the Greek Memorial. The Android application directs the user to view the three buildings of Lalbagh Fort in a VR environment. The experimental results demonstrate that the model is successful in utilizing 3D modeling techniques and Virtual Reality applications that can help to conserve the heritage sites of Dhaka.

Keywords: Virtual Reality, 3D Modeling, 3D Scanning, Photogrammetry, Heritage Sites, 3ds Max, Digital Archive, Unity, Android

CHAPTER 1
Introduction

Dhaka, the capital of Bangladesh, is a 400 year old city with monuments and heritage sites that have significant historical and cultural values. Starting from the magnificent buildings of Sultanate period, Mughal and Nawabi era, British rule to the Liberation War of 1971, this city is adorned with beautiful architectural attractions comprising of more than several centuries [1-2]. However, due to natural calamities, unplanned construction for commercialization, poor urban planning, and risk of crumbling due to fragile structure of old buildings, many of the historically important sites are being demolished and damaged [3]. Thus, protecting the heritage places of Dhaka is essential as the historical accomplishments will be lost forever otherwise. In this age of rapid advancement of Virtual and Augmented Reality, 3D data acquisition and visual technologies, numerous ways of presenting and reconstructing heritage sites have been used for different purposes [4]. Therefore we aim at map-based approach to create the 3D models with the help of digital images as reference and import the models on Virtual Reality (VR) platform to give a lifelike experience of exploring the historical sites in real time and storing them in a digital archive to make it accessible for everyone.

1.1 Motivation

The advent of three dimensional technologies has transformed the reconstruction and acquiring of cultural heritage establishments. Many research and practical implementation has been done for preserving architectural sites for several purposes. Many scholar, research teams from universities and companies, students and independent hobbyists have taken initiatives for digitally documenting cultural establishments as we are approaching towards a world of 3D and augmented reality. In Bangladesh, very few models have been created using a software called SketchUp [22]. However, these models are not up to the mark and were not created with the purpose of preserving the heritage sites. Therefore, in our country, there has been no such approach for digitally modeling and archiving the historical sites. Hence, we were motivated to research upon digitally preserving the monuments of Dhaka. Firstly, three dimensional models and virtual reality will help people interact with the places like real life. It will help in surveying

without causing harm to the fragile buildings. Secondly, our website and VR application will give free and worldwide access to heritage sites of Bangladesh from any corner of the world, thus improving accessibility to wider range of audience. Thirdly, the digital archive of 3D models and the VR app will provide a realistic experience of visiting a virtual museum that will help Bangladesh to enable virtual tourism. Fourthly, many disabled people are unable to visit the sites in person. Our project will work as a solution towards that as it will enable them to visit the sites and interact with it and have the lifelike experience. Fifthly, 3D data will help greatly in architectural, archaeological and historical studies and research. Moreover, the VR app also provides a recreational tool that is also educative. Lastly and most importantly, 3D modeling will help in preserving the heritage sites from damage caused by natural disasters and preserve the architectural information, as many of those sites are prone to destruction due to lack of maintenance and are crumbling, as some of the buildings are more than hundred years old. In our digital archive 3D models of the historical sites will always stay protected and will work as a repository of the past for people all around the globe.

1.2 Methodology

In order to make the 3D models we tested various technologies and methods. After trial and error, the final methodology that was settled for in order to construct the 3D models is 3D modeling. This method is cost-effective, gives high accuracy of depth of all three dimensions, developer-friendly, and a can be a thriving financial investment. It involves building three-dimensional models of the buildings at Lalbagh Fort in 3ds Max [16] using digital photos as reference, and then importing those models into Unity to create a Virtual Reality smartphone application as well as creating animations of the models to store in the archive website. The workflow is explained in detail in Chapter 3.

To start with, we took the map-based approach of 3D modeling. We accumulated thousands of digital images from eye-level to 360 degree angle, while capturing in-depth details for clear reference. Then, we used a 3D graphics software for making the models. To make the models, first of all, we referenced them with the digital images. After that we used primitive shapes such as square, sphere, cylinders, etc. for the basic structure. By adjusting the shapes,

terrain, surface, lighting, and implementing intricate details and textures on them, we rendered the final product and compared them with digital images to achieve life-like resemblance.

Next we imported the 3D models into a software called “Unity” which is a game engine for creating live-interaction applications and games in order to make the Virtual Reality application. By adjusting camera position, enabling VR cardboard, using C# scripts, switching platform to Android and finally installing the app in mobile phone, we successfully launched the app where audience can interact in a 3 dimensional virtual reality. Subsequently, we added adjusted timing, accurate camera position, image format, 3D effects to create animation from rendered images.

After that, we uploaded the animations of our 3D models into the website which is our digital archive. Thus, the 3D models of cultural heritage buildings are accessible from both platforms: smart phone and computer.

1.3 Contribution Summary

Universities, companies, archeological surveys, scholars and independent projects have explored the archiving of historical sites in three dimensional form for acquiring data and reconstruction of those buildings utilizing numerous techniques. Therefore, it is essential to explore and implement such projects in our country as Bangladesh has rich cultural and historical significance.

Through conducting our research on 3D graphics and animation and Virtual Reality we have at first encountered different 3D modeling techniques and technology for VR and their respective advantages and shortcomings by which we produced the optimum outcome for application of 3D digital archives in Bangladesh. Furthermore, we implemented an integrated approach of three techniques and technologies which are 3D modeling, virtual reality for smartphone application and a digital archive for online access through computer. Additionally, the resulted models of heritage sites have details with in-depth accuracy. We tried to build our models using high resolution texturing, accurate position of lighting and detailed polygon modeling for higher precision that makes the resultant 3D models more authentic and realistic. This makes the models useful for architectural, historical and archeological surveys and

researches. Similarly, while making the Virtual Reality app we adjusted the camera angle in such a way that gives optimum ease of viewing for users. In addition to adjusting the camera position, we added a pointer for interacting with the models in VR. Lastly, smartphones are expensive, thus many people cannot afford it which causes exclusion of a vast majority of audiences. It is a contradiction with our goal as we want to spread the exploration of historic testimonials of Dhaka to a global platform. Therefore, we made a website which functions as a repository for widespread inclusion of public.

1.4 Thesis Outline

- Chapter 2 outlines the previous works done in the field of building 3D models of heritage sites.
- Chapter 3 describes the proposed model including the implementation specifics.
- Chapter 4 illustrates the result outcomes of the implementation of the selected methodology.
- Chapter 5 concludes the paper and explains why this field of 3D modeling has future prospects.

CHAPTER 2

Background Study

As the world is approaching a realm of 3D information and augmented reality, significant study has been conducted by scholars, technology companies, independent hobbyists and research teams from various universities for digitally documenting cultural heritage establishments [6]. One of the most widely used method for 3D data acquisition and model reconstruction is the image-based approach. Traditionally, image-based approach is executed by using Photogrammetry [7]. However, there are quite a few drawbacks of this method. Firstly, the pictures used in photogrammetry have to be taken by professional photographer in order to get the best outcome [8]. This method also entails rigorous training to get the perfect photographs using the same angle, lighting and reference point but nonetheless cannot ensure perfectly detailed results of 3D models [7-9]. Additionally, photogrammetry uses many tools such as various black-box software. These software have automatic image alignment and 3D model reconstructions. It gives incomplete output as the user cannot interact while the results are processing. Another widespread practice of 3D modeling of historical sites is the range-based method using active sensors such as laser scanners [9]. Lasers scanners give excellent detailed modeling with high accuracy and automation [7, 8, 10]. However, this technique is extremely costly as laser scanners are very expensive. Moreover, it requires professional supervision that makes the whole process very cumbersome to function and calibrate [11]. Also, numerous scans for large-scale historical establishments which causes great time for 3D data gathering [7]. Alternatively, inexpensive methods for 3D modeling has been applied using Microsoft Kinect [12-14]. This technique also has some disadvantages. Such as, low speed for processing the data and unclear 3D models that cannot be used for further research of historical sites [12]. Lastly, several integrated techniques like combining image and range-based modeling was taken up by several researches in the past [11]. Low level of automation, ease of use, high computing time, cost of instruments, distance dependence, huge data volume, absence of texture dependency and sorting out unnecessary data from the final results was the downside of the aforementioned approaches.

To overcome the limitations of existing models, this paper presents a model which is based on implementation of an integrated approach of three technologies which are 3D modeling, virtual reality for smart phone application and a digital archive for online access through computer. Additionally, the resulted models of the heritage sites have details with in-depth accuracy. The 3D models were created using high resolution texturing, accurate position of lighting and detailed polygon modeling for higher precision that makes the resultant 3D models more authentic and realistic. Similarly, in the Virtual Reality application the camera angle is adjusted in such a way that gives optimum ease of viewing for users. Moreover, different functions have been added to increase interactions with the 3D models. Lastly, as smartphones are expensive, many people cannot afford it which causes exclusion of a vast majority of audiences. It is a contradiction with the goal as spreading of the exploration of historic testimonials of Dhaka to a global platform is the target of the proposed model. Therefore, a website is made which functions as a repository for widespread inclusion of public.

2.1. Techniques

2.1.1 Photogrammetry

The first one is photogrammetry. It is a process that combines multiple photos of an object to form a three-dimensional structure. The photos taken from various angles are first aligned to construct an accurate high-density point cloud, which is then used to build a mesh structure of the object. The texture of the object is then mapped onto the mesh to create a photorealistic model of the object. In our attempts to create the 3D model of the Lalbagh Fort using photogrammetry, we took over 600 photos of the buildings from every angle, and manually aligned them so as to optimize them for a 3D reconstruction using AgisoftPhotoscan. However, the results were not satisfactory enough as seen in Figure 2.2. The methodology for photogrammetry is shown below in Figure 2.1.

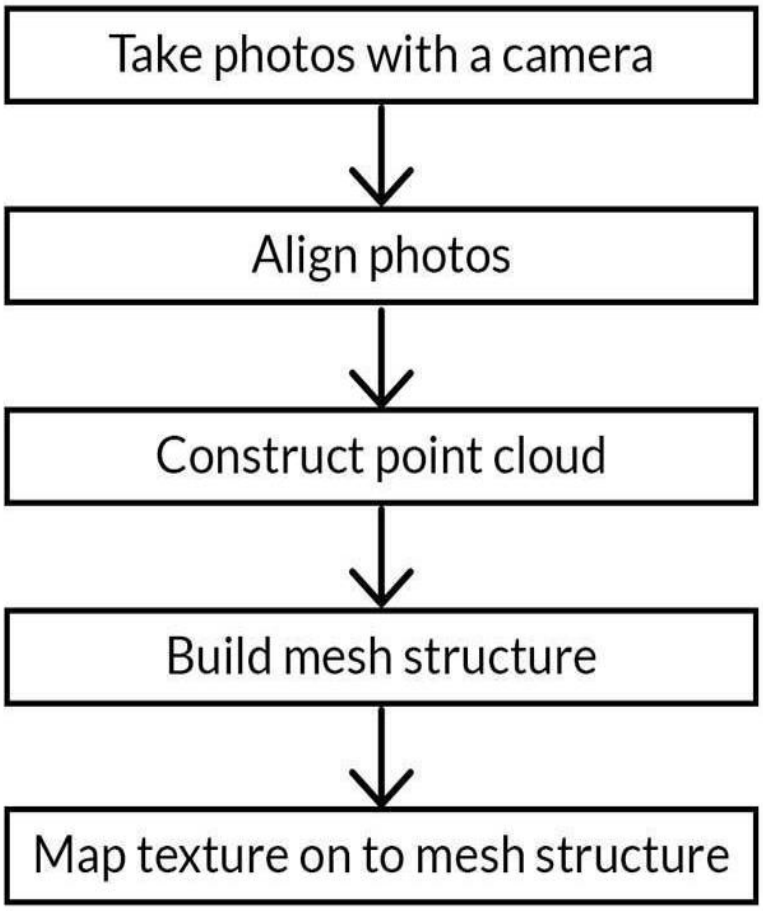

Figure 2.1 Photogrammetry Methodology

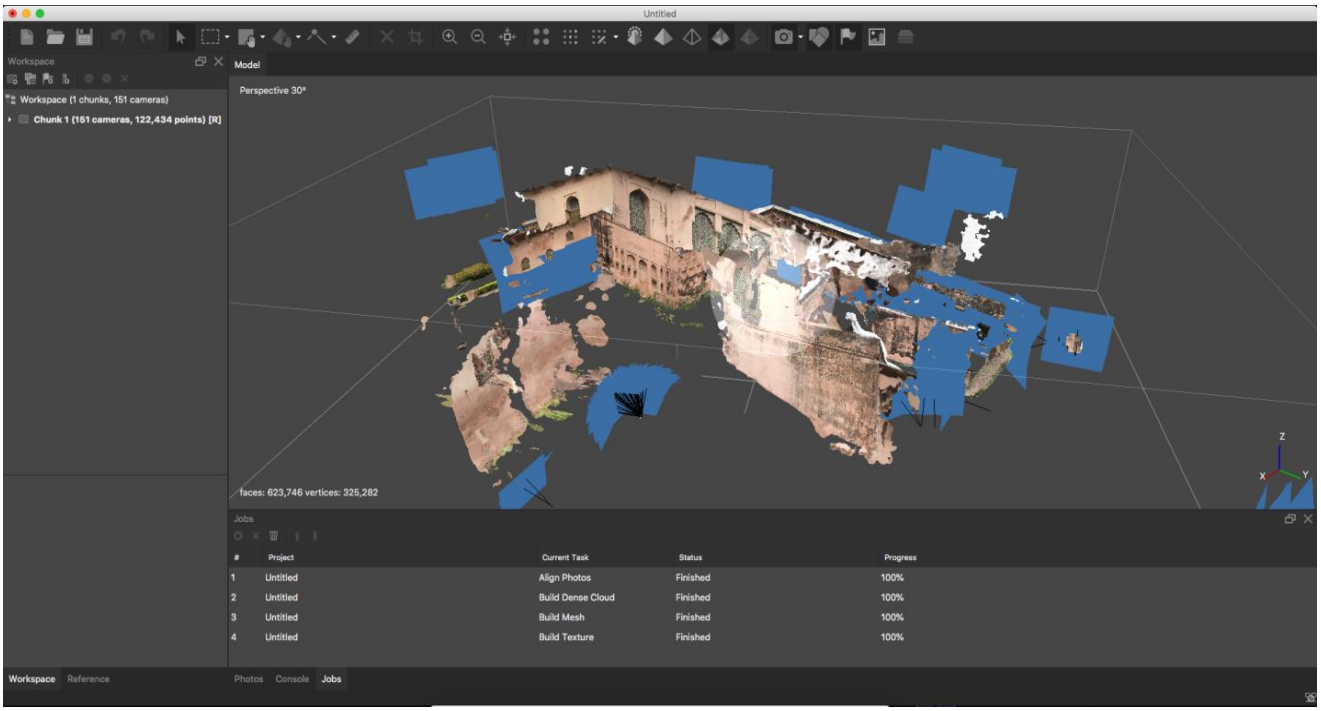

Figure 2.2 Render of Diwan-i-Aam using photogrammetry

2.1.2 3D Scanning

We then moved on to 3D scanning. 3D scanning is somewhat similar to photogrammetry, but uses specialized hardware, such as laser scanners. As such hardware are too expensive for using in an educational project, we decided to use a Microsoft Xbox Kinect [19], which is an attachment device for Microsoft's popular Xbox 360. This device consists of 3D depth sensors, an RGB camera, multiple microphones and a motorized tilt which gear the Kinect towards capturing movements of humans in 3D. By using the Xbox 360 Kinect along with the Kinect Power adapter on a computer, with a powerful processor and graphics processor unit, it is possible to use the device as a low-cost scanner. After the device is plugged into the computer and the Skanect 1.9.1 software is installed [20], the Kinect is moved carefully around the object that is to be scanned. In order to scan larger objects or a room, it is important to hold the Kinect at a distance of 50 centimeters from the target body to generate several images on the Skanect. Even though the Kinect is an affordable scanner, the process requires the device to move at a minimum speed of 15 frames per second. However, due to the high intensive GPU processing, the Kinect becomes extremely sensitive to movements and fails to continue the scanning process

when the speed exceeds beyond 5 frames per second. Therefore, it was not even possible to finish scanning one single wall of a room. As a result, the Kinect was effective in terms of accuracy for smaller objects but did not produce much accurate results when we tried to scan the inside of a room, as seen in Figure 2.4. Since it was extremely difficult to work with the Kinect to scan the inside of a room with featureless walls with a relatively larger area, 3D scanning of buildings of heritage sites using the device is not a good candidate for modeling. The Figure 2.3 shows the process of using Microsoft Kinect.

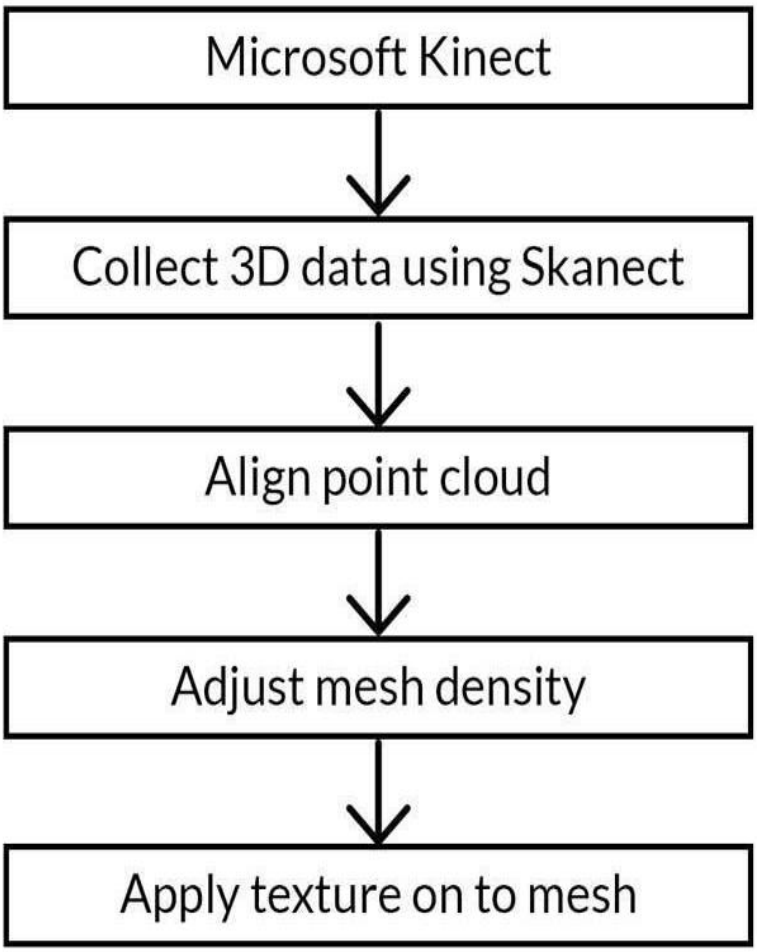

Figure 2.3 3D Scanning Methodology

Figure 2.4 3D Scanning of a room using Xbox Kinect

2.1.3 3D Modeling

As we were not able to produce satisfactory results using both photogrammetry and 3D scanning technology, we moved on to using 3D modeling programs. In this option, we started with a blank digital space and created the model of the whole structure from scratch. Even though the process is very time consuming, the results were visually more accurate and optimized for our purpose. The Figure 2.5 demonstrates the methodology of 3D Modeling.

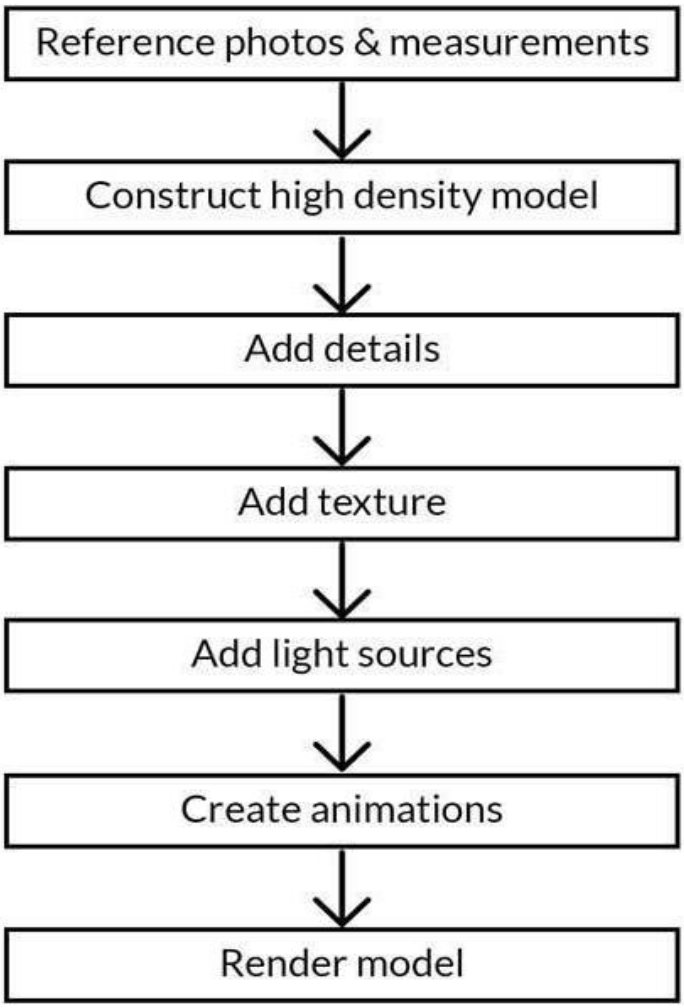

Figure 2.5 3D modeling methodology

We picked 3ds Max, one of the most popular and complex 3D modeling programs, to make our models with. The interface of 3ds Max seemed more intuitive than its counterparts and more importantly, we got a Student License from Autodesk which allowed us to use all features of the program free of charge.

CHAPTER 3

Workflow of the study

3.1 Taking Reference Photos and Measurements

The first step to constructing a 3D model from a real-life object is taking precise measurements and good reference photographs. The Figure 3.1 below shows the process of using AirMeasure. The primary goals for using reference photos are:

a. To maintain utmost accuracy. If the models do not reflect the real-world proportions of the heritage sites, the final Virtual Reality representation would become misleading.
b. To map the texture of the buildings from the photographs on to the model for life-like visuals.

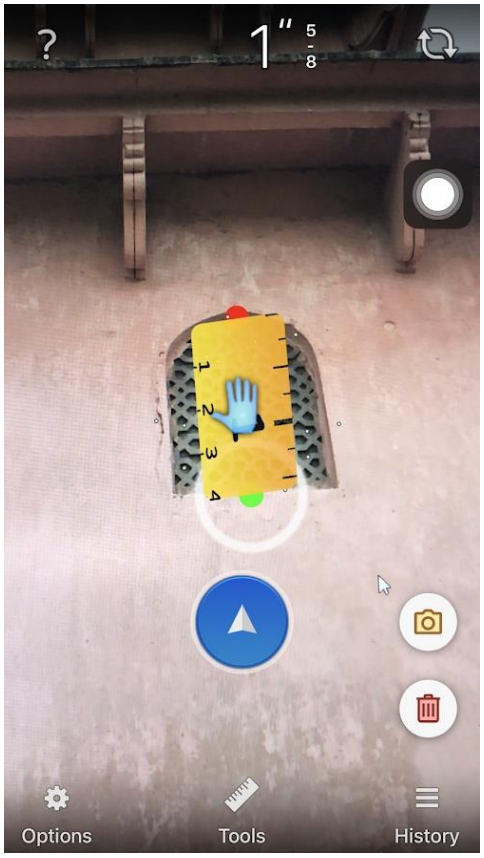

Figure 3.1 Taking accurate measurements using AirMeasure

Figure 3.2 High resolution photograph of Lalbagh Fort

As the Lalbagh Fort spans over a huge area and comprises of several structures, it took a lot of time for taking reference photos that would be usable in producing the final model. We used an iPhone 7 Plus for taking the photographs, shown in Figure 3.2 for example, which has a 28mm f1.8 and 56mm f2.8 lenses. Moreover, as it would be impractical to physically measure the structures of Lalbagh Fort, we used an Augmented Reality (AR) smartphone application called AirMeasure, as seen in Figure 3.1, that uses Apple's ARKit SDK to accurately measure objects of any size.

3.2 Modeling

For constructing the models of the heritage sites, we used 3ds Max, a popular 3D modeling program. After we had our measurements and reference photos set up, we started with a primitive shape of a box as referenced in Figure 3.3, as all the structures inside the Lalbagh Fort are rectangular. We added details and more components of the structures, such as domes, doorways, and windows using the other primitive shapes (eg. sphere, cone, etc.) until we got an accurate representation of the buildings.

For constructing the model of the Tomb of Pori Bibi, we started with building the frontal doorway, as seen in Figure 3.4, and made iterations of it that were stitched together over a square base with domes in between. After that, the central dome was placed above a plane on the roof of the whole structure. The domes, gateway, and the pillars were segmented multiple times to get better manipulation results using them. Each individual object was separately created, grouped and then merged together to create the overall building. The building, however, is a complex structure and has many intricate details on the surface of the walls as well. The challenging part was to figure out how to add these details to get the desired result. We mainly used the Boolean function which allowed us to manipulate standard and primitive objects to add the complex details to the structure. In the end, we had to render the model as seen in Figure 3.5.

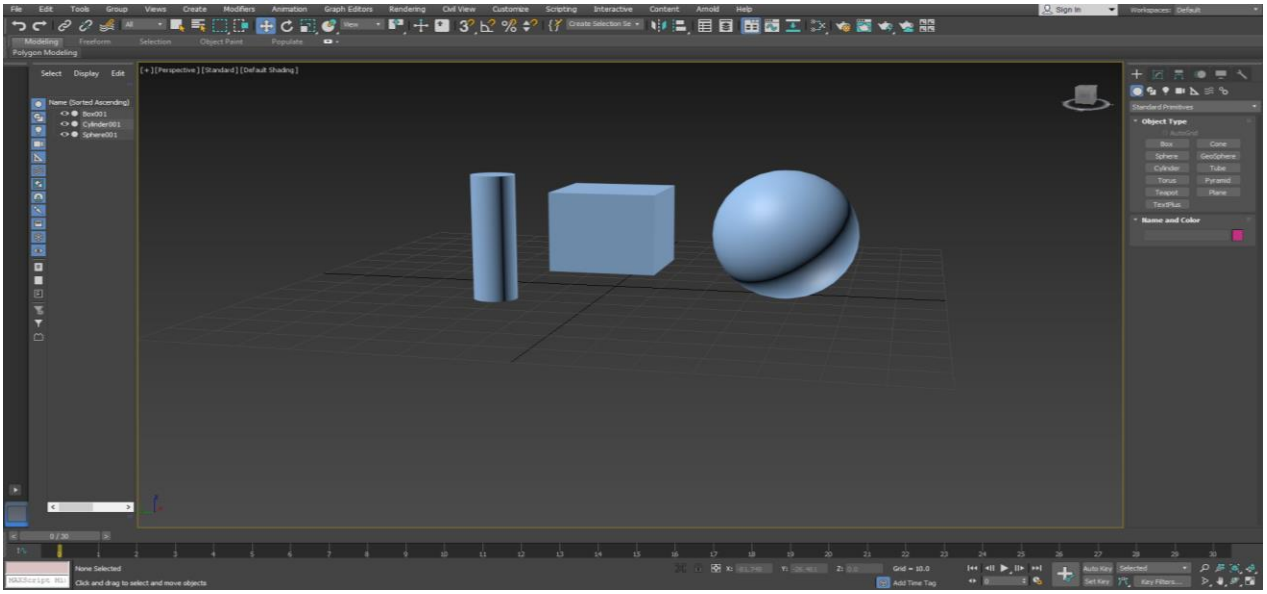

Figure 3.3 Primitive shapes in 3ds Max

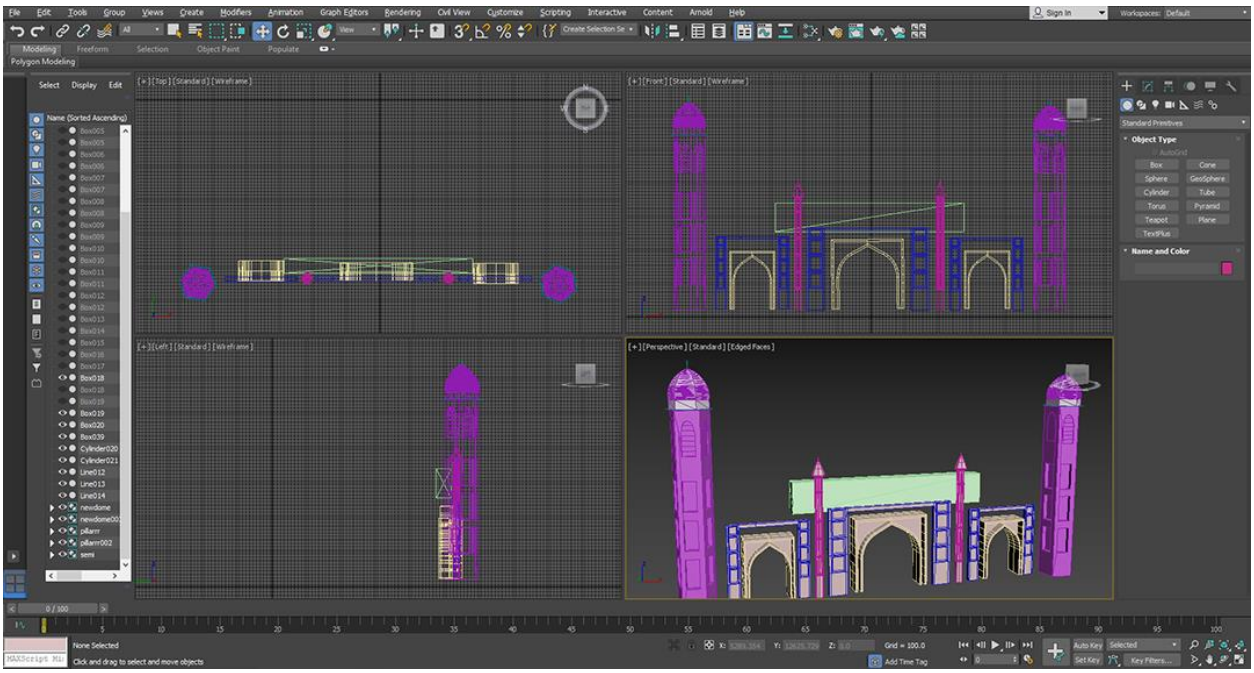

Figure 3.4 Building the model of the Tomb of Pori Bibi

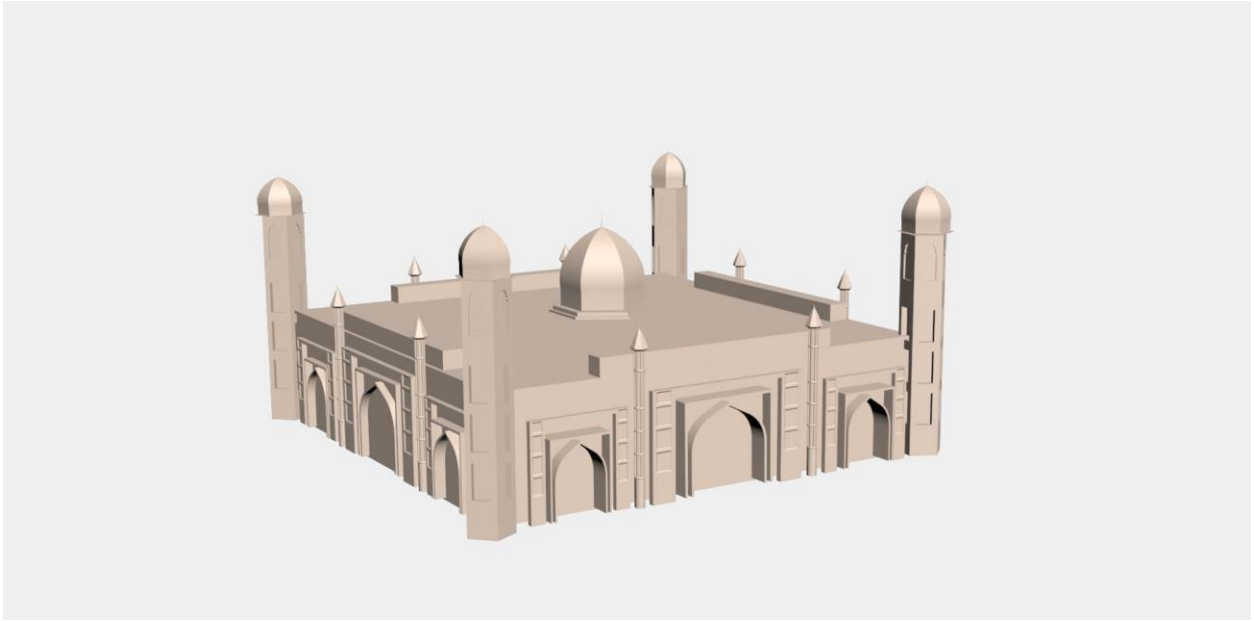

Figure 3.5 Rendered model of the Tomb of Pori Bibi

For the structure called Diwan-i-Am, we followed a similar approach to efficiently construct the model. As this structure is mostly comprised of smaller rectangular structures, we

started out with three rectangular shapes and added details for the window and doorway cutouts using the Boolean function for compound primitives. The three cubes were then brought in closer together to form the overall shape of the structure, and then layers of curved planes were aligned individually and added over them to construct the roof as seen in Figure 3.6. The rendered model is shown in Figure 3.7.

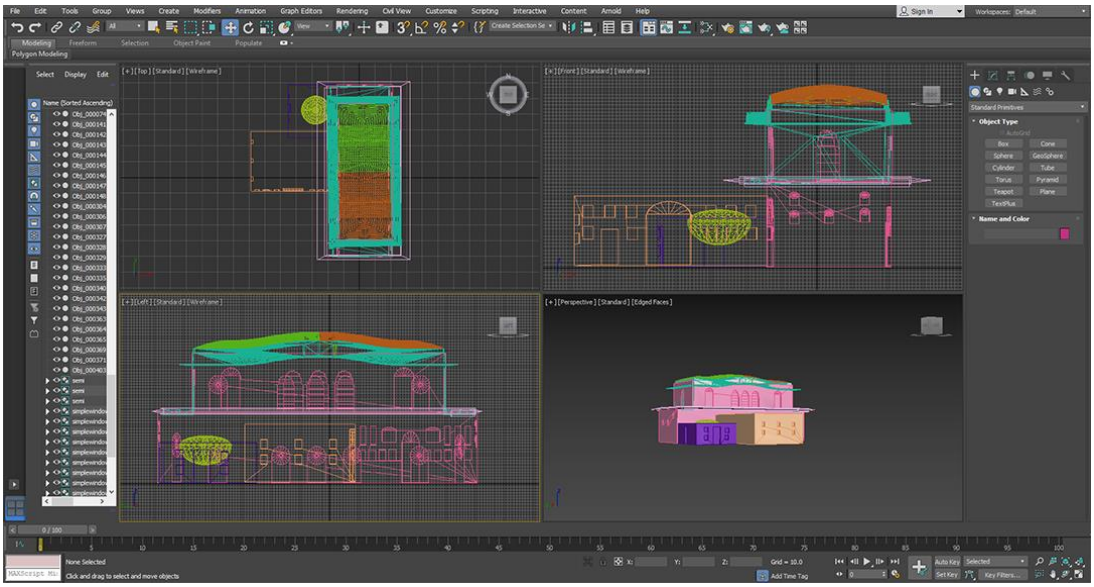

Figure 3.6 Building the model of the Diwan-i-Aam

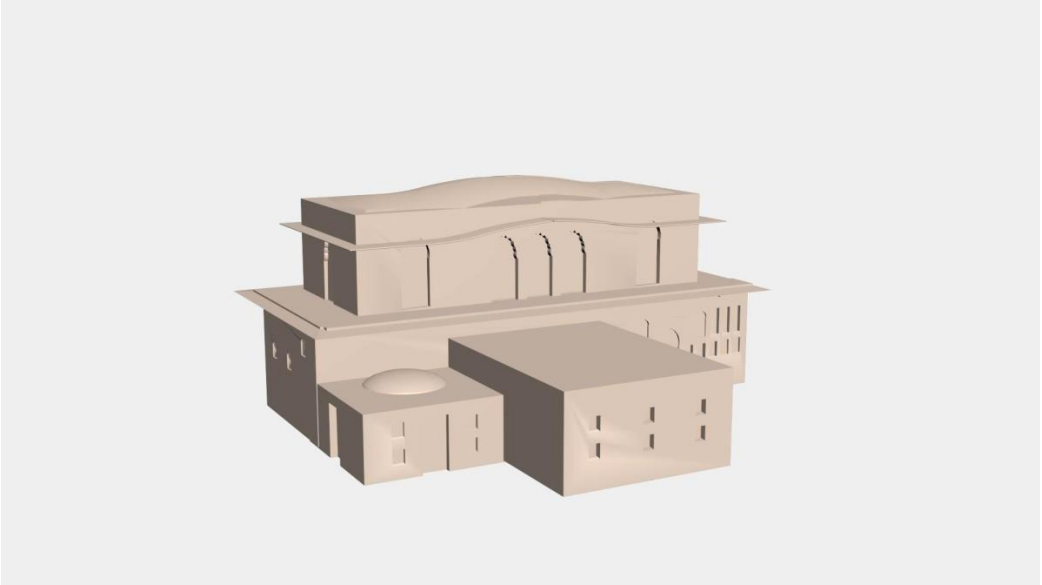

Figure 3.7 Rendered model of the Diwan-i-Aam

As for the structure of the mosque situated inside Lalbagh Fort, we started out with two boxes interconnected using the Boolean function inside 3ds Max. The doorways and windows were also cut out using the Boolean functions, and the pillars and domes, as shown in Figure 3.8, were built and then merged with the cubes to completely construct the rendered model shown in Figure 3.9.

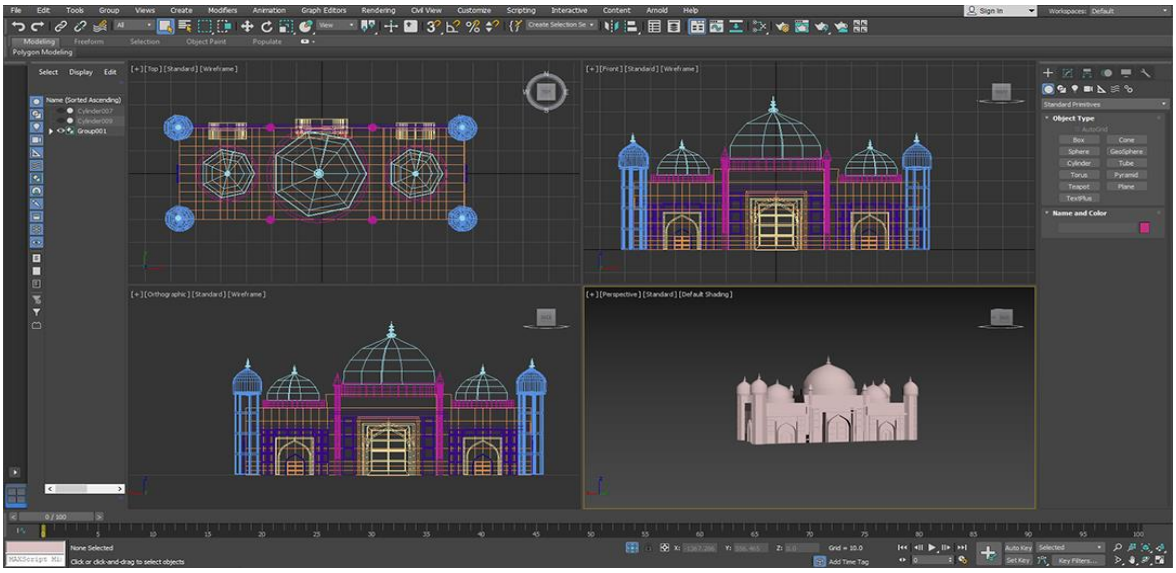

Figure 3.8 Building the model of the mosque

Figure 3.9 Rendered model of the mosque

Besides Lalbagh Fort, we also constructed a 3D model of the Greek Memorial situated in the premise of Dhaka University. It was built by the Greeks who were the last Europeans to come to Bangladesh. This structure was built by them in the memory of the Greek merchants who died in Dhaka. The Greek Memorial is a relatively smaller structure, but has intricate details on the walls. The structure is mainly made up of multiple pillars around a cubic base, as shown in Figure 3.10. Several segments were created for each individual primitive object that we used, in order to form bridges and join them to avoid adding too many basic shapes and ending up with a complicated mesh. Once the pillars were built, we added a roof by modifying a rectangular primitive shape to finally produce the rendered result as shown in Figure 3.11.

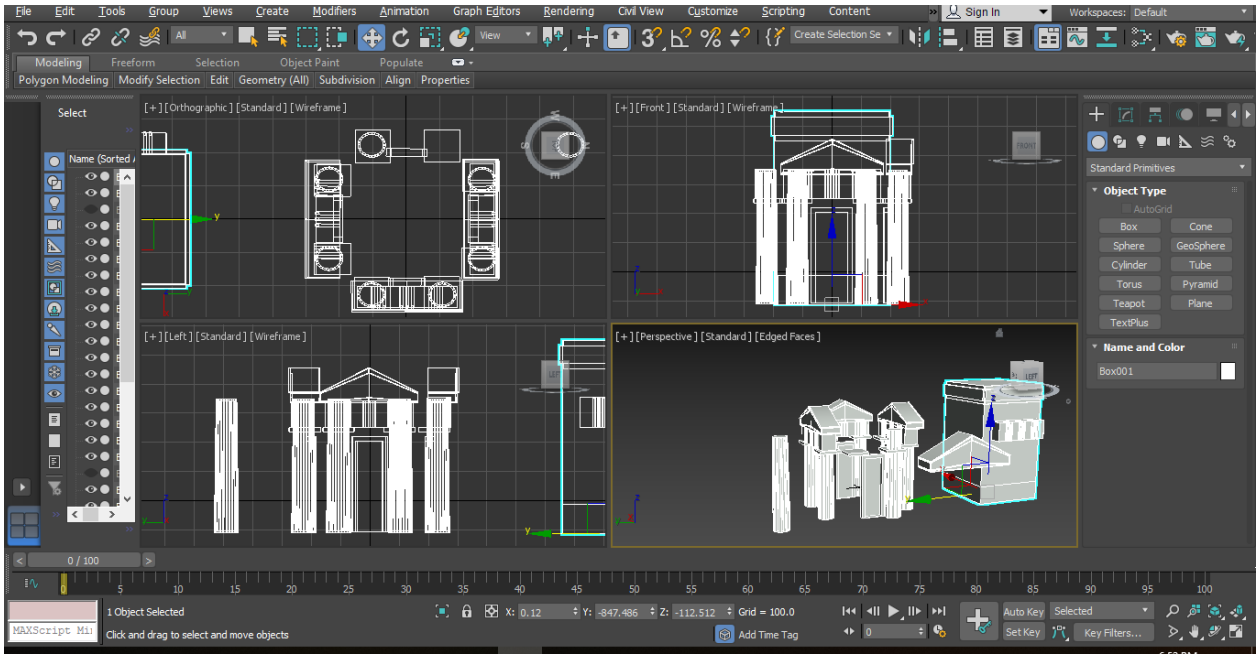

Figure 3.10 Rendered model of the Greek Memorial

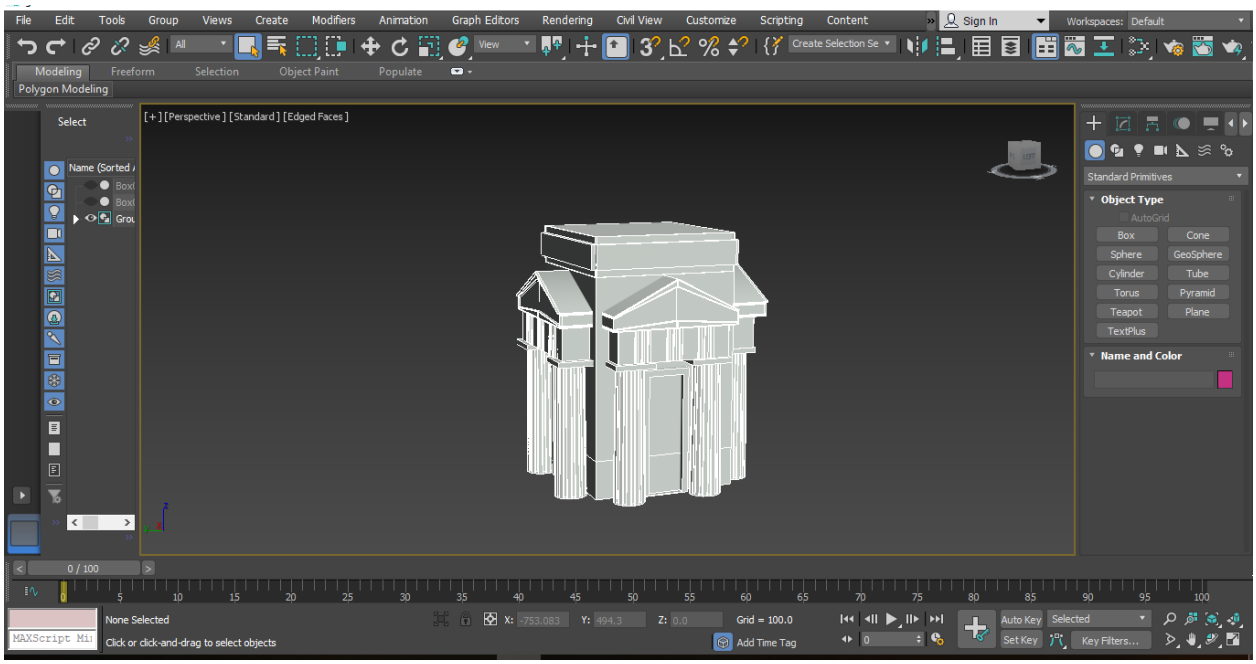

Figure 3.11 Rendered model of the Greek Memorial

We also constructed a 3D model of the Shahid Minar, which is the National Monument of Bangladesh. It has great significance as it was built to commemorate the people who died during the Language Movement in 1971. This structure was relatively simple and easy to model. We used rectangular and cylindrical shapes to model the figure, and also used the Bridge operation to create links between them. The circle was created using the spline circle and a basic flat surface. The Figure 3.12 shows the building of the model of the Shahid Minar. The staircase was made using the Extrude operation after which all the individual components were merged together to produce the resulting model shown in Figure 3.13.

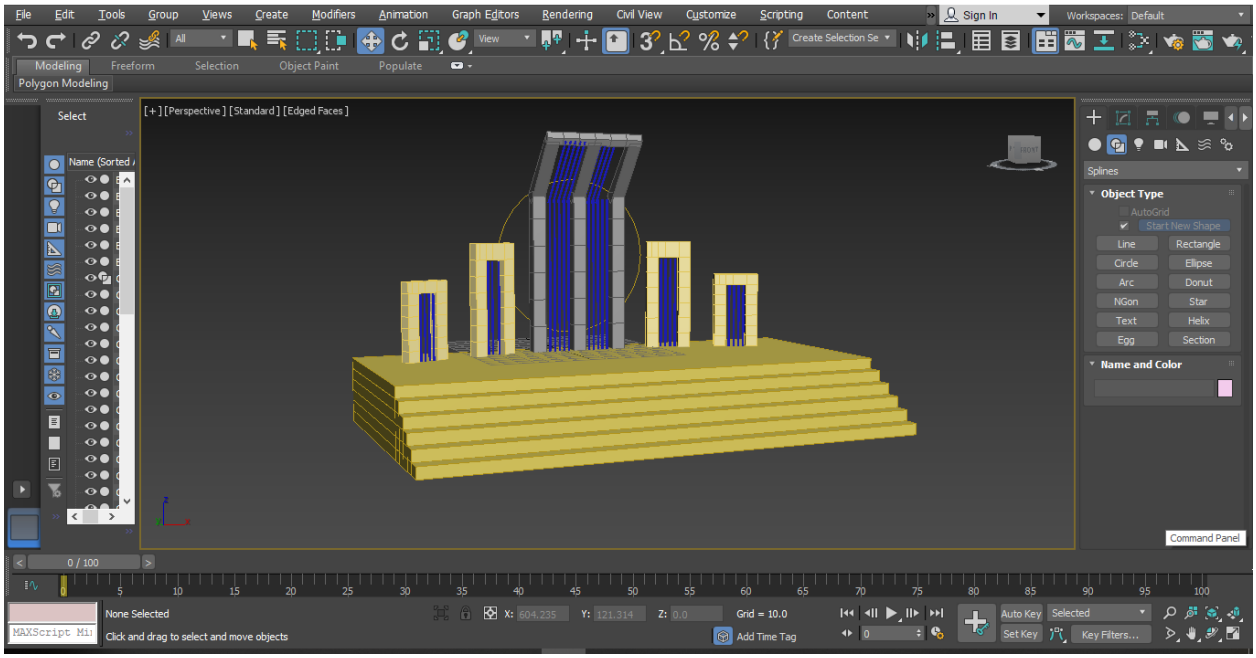

Figure 3.12 Rendered model of the Shahid Minar

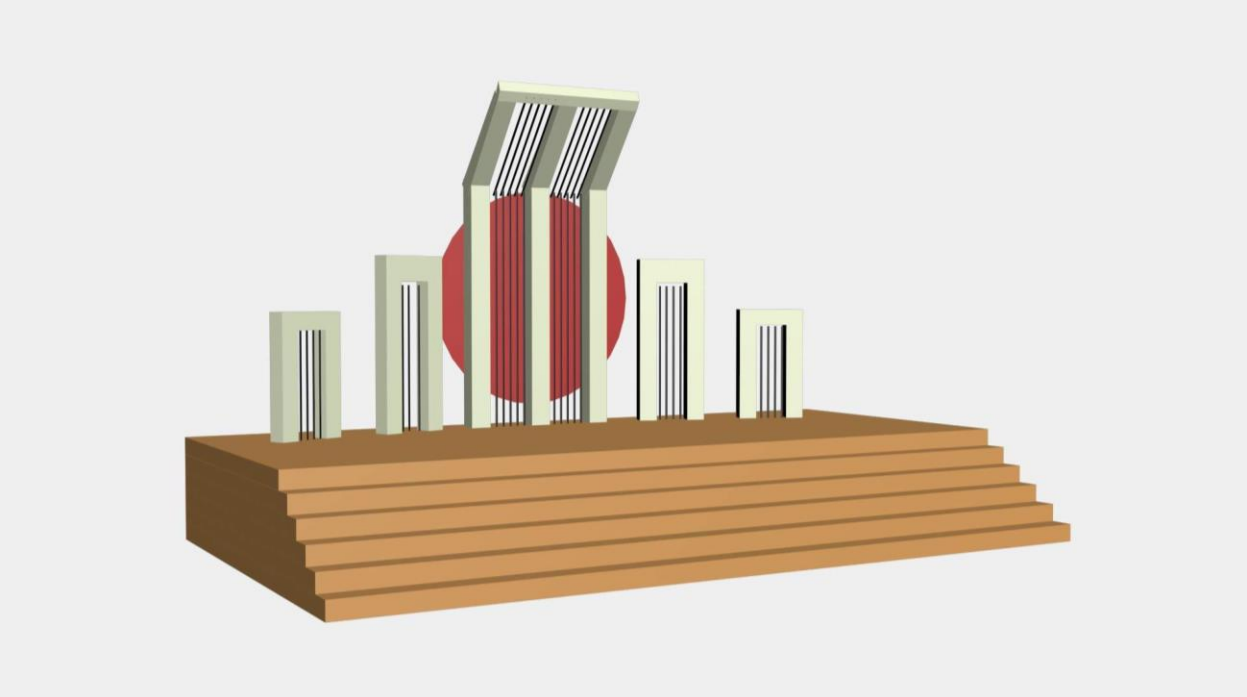

Figure 3.13 Rendered model of the Shahid Minar

While constructing the models, although we needed to create multiple segments for object manipulation and modification, we also had to make sure that the mesh complexity was kept relatively low so as to make the VR experience smooth for mobile devices without much CPU and GPU resources. This is important because when multiple structures are imported into a single Virtual Reality environment, the mesh complexity adds up and requires more CPU and GPU resources. So, to cater to users of mid-range to high-end smartphones, we tried to keep the overall mesh complexities low for each structure.

3.3 Texture Mapping

The photographs of the site that we had initially taken were then used to build the texture over the high density mesh that we created using 3ds Max. This step was particularly challenging because there is an expansive vocabulary around the texturing process. The materials used on the mesh of the model determine how the light from the light source is reflected or absorbed and how it looks from different angles so it had to be made sure that the light falls consistently over the non-reflective surface of the walls of the structures.

3.4 Lighting and Animation

To keep things simple, we used the daylight source in 3ds Max. We chose this in order to keep the light uniform and consistent over all of the three buildings within Lalbagh Fort.

Animation of a model is used to give them life when used in other applications, which in our case are the Virtual Reality smartphone application and the archive website. To animate all of the structure models inside the Lalbagh Fort compound, we used a standard target camera setup on a custom path which it moved along to create a real-life animated visualization of the models.

3.5 Creating the VR Application

With the advancement in smartphone technologies, Virtual Reality has become a widely used medium to create immersive and interactive environments with virtual realism. Even though conventional virtual reality hardware is hard to adopt due to their high costs, the implementation

and widespread use of virtual reality using smartphones has made the technology available to general people. VR is widely used to simulate dangerous or expensive situations such as fire safety training, airplane simulation, 3D tours, etc. Generally, immersive Virtual Reality uses a stereoscopic headset with some sort of motion tracking to determine where the user is looking [20-21]. Among popular VR headsets such as the HTC Vive, Samsung Gear VR, and Google Cardboard, we decided to go with the Google Cardboard because of its simplicity and ease of use. The Google Cardboard headset requires a smartphone to be attached to the headset that acts as the main display for the VR content.

In order to build the VR smartphone application, we used Unity, coupled with the Google VR SDK. We added and edited C# scripts to build the movements and animations, and added pointer click as the base event data. This enabled us to swiftly deploy a VR app using the 3D model of the mosque as the environment as seen in Figure 3.14.

In addition to that, for a more intuitive user experience, we added an onboarding screen that is shown in Figure 3.15 and menu in the application using Android Studio that describes the purpose of the project and presents all models to the user in a single screen.

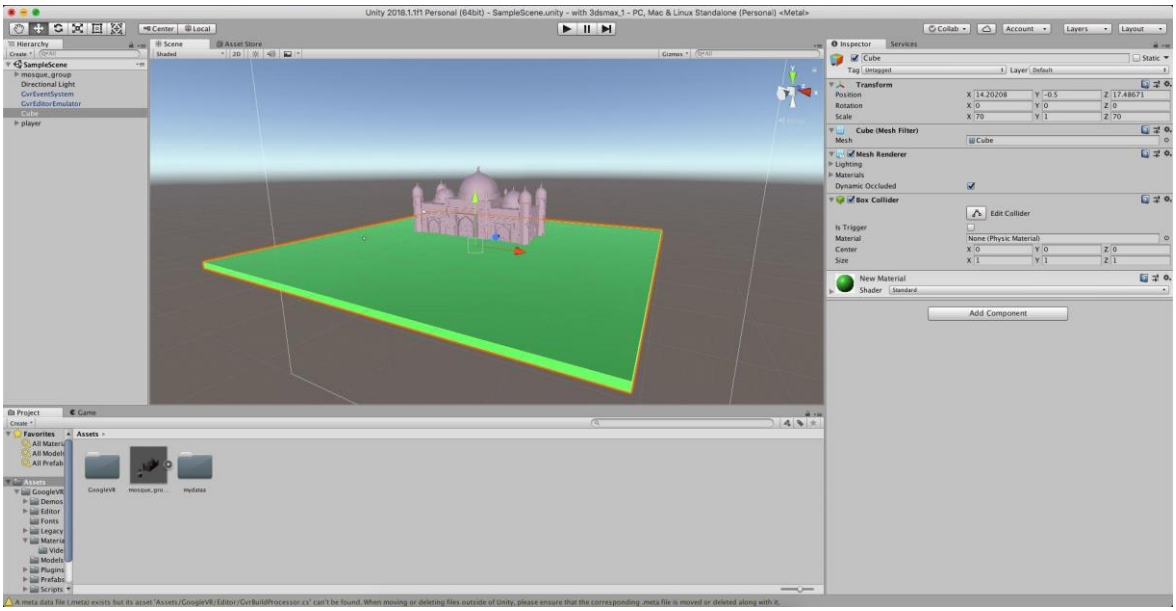

Figure 3.14 Using Unity to create the VR application

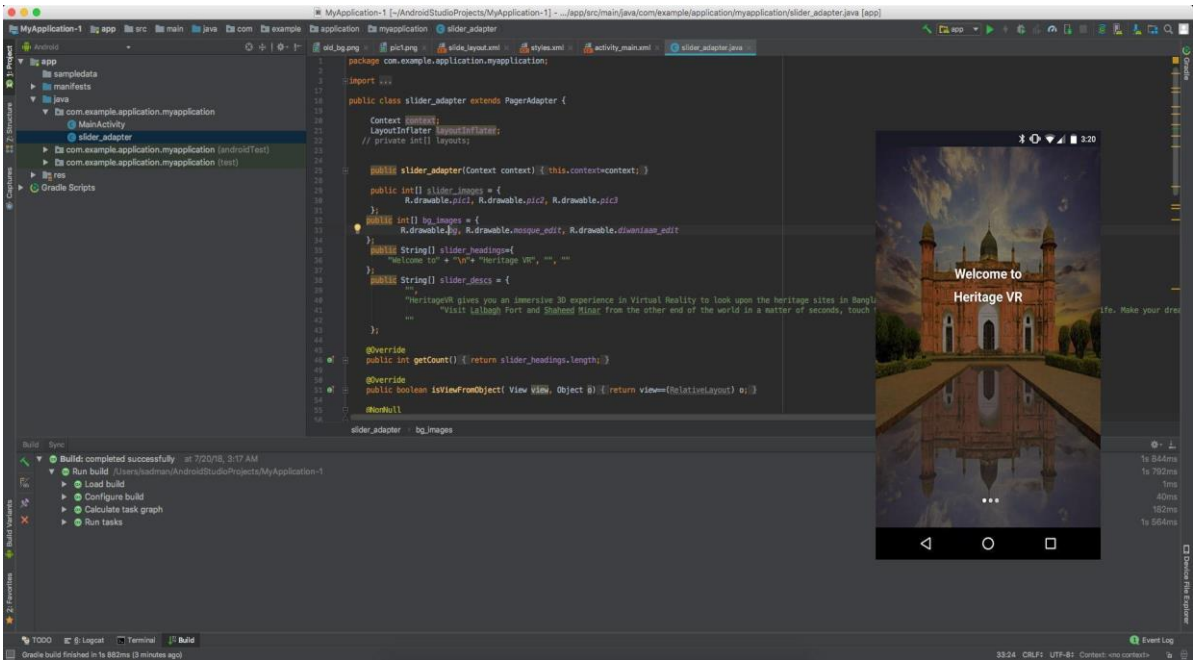

Figure 3.15 Onboarding Screen for the Android application

The environment was then exported as an APK file and ran on an Android smartphone which showed the exact models that we have seen in the figures above, but through a VR interface. To be able to use this VR interface, a Google Cardboard or similar VR headset has to be used that will be able to show the user an immersive and interactive environment of a 3D model, as shown in Figure 3.16.

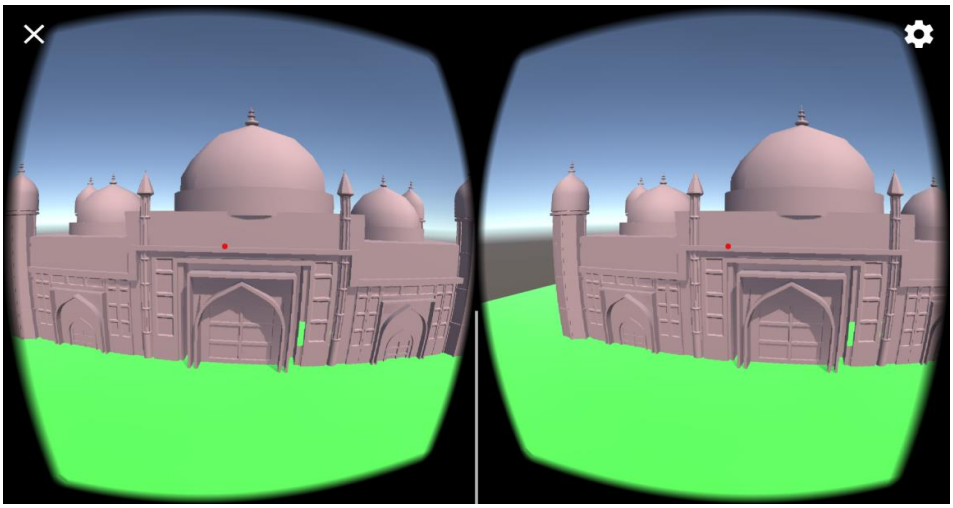

Figure 3.16 Virtual Reality Application

3.6 Archive Website

Besides the VR application, we wanted to create an archive with all of the 3D models so that people without VR headsets can view them too. To achieve that goal, we built a website that contains animations of the models exported to video formats. This allowed us to upload the videos on video-sharing websites and embed it on to the website for easy access. The website was built using HTML5, CSS3, and JavaScript. The template of the website was built fully from scratch in order to keep the user interface consistent with that of the VR application.

The animated videos of the heritages sites are rendered using 3ds Max and then combined with a clip from Google Earth to zoom in on the location. This is done solely for a visual effect in order to make the animations more immersive.

Since the layout of the website is fairly simple, we decided against using any off-the-shelf content management system, which also helps in terms of loading speeds for the website. Not using a CMS (Content Management System), however, could adversely affect scalability, but for keeping overhead costs low, we hosted our site on GitHub pages which does not support any content management systems.

CHAPTER 4

Experimental Results

After creating and rendering the model, the texture was assigned to define the type of material. The animation was made in 3ds Max and the overall model was imported to the Virtual Reality application to view it in a Virtual Reality environment. As stated in the previous section, 3ds Max has been used to build the 3D models of the heritage sites. About five 3D models of various sites have been built in total. The resultant models have the second Level of Details (LOD) [17]. The second LOD has accuracy rate of 60 ~ 65%. Figures 4.1, 4.5, 4.9, 4.13 and 4.17 portray the progress of the work and the outlook of these models while they were constructed in 3ds Max. The resulting rendered models are shown below in Figures 4.2, 4.6, 4.10, 4.14 and 4.18.

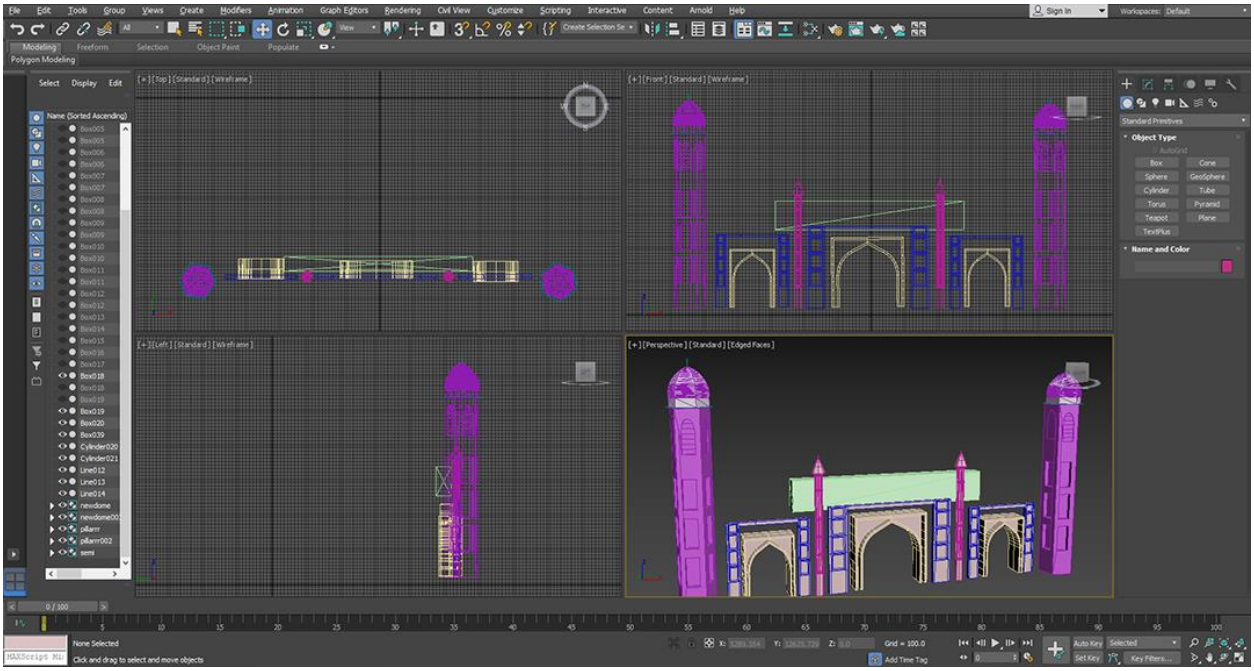

Figure 4.1 Building the model of the Tomb of Pori Bibi

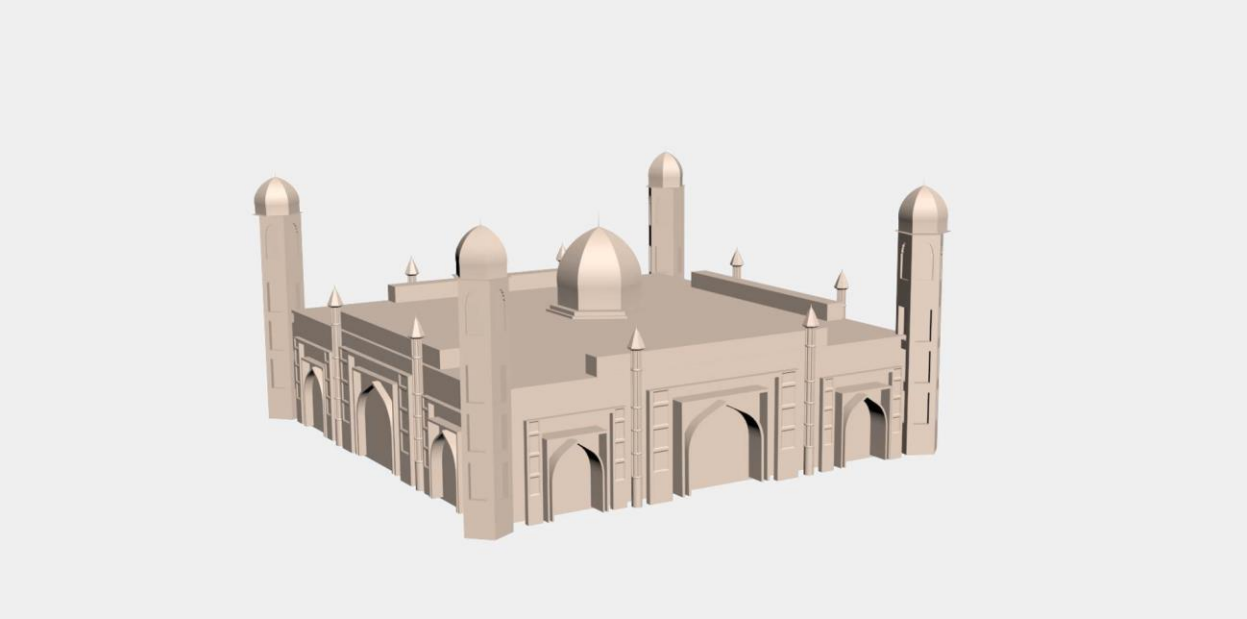

Figure 4.2 Rendered model of the Tomb of Pori Bibi

Figure 4.3 Complete model of the Tomb of Pori Bibi

Figure 4.4 Real image of the Tomb of Pori Bibi

In order to demonstrate the Level of Detail 2 or LOD2 achieved through the proposed model in Figure 4.3, Figure 4.4 is given above. From the Figures 4.3 and 4.4, it can be perceived that the implemented model of The Tomb of Pori Bibi has LOD2 details. The 3D model has high depth accuracy in shape of the doors and the windows with medium detail and low poly. Moreover, the texture on the 3D model has been applied in such a way that it makes the final rendered model visually attractive and at the same time nearly photorealistic.

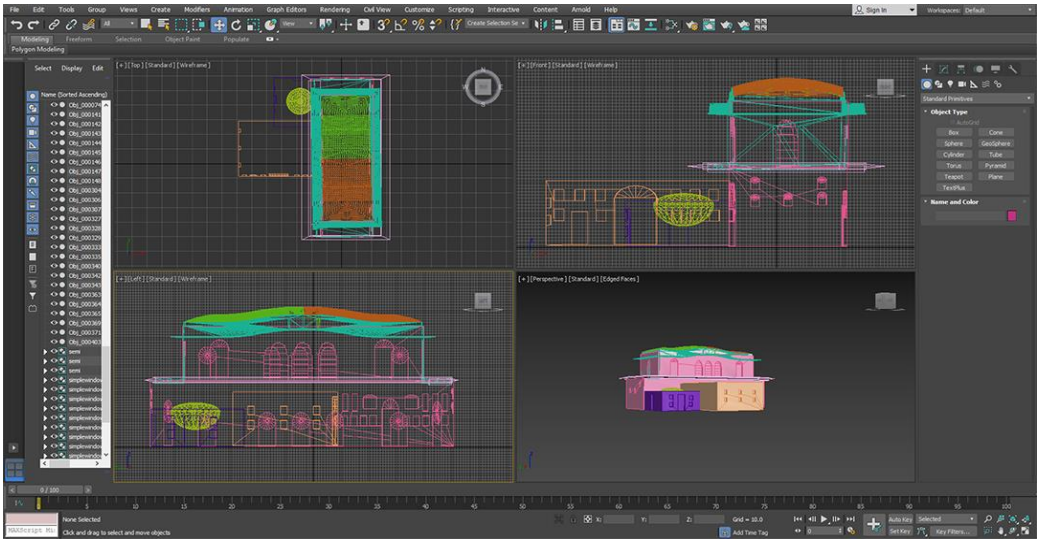

Figure 4.5 Building the model of the Diwan-i-Aam

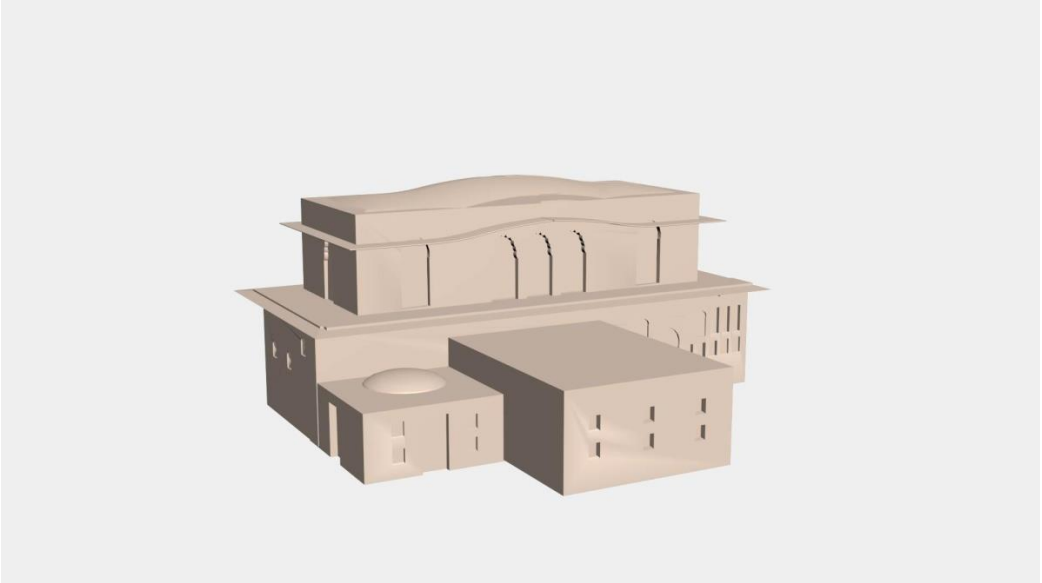

Figure 4.6 Rendered model of the Diwan-i-Aam

Figure 4.7 Complete model of the Diwan-i-Aam

Figure 4.8 Real image of the Diwan-i-Aam

The above Figure 4.8 shows the real image of the Diwan-i-Aam. From the Figure 4.7, it can be perceived that in the implemented model of the Diwan-i-Aam some of the features like intricate designed details of the windows have been omitted to keep the 3D models light, low poly and cost-effective yet geometrically accurate.

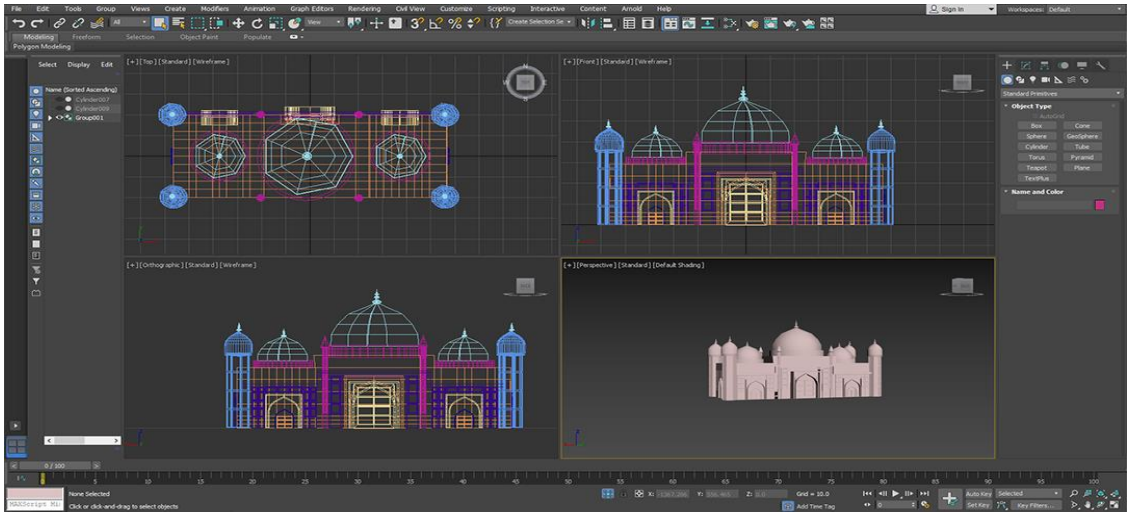

Figure 4.9 Building the model of the mosque

Figure 4.10 Rendered model of the mosque

Figure 4.11 Complete model of the mosque

Figure 4.12 Real image of the mosque

The above Figure 4.12 shows the real image of the Lalbagh mosque. From the Figure 4.11, it can be seen and compared with the real image that other than some details in the dome, all the other designs and details have been added implemented in the model that we created.

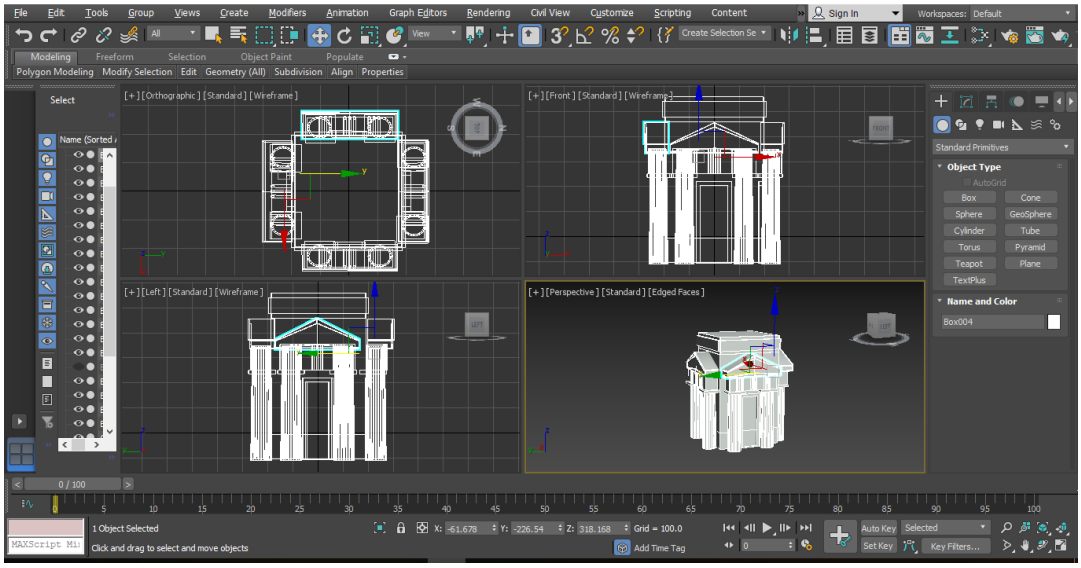

Figure 4.13 Building the model of the Greek Memorial

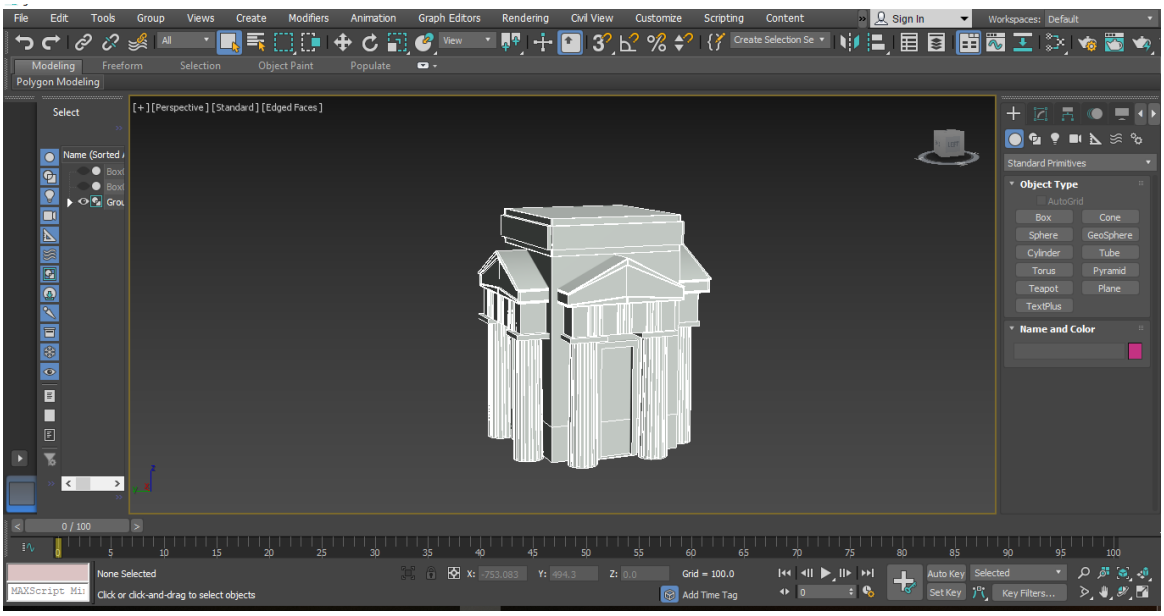

Figure 4.14 Rendered model of the Greek Memorial

Figure 4.15 Complete model of the Greek Memorial

Figure 4.16 Real image of the Greek Memorial

From the Figure 4.15 we can observe that implemented model of the Greek Memorial looks eye-catching and looks almost similar in terms of detail and precision compared to the real image in Figure 4.16.

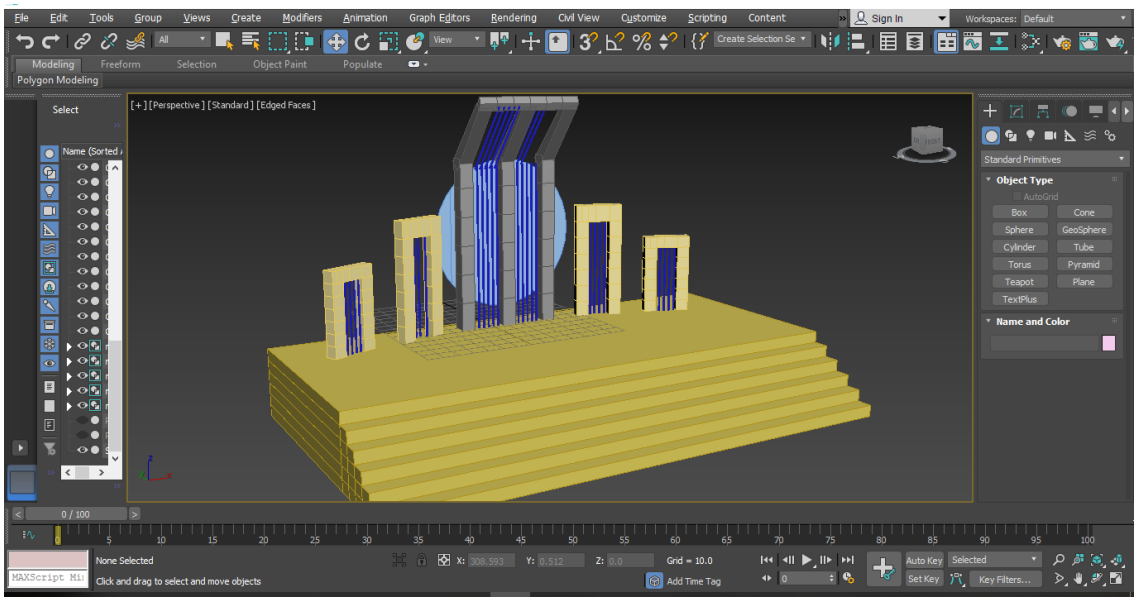

Figure 4.17 Building the model of the Shahid Minar

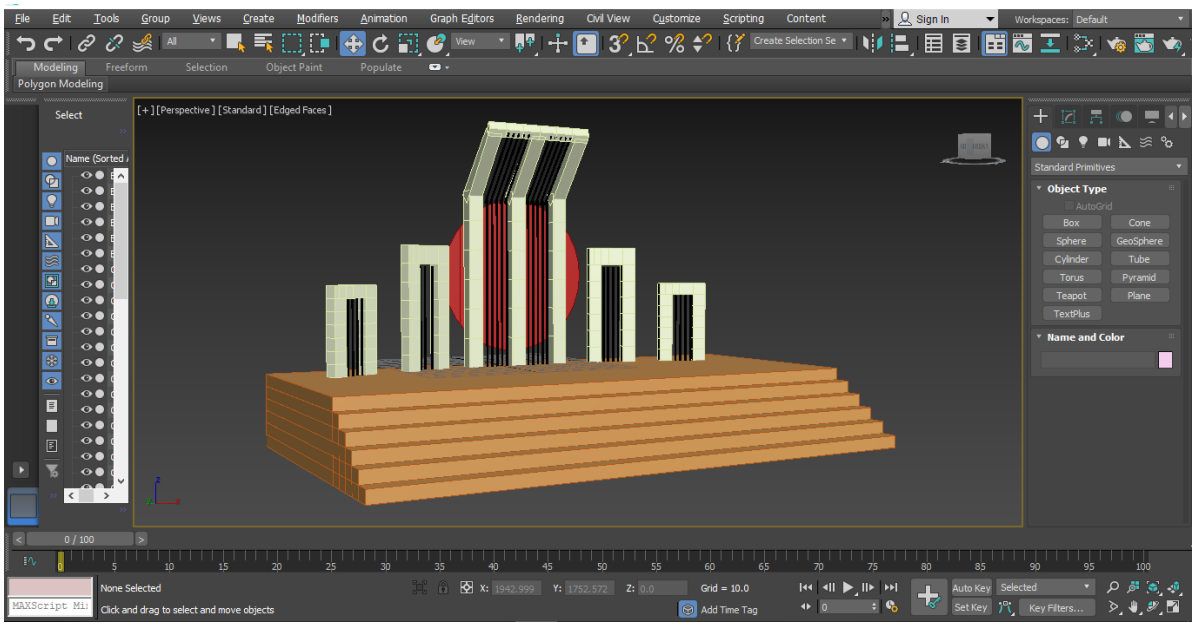

Figure 4.18 Rendered model of the Shahid Minar

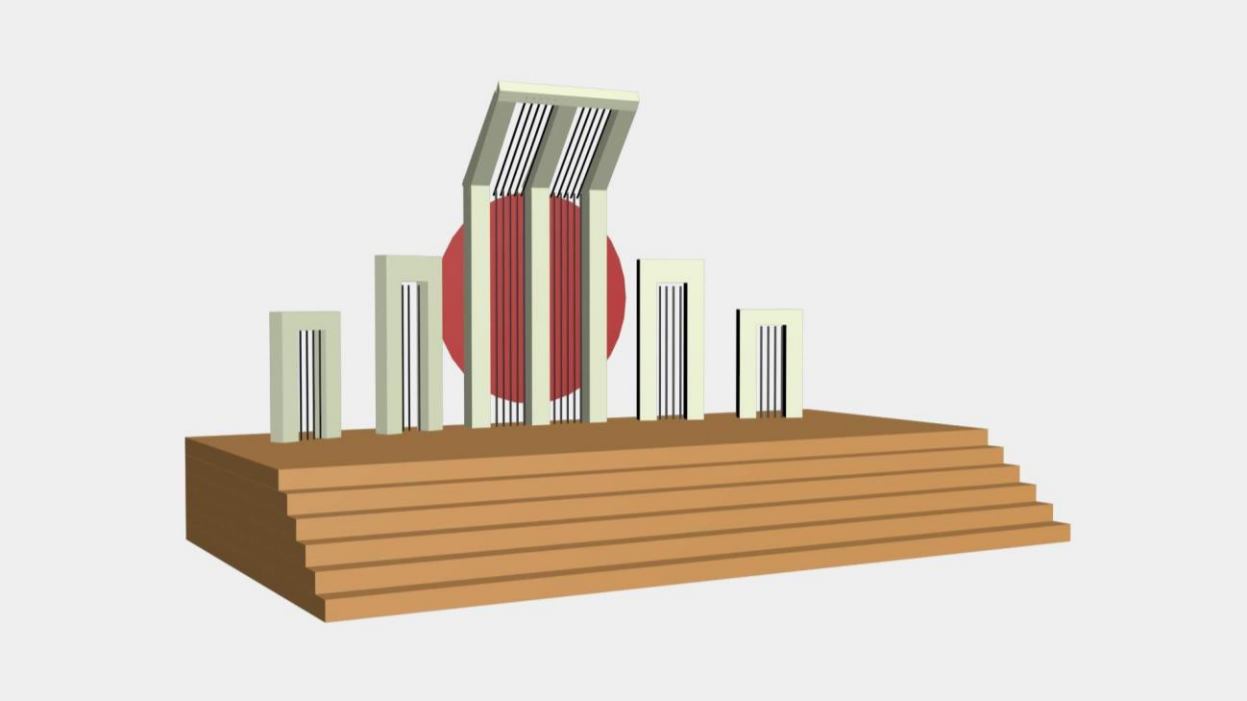

Figure 4.19 Complete model of the Shahid Minar

Figure 4.20 Real image of the Shahid Minar

Similarly, the implemented model of the Shahid Minar in Figure 4.19 can be compared with the real image in Figure 4.20. It can be seen that they look very much alike. The Figures 4.21, 4.22 and 4.23 below show the models of Lalbagh Fort in a VR environment.

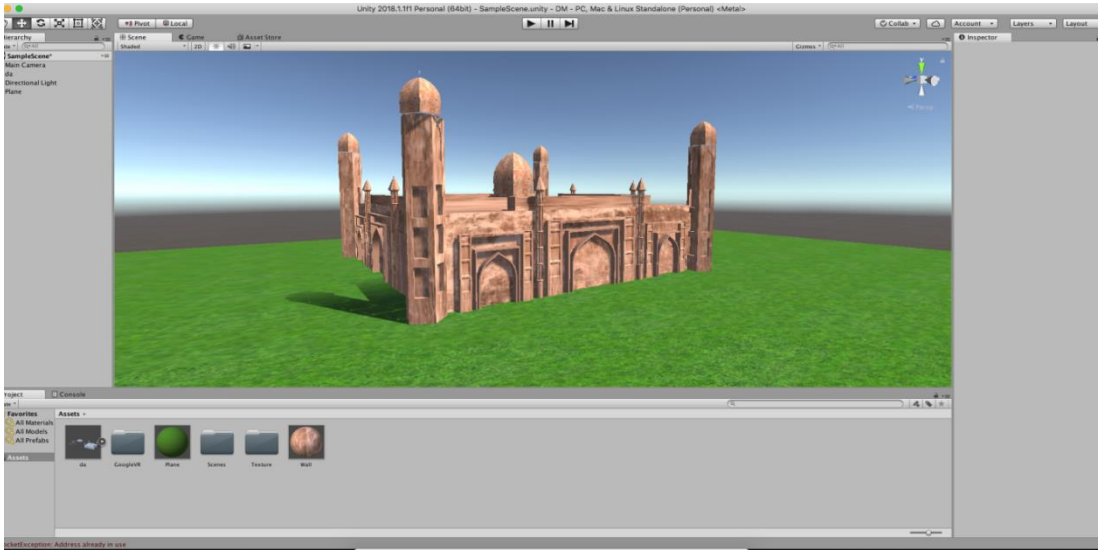

Figure 4.21 VR Environment of the Tomb of Pori Bibi

Figure 4.22 VR Environment of the Diwan-i-Aam

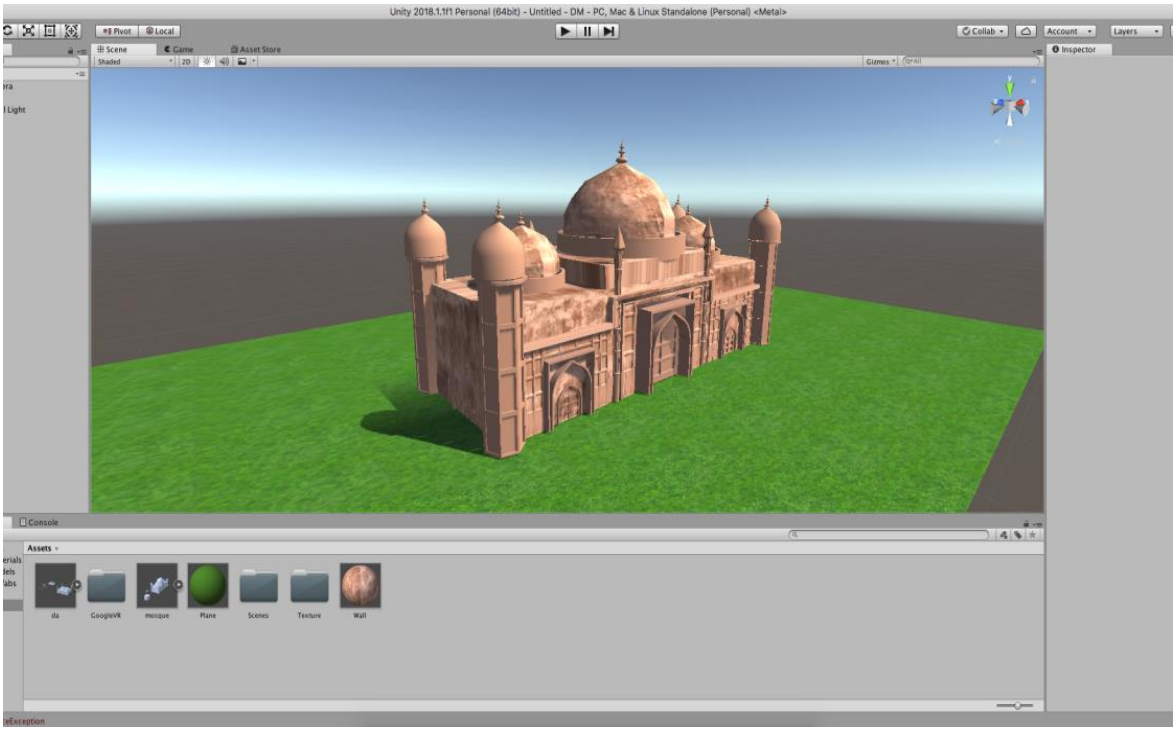

Figure 4.23 VR Environment of the mosque

The outlook of our Android application, which is called "Heritage VR", has the following three screens: the welcome screen, Heritage VR Information screen and the View Models screen, as shown in Figure 4.24. Figures 4.25 and 4.26 demonstrates the models in the Heritage VR application. Our Heritage VR application allows the user to walk, fly and interact with the models in a virtual reality environment.

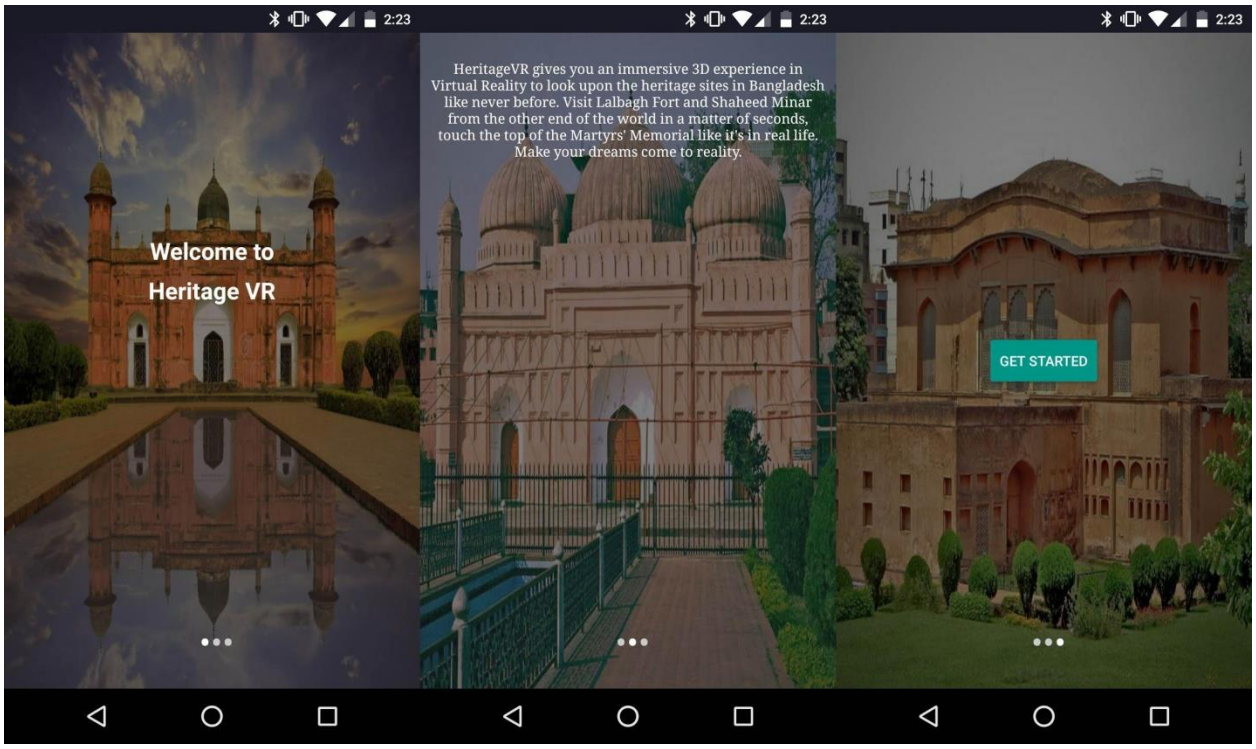

Figure 4.24 Heritage VR Android application

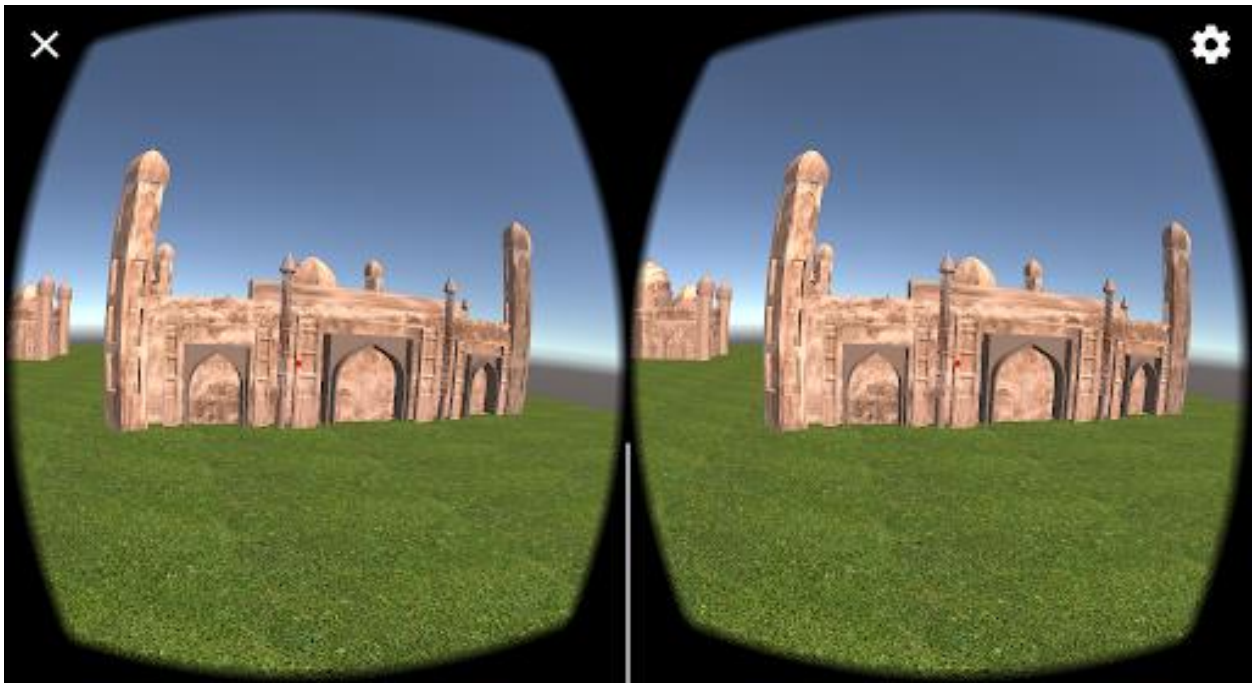

Figure 4.25 Demonstration of one model in Heritage VR

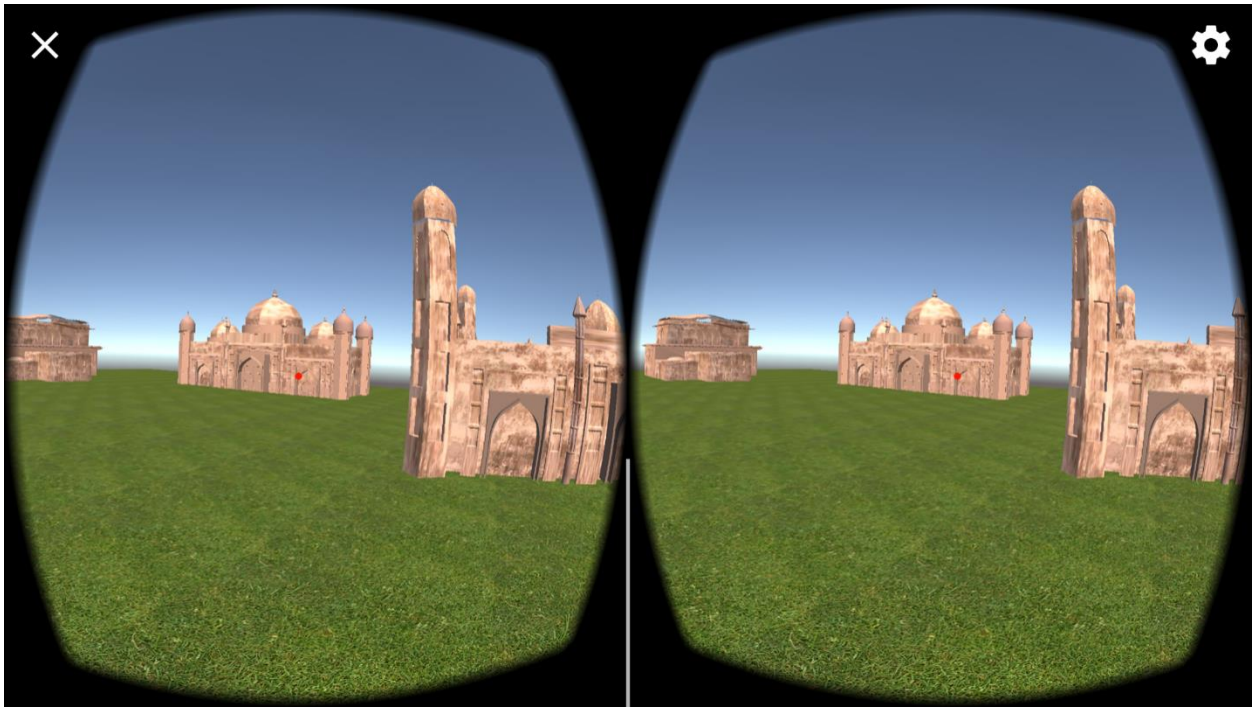

Figure 4.26 Demonstration of models in Heritage VR

The landing page of the website, as seen in Figure 4.27, shows an overview of the project and directs the user to download the Android application. The hero image on the website shows a video animation which plays once the "play" button is clicked. The link of our website is https://heritagevr.sadmansh.com and it contains all the animations of our models which can be found when the Model heading section is clicked.

Figure 4.28 shows the Models page of the website which contains all models with their respective images. Once clicked on the name or image of the model, the user is directed to another page where the video animation for said model is played in and embedded frame.

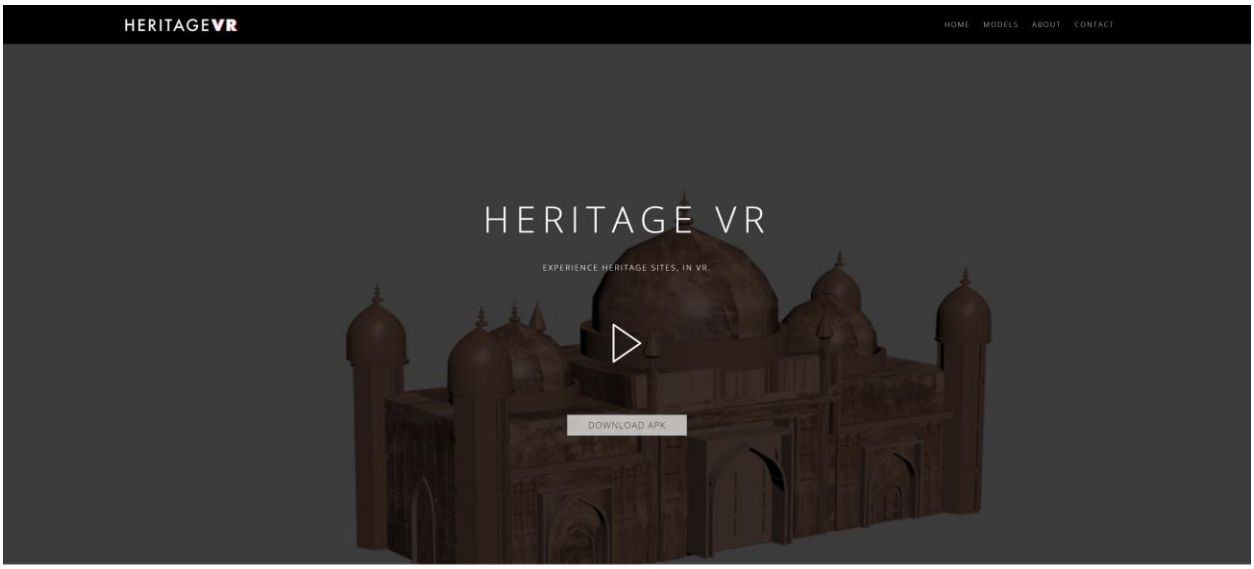

Figure 4.27 Website homepage

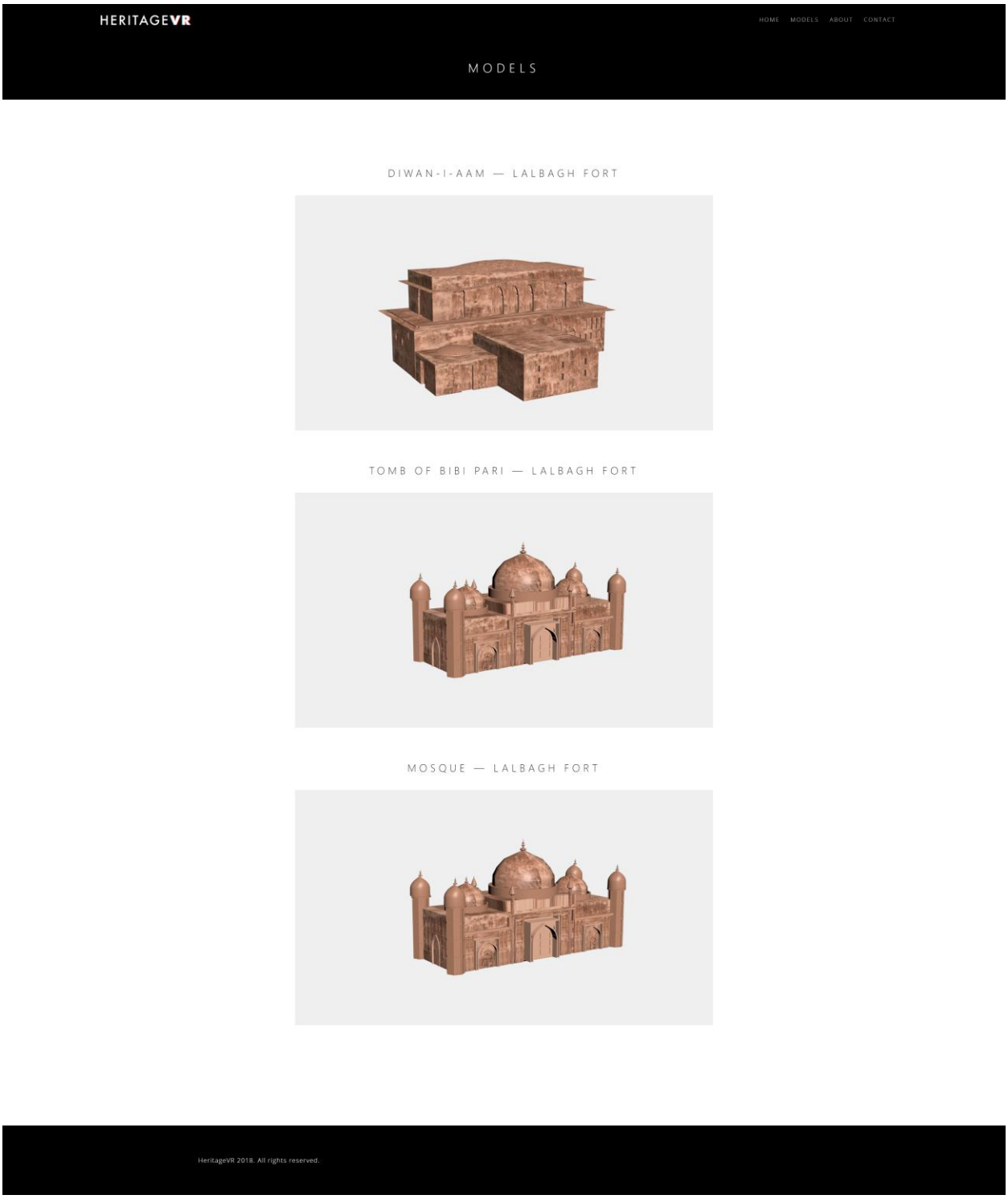

Figure 4.28 Models page of the website

CHAPTER 5
Conclusion

The use of consumer software, combined with Virtual Reality technology described throughout the paper is going to build a promising technique in order to produce scalable 3D models for multiple purposes such as conservation and presentation, as well as documentation and research. Although this process turned out to be more time consuming, the accuracy of the data collected so far using this technology, and the calculated costs and expenses to implement it show that 3D modeling of the cultural heritage sites of Dhaka using this technology will serve our purpose of preserving and making them available as an immersive and interactive Virtual Reality experience as well as in a regulated repository. Our website serves as a platform to showcase the heritage sites of Dhaka and shows 3D animation of the Shahid Minar, the Greek Memorial and the buildings of Lalbagh Fort, which include The Tomb of Pori Bibi, The Diwan-i-Aam and the Mosque. Moreover, our Android application gives access to our users to experience looking at the models of Lalbagh Fort in a VR environment.

5.1 Limitations

Even though 3D modeling technology to preserve heritage sites has proved to be more convenient and cost-effective compared to the other modeling techniques, the process is very time consuming. It takes a long time to construct and render a particular model. Furthermore, it was difficult extracting the exact texture from the photos and mapping it onto the rendered models. Therefore, the resulting structure lacks precision in terms of detail and texture. Increasing the level of detail, however, requires more time and makes the overall model more critical. Nevertheless, our future work involves overcoming these limitations and creating models better models.

5.2 Future Work

In the future, we plan on including more models of Dhaka city and archive the whole city in our digital repository. We also want to achieve and bring about more precision and photorealism in our 3D models. Not only will it enhance the outlook of the model but will also elevate the

geometric accuracy. Furthermore, we want to incorporate model façade detail, which will be ideal for street level viewing, and terrain model for achieving visually attractive 3D models of the historical establishments of Dhaka city. In order to cater to more smartphone users, we also intend to create a similar application for the iOS platform and add features for Oculus and Daydream users. Overall, we want to create a more interactive application for our audience by using Augmented Reality that would lead to better user experience.

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