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A Fictional Virtual Museum in A Responsive Web Design

MSc Project Dissertation

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Abstract

This project involves designing a responsive web site which represents one of the popular virtual museum designs. The concept of virtual museum is based on fictitious mythological artefacts, instead of replicas of the real exhibits. The models and an animated showcase scene of them were designed in Autodesk's 3DS Max 2017. Designed 3D models were displayed on the web page in X3D format by the use of X3DOM technology. HTML5, JavaScript, PHP, JQuery, AJAX and CSS3 technologies were utilised in an MVC (Model, View, Controller) based system framework to provide interactive updates on the page, responsive page design and manipulations on the models. The combined use of these or alternative technologies has already shown that, media-based systems on web pages can change old methods or offer very attractive alternatives, in terms of cultural heritage transmission in the near future. Along with this, in this study, it has been proven that current web technologies can also offer further virtual museum solutions such as fictitious concepts. With the popularity of VR and AR systems, fictitious virtual museum concepts may be more popular soon.

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1. Introduction

Museum collections are the source of the public enlightenment with their educational and cultural contributions to society. However, large collections and some of their precious items do not have the opportunity to be exhibited due to the lack of space in the museums, the excessive cost of maintenance or the fragility of the artefacts. A previous research conducted in 2002 and a survey to European museum industry showed that the technologies such as World Wide Web and 3D visualisation tools could offer a solution to solve these problems [15, 33]. Furthermore, the integration of Augmented Reality (AR), Virtual Reality (VR) and 3D Web technologies benefit cultural artefacts, such as their preservation, distribution and presentation. Augmented Reality (AR) is created by placing computer-designed 2D or 3D objects on a real-world infrastructure, whereas Virtual Reality (VR) represents a completely artificial world which is not real. Web3D is used to represent XML applications, and VRML is used to deliver interactive 3D virtual objects to 3D virtual museums [22]. Previous studies have used 3D multimedia techniques to turn into archaeological ruins into computer graphics, design and visualize them [30]. It also provided interactive AR guidelines for images on cultural heritage sites [11]. Some research has even shown that 3D technologies provide many opportunities such as protecting the museums or opening them to public access. These innovative technologies are not only preferred for their popularity, they offer an enhanced experience to visitors with all these benefits. And it accomplishes this in an innovative, engaging and low-cost way. Virtual museum exhibits allow artefacts in a museum to be presented in a real museum environment or via the World Wide Web. A system called ARCO has been developed to address these problems [18].

In recent years, with the evolving technology, 3D virtual spaces have become more widely used. It is especially frequently used by some cultural organisations and independent companies for educational and entertainment purposes. Though restrictions or things that can be done in this area are not yet clear, technologies such as 'virtual reality', which is rapidly evolving with the advancement of the technology, offer considerable diversity and progress.

The subject of this project 'virtual museum' is a subcategory of 3D virtual spaces and can often be presented as a copy of an actual museum or as an imaginary museum design. For a virtual museum, although there is not a generally accepted exact definition, it could be said that the presentation of a number of digital 3D objects which have some similar features through various media types. Thanks to its easy accessibility and the digital features it offers, it has gained a more popular place over time than the traditional museums. Accessibility from all around the world without needing any specific physical location is also one of the reasons of its rising popularity [23].

Now, virtual museums can offer access to their presentations and exhibitions online at their websites. And this is especially preferred for the objects which are impossible to exhibit or too fragile. A recent study has shown that around 75% percent of the virtual museum visitors expect to find exhibitions at the web sites. Again, in the same research it is stated that 87% of people hope to be able to find pictures on museum web sites [4].

In this study it is aimed to design and develop a mobile first web 3D application. This 3D application is based on a 3D Virtual Museum theme.

1.1. Background

Today, Virtual Museum implementation systems range from simple multimedia presentations to more detailed and complex systems. The virtual museum designs which are based on projection or immersive virtual reality technology being developed in recent years, offer probably the most interesting experience for now. However, the number of these systems which uses the latest

technology is limited due to their excessive cost. Cave at the Foundation of the Hellenic World and the Hayden Planetarium's dome-projection system are some good examples of these high-tech systems. On the other side, there are virtual museum systems that can be viewed even on low cost computers, with internet access. Users can interact with 3D objects and control the 3D models of objects. Good examples of such virtual museum systems are located in the web sites of The Hermitage Museum, Tower of Pisa and the Louvre Museum. Apart from these two categories, there are also mid-level virtual museum solutions which are more affordable but also more effective. These systems are equipped with desktop virtual reality systems, high resolution or 3D glasses supported monitors and shutter 3D glasses [21].

The virtual museums offer engaging and entertaining exhibit for visitors. In addition, there are other motivational factors for designing such systems.

- Since there may not always be enough space in a museum, sometimes the pieces that the museum has might not find the opportunity to be exhibited completely. Moreover, some objects can be very sensitive and valuable to exhibit in a real space. In such cases, the stored pieces can be exhibited in accordance with the actual museum context with a virtual reality presentation.
- Such systems may be used to provide visitors with a historic environment that is not currently available, to provide a museum experience that is damaged or being restored, or to present objects in an environment that is not adequate to easily navigate because of the internal conditions.
- These systems can be used for presentations of environments that can endanger the safety of visitors or are too remote for transportation, such as traveling in a volcano or visiting environments on other planets.
- Mobile accessibility allows a system that has been converted into its digital replica to be easily transferred to any exhibition area or to a remote location. This helps to ensure that the exhibition reaches a wider audience without the need for physical access.

In addition to all these advantages, there are also some difficulties in designing a public virtual environment, such as expensive equipment, the experimental and sensitive devices to museum environments and sensitivity of some visitor to virtual simulators, etc [21].

1.2. Problem Statement

In accordance with the mentioned virtual museum concepts and methods, it was aimed to design an interactive and informative virtual museum. The current virtual museum examples are mostly developed as a replica or as an addition of real museums. However, in this project, instead of designing a replica of a real museum, it is aimed to design a virtual museum with mythological objects which come from mythological history. The project consists of several sacred items, such as weapons, wands or armours which belongs to mythological characters and gods. These characters come from several different ancient beliefs and the items they used became their symbols in time and represents the characters' personalities.

The use of these sacred objects offers an instructive web environment about the origins of the objects which symbolises the divine beings in mythological beliefs by laying them out in a 3D virtual museum environment. By offering these models accessible on a web page and collecting these diverse cultural heritages in a single environment for visitors, it is aimed to indicate the similarities and differences between diverse cultural heritages.

1.3. Objectives

In order to carry out this project design, some primary and secondary objectives are required. These objectives are the minimal elements which are necessary for the application of the project and the possible objectives that could be added to the project secondarily.

1.3.1. Primary Objectives

I. An interactive virtual museum environment will be developed which presents mythological sacred weapons in a sleek 3D application layout

II. The gallery page will include at least 5 object models in similar level of complexity (6 models are included in this project) and these models will be in a mythological theme. The theme is based on the symbols (mostly weapons) of gods from various parts of mythological history. Each model will have a metadata which includes model descriptions and a brief historical information of it.

III. These models will be integrated into a virtual gallery which will be the virtual museum.

IV. There will be an appropriate level of interactivity on the 3D models. This will be achieved by using X3DOM's VRML Helpers and some JavaScript or JQuery code.
   - X3DOM inline will be used in HTML5 for more flexibility and manipulating items by using JavaScript or JQuery codes in gallery page.
   - NavInfo VRML97 helper will be used to set up the navigation. Its parameter will be set to 'Examine' to be able to examine, rotate and zoom the 3D model in gallery page easily.

V. The web site will have a homepage with an animated video of the included models to welcome the visitors, a gallery page to showcase the 3D models and an about page which includes a download link to VRML models, textures and documentation.

VI. Each model will have 2 different camera angles and there will be a button panel to switch between them.
   - There will be a button for wireframe mode for models. JavaScript or JQuery code will be used to implement this function.
   - There will be another button to turn on and off an extra headlight.
   - There will be a model pane to load a new model in the gallery page. This will be implemented by using AJAX and JSON (or XML instead) with JQuery (or JavaScript) to load the models in the gallery page dynamically. The model packet will be supplied by the backend.

VII. The 3D App layout will have a couple of responsive block elements. These are
   - A header element which will be stylised in CSS3.
   - An X3DOM inline method for displaying the selected 3D object.
   - Buttons for 2 different camera views, controlling headlight and wireframe mode and a method which will be implemented JavaScript or JQuery for interacting with the 3D models.
   - A method for descriptions of the displayed model. It will be activated when a new model is invoked.

VIII. A model, view, controller (MVC) design pattern will be implemented in the virtual museum theme.
   - An AJAX code will be implemented to update the 3D content asynchronously by the use of controller between the view and model.
   - A PHP script will be used to access the data.
   - The metadata (titles, descriptions and brief histories) of the models will be stored in the model part of MVC pattern (a database simulation in the model class in XML format).

1.3.2. Secondary Objectives

I. Duplicates of the models could be used secondarily to exhibit them in different variants, changing their textures, adding them extensional parts or changing their shapes, etc.
II. Touch Sensor VRML helper could be implemented to trigger a prepared demo animation with onClick method for each 3D model.
III. Several optional textures and a texture switch button could be added for each model to swap textures and exhibit them in various looks. Or instead, a texture selection pane could be added which could include optional textures to swap the texture of active 3D model.
IV. Several control buttons could be included, such as left, right, top and bottom. However, this is left as a secondary objective to avoid too much complication, because two camera buttons, a lighting button and a wireframe button are already included as primary objectives.
V. Theme change button could be added for 3D objects or page background.
VI. Some other media elements could be added to improve the user experience, such as audio and model change effects, etc.
VII. SQLite could be used as storing metadata and an admin page could be provided to create, read or update content. However, an XML structure implemented to store metadata of 3D models.
VIII. The metadata section could contain more comprehensive and deep historical information about the models and owner characters of them.

2. Requirements

The requirements are the essential needed elements which shape the design.

2.1. Requirements Gathering

Museums are visual and informational environments which are used for educational purposes. They allow the transfer of cultural heritage to new generations. They contribute to the cultural development of the society by ensuring that new generations are informed about the cultural heritage. The virtualization of these institutions which can have a significant contribution to education will undoubtedly contribute to the forms of in-class and out-of-class education. Museums has begun to deal with educational environments for various age groups; such as universities, schools and teachers. These collaborations have spread widely in various groups. These are, from the universities which provide technological consulting to small museums, to educators who prepare their own modules, etc.

Education is no longer considered as age related. It covers every group of people from pre-school children, to out-of-school and even senior citizens. At this point, a lifelong definition of learning which covers a wide group of audience will have particular importance for virtual museums. Because the visitors of a virtual museum do not belong to a particular geography mostly and they are potentially higher in number and more varied than real museum visitors. In addition to these, it is possible to identify the specified subgroups of learners and their learning needs based on functional requirements [7].

From this knowledge, it could be said that virtual museums focus a very wide range age group. Although it is mostly used for educational purposes and contributes to conveying cultural heritage to students and young people, it can also be used for exhibition purposes with its visual characteristics and the information it contains. This indicates that it has a focus group for people of all age groups. Given this information, the features that a virtual museum should possess are roughly derived.

Firstly, one of the most important feature of a virtual museum themed web site might be the home page of it. The visitors arrive this page first and it should give an idea about the concept of the museum. An animated scene or a video and a sound element with them could be a proper welcome for the visitors. It should not take too long for the homepage and frequently used navigation pages to load to keep the user experience fluid [5]. Secondly, in the gallery section, which is actually the main section of a virtual museum, there is a need for elements that can attract attention of the target groups and fulfil the educational and exhibition functions of the museums. These are basically, an X3DOM panel in which the model is exhibited, a model selection pane to swap the between other models and an informational html div where the information displayed about the model such as the name of the selected model and a brief information (such as names, origin, its age, etc.) about it. This section could be expanded according to the purpose of the museum and its style, or it can be directed to different pages for more detailed information. However, because of primary purpose of this work is to exhibit the sacred weapons of the gods, the metadata is kept short and simple in this study.

2.2. Requirements Analysis

In this section, some experimental methods will be mentioned to evaluate the functionality of the project. In order to observe its experimental functionality, 'personas' will be classified and potential 'use cases' will be mentioned which are related to the website. In this project, the user experiences that visit the virtual museum website will be discussed.

2.2.1. Personas

The purpose of the personas is to create representative groups that reflect the communities of target user groups. These representations should be made according to some qualitative and quantitative web analytics and user research. Personas help focus on the target ideas between the site components and adding appropriate new layers according to the real-world experiences. For the development process, they can also be a quick and cheap way to test site features. The intention of the personas is not to represent all visitors or determine all the needs of the web site. Instead, it targets the needs of the most important user groups [34].

To classify the personas for a site, it is needed to define ‘the purpose’ and ‘the goals’ of the site. These questions for this project have already been answered in the introduction. However, to remember briefly;

- The purpose of the site is to exhibit some sacred weapons which are believed to be used by some divine beings and gods. This is presented in a mythological virtual museum concept.
- The goals of the site,
  - To exhibit the 3d models of these fictitious prehistoric objects which could be accepted as historical artefacts to visitors,
  - To give brief information about the gods who used these objects and their mythological histories.

Persona Groups

Young Person

Personal Information

- This group of personas could be set between 12-17 years old. A research was published in 2010 which is based on the research data gathered between 2000-2009 about internet usage between several age groups. According to the study, young people between the ages of 12-17 is the first group among others on internet usage with young adults which are between the ages of 18-29. Both groups share the same percentage which is 93% on internet usage [20].

- This user group can have any gender.
- The level of education expected usually pre-university, it covers primary school, secondary and high school.

Professional Information

- Work experience and professional background in this age group is usually not expected.
- People in this age group usually come to the web page for educational purposes. They may be encouraged to visit the site by their parents or classroom teachers who wish to contribute to the child's cultural development. In addition, reactions and ideas of this age group can be evaluated by providing a short trip on the web site to inspire some ideas and enthusiasm about the things that can be done with current 3D supported web technologies.
- This persona can be informed about the site or similar programs, from their teachers or parents as mentioned above. In addition to this, they may also encounter in the internet while looking for samples related to virtual museums or websites which includes X3DOM models.
- The website can be accessed at anytime and anywhere from this persona.

Technical Information

- Again, according to the study mentioned above, 58% of American children aged 12 years old own mobile phones. In addition, 75% of American teenagers aged between 12-17 have mobile phones. Since 2004, age is the most crucial factor in predicting the use of mobile phones. Furthermore, 69% of young people aged between 12-17 have a computer. Again, in the same study, the percentage of the internet accesses using the devices they own among the 12-17 years old teenagers were obtained as; 93% for desktop or laptop computers, 27% for mobile phones, 24% for game consoles and 19% for portable game devices [20]. Based on this information, young people between the ages of 12-17 still prefer to use laptop and desktop computers for accessing the internets, although mobile phones are portable devices and more popular than computers among this age group teens.
- The person may be using various applications, but because of their regular basis device they use are mobile devices, the applications they mostly use would be mobile applications.
- Since the devices they regularly use and have access to are mostly mobile devices, they will be used most frequently when accessing information. However, in education they also have access to computer laboratories, so they can also access the information using desktop computers.
- According to the survey, which explores the use of internet among young people, 63% of teenagers use the internet every day. 36% of them access to the internet several times a day and the remaining 27% access to the internet once a day. 26% of teens access to the internet once a week and the remaining 11% use the internet less frequently [20].

Adult Person

Personal Information

- Persons representing this persona may be 18 years old or older any age. However, since the use of the Internet is noticeably reduced over the age of 65, it can be considered as the upper limit for much cases, to be more efficient on the usage data.
- Different genders have no impact on site access for this age group as well.
- One of the most distinct differences that distinguishes visitors in this group from the others is their level of education. Especially the wide range of education level will lead to the inability to make a very detailed deduction from the level of education for this persona. A person who has graduated from the high school, academics with expertise on the subject, and even professors can be included within this group.

Professional Information

- It is expected that people in this persona group usually have work experience. Although this experience is not always in an area which is related to web technologies, a more conscious visitor group is expected in general.
- Theoretically, a professional background covering large area is expected. However, in general, people who are interested in virtual museums, history, art and cultural heritage or 3d internet technologies are expected.
- People who are considering visiting the website in this persona group often visit this kind of websites for their interests and hobbies. These may be people who like to visit museums in real life, who are interested in cultural heritage, or who are interested in history and prefer to interact with mythological items in a virtual concept. Moreover, this persona may be a computer programmer, a web designer or a student. Or, just someone who interested in 3D modelling and embedding 3D objects into web interfaces.
- This user group can access the information about this website from web pages which contains lists of virtual museum examples, the pages which contains examples about 3D modelling or simply search engines.
- The website can be accessed at anytime and anywhere from this persona.

Technical Information

- According to the research (Social Media & Mobile Internet Use among Teens and Young Adults), 83% of all age groups (between 18 and 65) use a mobile phone, 58% use a desktop computer, and 46% use a laptop computer. From this information it can be deduced that a very large proportion of adults, including all age groups, are using mobile phones on a regular basis. In addition to this, nearly half of adults are using computers regularly [20].
- It is mentioned that wireless devices and game consoles are a new and alternative way of accessing the internet. For adults over 30, the rate of having a game console is lower than for young adults or teenagers. And the gender difference in this area is evident; while the percentage of men having a game console is 39%, this rate is 34% in women [20].
- Many adult internet users use more than one device to access the internet, especially for Internet users under 50 years old. For users aged between 18-65 years old, the rate of multiple device use for internet access is 63%, while for users between 18-50 years old it is 70%. 54% of these adults prefer to use the wireless connection to access the internet. Among them, 38% use a laptop for internet access [20].
- Although the Internet now provides access to nearly every kind of service, in recent years people in almost every age group are accessing the internet for social media use firstly. In a study conducted by the Pew Research Center, the use of social media among adults was 7% in 2005, but with the rapid developing technology, it reached 65% by 2015. On the other hand, among the young adults, social media use is much more common, and it decreases with the increasing age. According to 2015 data, social media usage rate which is 90% in the 18-29 age range, drops to 35% about the age of 65 [9]. The reason for examining the rates of social media use for this persona is that social media usage is directly linked to internet access. Current researches are mostly targeted to social media usage and people who may be interested in virtual museums are most likely among these social media users. Adults also use almost all kind of social media applications such as teenagers, when they go online. However, adults, unlike teenagers, use Twitter more commonly than young people [20].
- According to the study published by the Pew Research Center in 2010, the rate of device use among adults is as follows. Among all adults, the percentage of having a mobile phone is 83%, the rate of having a desktop computer is 58%, and the rate of having a laptop computer is

46%. This data was generated by taking the average of the percentages given to all adults for men and women [25].

- Regular Internet use among adult users is slightly lower than young people. According to the September 2009 data, 68% of all adults every day, 21% of them several times in a week and 10% of them access to the internet less frequently.

Table 1: Example Personas

Persona	Young person
Photo	An example profile photo
Fictional Name	Tom Goodwill
Job title/major responsibilities	Primary School Student, Coombe Road Primary School
Demographics	• 10 years old • Lives in Brighton, UK • Lives with his parents • Has a brother and sister
Motivation	He is a hard-working student with a good concentration. His aim is to continue his education by successfully passing his modules with high grades. Spends his time in school: • Participating in classes and taking notes on what is taught in class, • Completing his homework that given in the school and delivering them in time, • To pass exams successfully during the semester by studying regularly.
Goals and tasks	• He is interested in technology. • He likes to explore new web sites. • He likes to surf the Internet and discover new web sites. • He likes to find out new websites which can offer him a virtual museum experience.
Environment	He has a mobile phone and owns a desktop computer at home. He has a LTE data package in his mobile phone and has a terrestrial internet connection at home. He regularly uses his mobile phone, but also access internet from his computer to study for school and complete his homework. He usually spends 2 hours a day online and uses social media applications.

Persona	Adult person
Photo	An example profile photo
Fictional Name	Chris Greenwell
Job title/major responsibilities	University Student, University of Sussex
Demographics	• 19 years old • Lives in Brighton, UK • Studying Computer Science BSc • Lives with his family • Has a sister

Motivation	He is a well-motivated undergraduate student. His aim is having his BSc graduation by passing his modules with high grades as much as possible, and starting to study MSc on Advanced Computer Science. Spends his time in university: • Participating in lectures and lab sessions, taking notes to prepare projects and coursework, • Completing his assessments and submitting them online in time, • To pass modules during the semester by studying regularly for his exams.
Goals and tasks	• He is interested in museums, art and history. • He wants to visit museums virtually without going out of his home. • He likes to have visual and historical knowledge about mythology. • As a computer science student, he is interested in web technology and wants to widen his knowledge about it by discovering virtual museum web sites.
Environment	He has an Android mobile phone and owns a Mac notebook and a Windows desktop computer at home. He also has a tablet and a game console which can access to the internet. He uses a mobile data package outside with his mobile phone and uses an unlimited fibre internet plan at home. He uses his mobile phone constantly, but he also accesses to the internet from his laptop and desktop computers, especially to study for his modules and complete his programming projects / writing his reports. He also uses his tablet and game console to surf on the web from time to time. He spends at least 5-6 hours a day at the computer and mostly goes online. He rarely uses social media applications.

Persona	Designer
Photo	An example profile photo
Fictional Name	Walter White
Job title/major responsibilities	Web Designer,
Demographics	• 32 years old • Lives in New York City, US • Married • Has a daughter
Motivation	He is a web designer in a private company. His aim is: • Understanding customers' needs and requests. • Designing a user interface that allows users to navigate easily and find what they need quickly and efficiently. Spends his time at work: • Designing user friendly and stylish web pages. • Preparing the appropriate designs for his customers. • Increasing site and application functionality by writing code.

Goals and tasks	• His likes to visit a website from his home which exhibits historical 3d models in a virtual museum concept. • His goal is to improve his designing knowledge by examining web sites that equipped with 3d models. • Inspecting new models with a designer's eye, and getting inspiration from other works and models.
Environment	He has a mobile phone and generally works on a MacBook at his workplace. He also has laptop computer to carry around, a tablet and a game console. All these devices can connect to the internet; however, he only uses his MacBook and laptop for professional works. He spends at least 6 hours online in a day at work. Apart from this, an average of 2 hours he goes online at home. He regularly uses social media applications.

2.2.2. Use Case Scenarios

Use cases are written descriptions of what tasks users are performing on the web sites. It specifies the behaviour of a system from point of view of a user, as the respond of the system to a request. Each use case is represented by a sequence of several steps starting from the user's aim and ends with the fulfilment of the user's purpose [34].

Use cases add value to a system by exemplifying how it will behave during process. It also helps to uncover problems when something goes wrong. Costs and system complexity can be measured based on the list of objectives provided. According to these, the project staff determine what functions are required and what they need to include in the design [34].

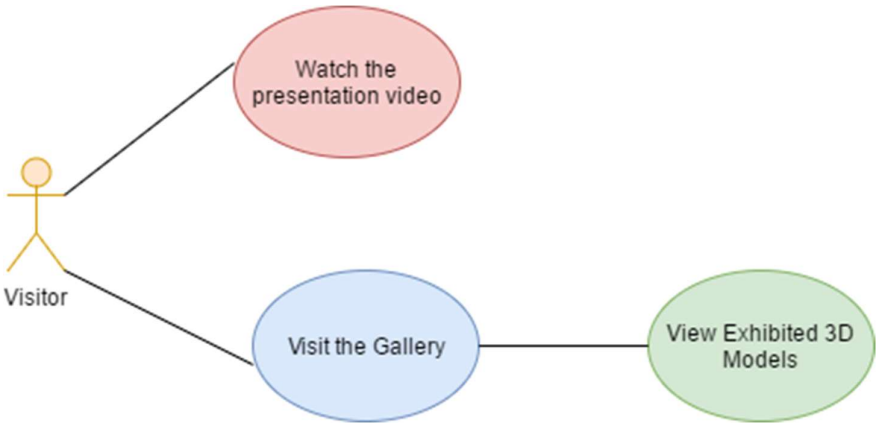

Figure 1: Virtual Museum UML use case diagram

Table 2: Example Use Cases

User	Tom Goodwill (young user) is using the website.
The user's goal	The aim of the user is to visually examine the 3D models on an online website.
User steps	• In the process that a user must pass to examine a model, first opens a browser and type the address of the site into the address bar to come to the home page.

	• Alternative flow: If he wants to watch the presentation video which is a short brief of the models, he will click the play button and the website will start to play the video as a response to the user's action. • After watching the welcome video in the homepage or skipping it, he clicks on the gallery link from the navigation bar and enters to the gallery page. And the website loads the gallery page as a response to the user's action. On this page the first model will already be loaded automatically. • After visually examining the first model with the help of the mouse, he switches between the different camera views by clicking the "Camera 1" and "Camera 2" buttons. • Each time when these buttons are clicked, the website responds to the user by changing the active camera angle with a predefined camera angle (Camera 1 or Camera 2). • Then he clicks on to the "Lighting" button and the headlight will be enabled which reflects more light onto the model. • Finally, he clicks the "Wireframe" button multiple times and sees the inner structures of the 3d models. This button has 3 different modes and requires a total of 3 clicks to return to normal view of the model. The user clicks the Wireframe button 2 times to be able to activate the 2-different wireframe mode and each click changes the wireframe mode as a respond. Clicking third time on to this button will activates the normal appearance of the model again. • After completing these steps that can be followed for any other model. He selects a different model from the model navigation pane and follows these steps again in the same order or in a different order.
Website's respond to an action	• The system responds instantly to user actions and process or brings the relevant data to the user with the clicked button or link on the website. In the user's goal section, the system's responses are also given along with the path the user follows.

User	Chris Greenwell (adult user) is visiting the website.
The user's goal	The goal of the user is to get a variety of information by navigating on a museum web site that offers a virtual experience to the user.
User steps	• The user visits the website and comes to the homepage first. • To watch the welcome video which includes a brief presentation of the models at homepage, he clicks the play button on video frame. • When the button is clicked, the video starts playing by the website's respond and the user watches the video. • Then the user clicks the gallery link from the navigation pane to navigate to the gallery and examine the 3D models, and the gallery page is loaded as the website's respond. • While the user is examining the model, he can rotate the model by using his mouse. The X3DOM interface reacts instantly to these user interventions. • Using this interface, Chris first examines Mjöllnir and clicks on the 'Wireframe' button to see the skeletal structure of the model. • The Wireframe button shows the skeleton structure of the model. Chris then clicks on the 'Lighting' button to see the details of this

	skeleton structure, and the web page responds with a headlight. He examines Mjöllnir's skeletal structure better under this light. • Chris clicks on Sword and Shield from the model pane to examine a different model. The system responds by changing the displayed model, the model name, and the description. When Chris sees the name of the model, he recognises that this Sword and Shield model is representing the symbols of Ares and this attracts his attention. Then, Chris learns the brief history of this fictitious model by reading about it from the model definition panel. • Chris examines the Ares' sword and shield model in 3D by using his mouse. After examining the model by using his mouse, Chris clicks on the Camera 1 button to return the camera angle to an appropriate angle again. • Respond: When Camera 1 button is clicked, the system returns to the pre-set camera angle, which was active when the model was first loaded. • Since Chris is also interested in mythology and history, he reads the item descriptions in the gallery page while examining the models.
Website's respond to an action	• The system responds instantly to user actions and process or brings the relevant data to the user with the clicked button or link on the website. In the user's goal section, the system's responses are also given along with the path the user follows.

User	Walter White (web designer) is visiting the website.
The user's goal	The intention of this user, unlike the others, is to examine the 3d models primarily on the site from a designer's point of view.
User steps	• The user visits the website and comes to the homepage first. • To see the models, without browsing the home page he clicks on to the gallery link directly from the navigation pane. • The system loads the gallery page and the first model is automatically brought to the screen. Starting with the first model, Walter decides to examine all the models in turn. • He clicks the interaction buttons (Camera 1, Camera 2, Lighting and Wireframe) in sequence, after examining the first model by rotating it with his mouse. • Each time these buttons are clicked, the system instantly changes camera angles, lights up the top light, and shows the inner structure of the model. • Walter then clicks on the other models in turn from the model pane to examine the other five models on the page, and each click brings the clicked model to the X3DOM pane. • To examine all the models, he clicks the buttons in the interaction section for all other models in same order, as he did for the first model. • …
Website's respond to an action	• The system responds instantly to user actions and process or brings the relevant data to the user with the clicked button or link on the website. In the user's goal section, the system's responses are also given along with the path the user follows.

2.3. Requirements Specification

In this section, the requirements of the users are derived, based on the use cases defined in the previous section. The requirements of these users are listed in the 'User requirement specification' table according to the use cases they correspond to. The primary objectives that are intended during web page design, represent essential requirements.

The primary objectives that are planned during the design of the system represent the essential requirements and the secondary objectives demonstrates the desirable requirements.

Table 3: User requirement specification

UR	UC	Description	E/D
UR1	UC1	The virtual museum website should have a presentation video on its homepage.	E
UR2	UC1	Online visitors should be able to access 3D models in a well-designed gallery page.	E
UR3	UC1	The gallery page should have an interaction pane that contains buttons that allow the user to easily interact with the 3d model.	E
UR4	UC1	There should be camera buttons (or equivalent feature) that can switch between at least two pre-set camera angles in the Interaction pane.	E
UR5	UC1	There should be a light button in the interaction pane in the gallery.	D
UR6	UC1	There should be a wireframe button that allows visitors to view the inner structures of 3D models.	D
UR1	UC2	There should be a welcoming and descriptive video on the homepage of the website which presents the models in the gallery.	E
UR2	UC2	Users should be able to examine 3d models easily in a pane which is located on the gallery page.	E
UR3	UC2	Users should be able to view internal structures of objects.	E
UR4	UC2	Users should be able to easily switch between other models in the gallery page.	E
UR5	UC2	Users should be able to easily switch between different camera angles using the provided camera buttons in the interaction pane.	E
UR6	UC2	The user should be able to see the names of the designed models while examining the model.	E
UR7	UC2	The user should also be able to get basic information or a brief description of these models on the same page.	E
UR1	UC3	The user should be able to examine 3d models on a gallery page to get an idea of the model designs.	E
UR2	UC3	The user should be able to navigate easily between the models.	E
UR3	UC3	The user should be able to interact with the models through the provided interaction buttons.	E

Key: User Requirement (UR), Use case (UC), Essential/Desirable (E/D)

3. Design

It is aimed to design a 3D app which is based on X3DOM. The main purpose of the application is based on this technology. Without the need of any plugins 3D models can be displayed interactively on web

pages thanks to this technology. Along with X3DOM, technologies such as HTML5, CSS3, JavaScript (and JQuery which already is a JavaScript API), PHP, XML and AJAX and a Model View Controller (MVC) pattern are among the requirements for this project. And finally, 3D models that are designed to be accessed through the gallery interface that makes up the main part of the design.

The site is basically designed as a responsive mobile web page. This ensures that the site is displayed correctly on all devices. When the site is visited from different resolution devices, or when the size of the web browser is changed instantaneously, the interface will not interfere, and the site design will adapt to the new resolution without losing ease of use.

3.1. Design Practice

Design procedure, prototyping, utilised technologies and system framework is explained in this section.

3.1.1. Prototyping

Prototyping is the provision of a working model of the final software in the development process. The early feedback of the user group allows the software systems to be developed according to the needs of the user. Apart from this, prototyping is also very useful for tracking evolution of the system during the development. [5]

At the prototyping stage, to be able to have an executable system, many features weren't included except the fundamental features. These are,

- At the starting page design from scratch, only mobile device media query was included in the CSS to able to obtain a responsive design.
- Before AJAX implementation, in the gallery page, the "HTML <a> tags" (hyperlinks) are used to load the models. In this way, a separated HTML page was being loaded for each model.
- Later, in order to use AJAX, the gallery page was replaced with the PHP server script language, which allows to design dynamic pages.
- At this stage, the model metadata was also stored in HTML files.
- The presentation video in the homepage and the about page also were not available at this stage.

3.1.2. Front-End

The front-end section describes the HTML5 design that makes up the View part of the system. The structure of the View of the system is explained in this section.

Gallery

In the gallery page, mainly HTML5 tags are used. The page design consists of a set of div tags and the section tags are located within them. The gallery page is the main page that forms the basis of the web site. The main purpose of the design of a gallery page is to exhibit 3D models in a web based framework, which were designed in 3DS Max. To achieve this, X3DOM's inline node is utilised, which allows to load external 3D models or scenes in HTML based web pages. This feature also allows to manipulate the loaded models [37].

To display the X3D models, the X3DOM frame is positioned inside the "model_section" section to be displayed as 400px * 400px on the left side of the page. At the top of the X3DOM frame, 4 buttons are positioned that make up the "model_control" section. These buttons can manipulate the active 3D model by the aid of JavaScript. The "model_properties" section is located on the right side of the X3DOM frame. In this section, the title of the active model, the mythological culture it belongs, and the description of the model take place respectively. At the bottom of the "model_properties" section,

"model_thumbs" section was placed that will be used for fetching other models. At the bottom of these, there is a “footer” tag placed which has a small copyright note. All these sections belong to the “middle” div. On right top of this structure on the page, an unordered list is placed for in site navigation within the “nav” HTML5 tag. This list is located inside the "top" div. On the left side of this navigation pane, the "header_top" div is located which contains the title and the logo of the website. All of these mentioned divs and the sections within them constitute the "wrapper" div in the body tag.

Homepage

Homepage has a simpler structure than the gallery. The title and navigation pane the same as the gallery and the middle div contains a short presentation video. This video has been implemented with the video element of HTML5. With the video support of HTML5, videos can now be played on web pages without the need of browser plug-ins, such as flash, etc.

About

It can be said that the structure of this page is similar with the homepage except for the "mid" div. In the mid div, there is a description of the website, a link for downloading the model files, a link for a word file which contains the statement of originality and the references for everything used or inspired in the development of the site.

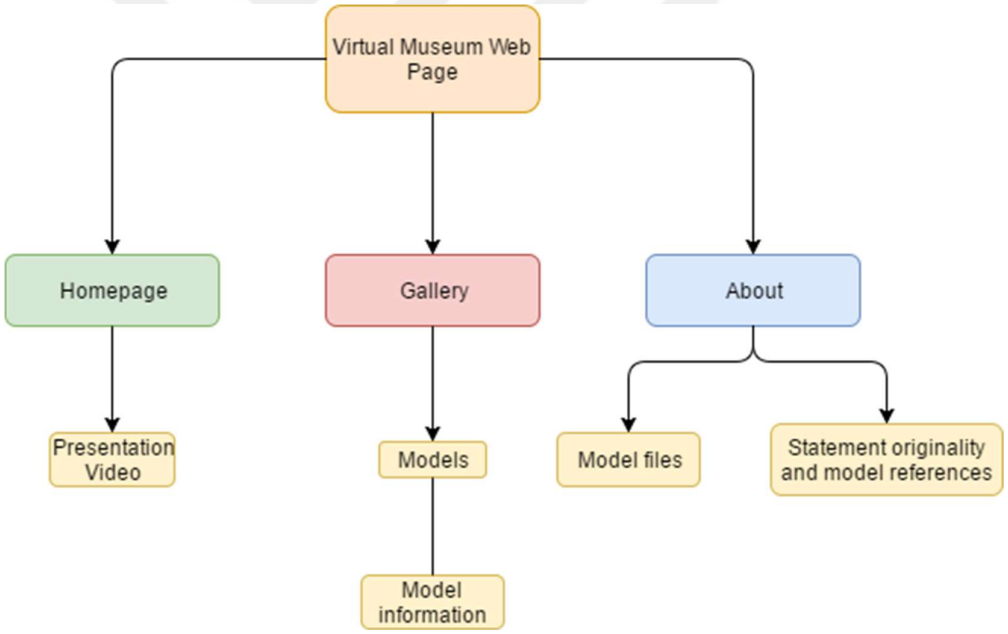

Figure 2:Website Architecture UML Diagram

3.1.3. Back-end

In this section the working principle of whole system is described. The handler function in the getModel.js is executed once when the HTML DOM is ready [17]. When the visitor clicks one of the thumbnail images of the changeModel class in the “model_thumbs” section of the gallery, changeModel method is executed. After resetting the current camera view with resetView method, updateUI method is invoked by the switch case according to received model ID.

updateUI method includes an AJAX function which is used to perform the asynchronous HTTP requests. AJAX requires technologies such as ASP, JSP, and PHP to perform asynchronous updates on pages, in this project PHP server scripting language was preferred. In the AJAX method; the request URL, request type, request data (model ID) and expected datatype from server response are specified.

The AJAX function sends a request to the controller.php and it is firstly checked if the ID is set in the submitted URL. If so, a new controller object is created and updateUIItem method is invoked from the Controller class. This method calls the getItemDetails method with the given item ID from the model.php. model.php file contains a getItemDetails method which is responsible for storing the metadata and echoing them to the AJAX function. Controller echoes the fetched data from model.php to AJAX method. Finally, AJAX method embeds the corresponding data into the View (gallery). Since the data to be used is not very large, instead of using an external database, the metadata is stored in model.php file in XML format. X3DOM models are updated in the View according to their URLs.

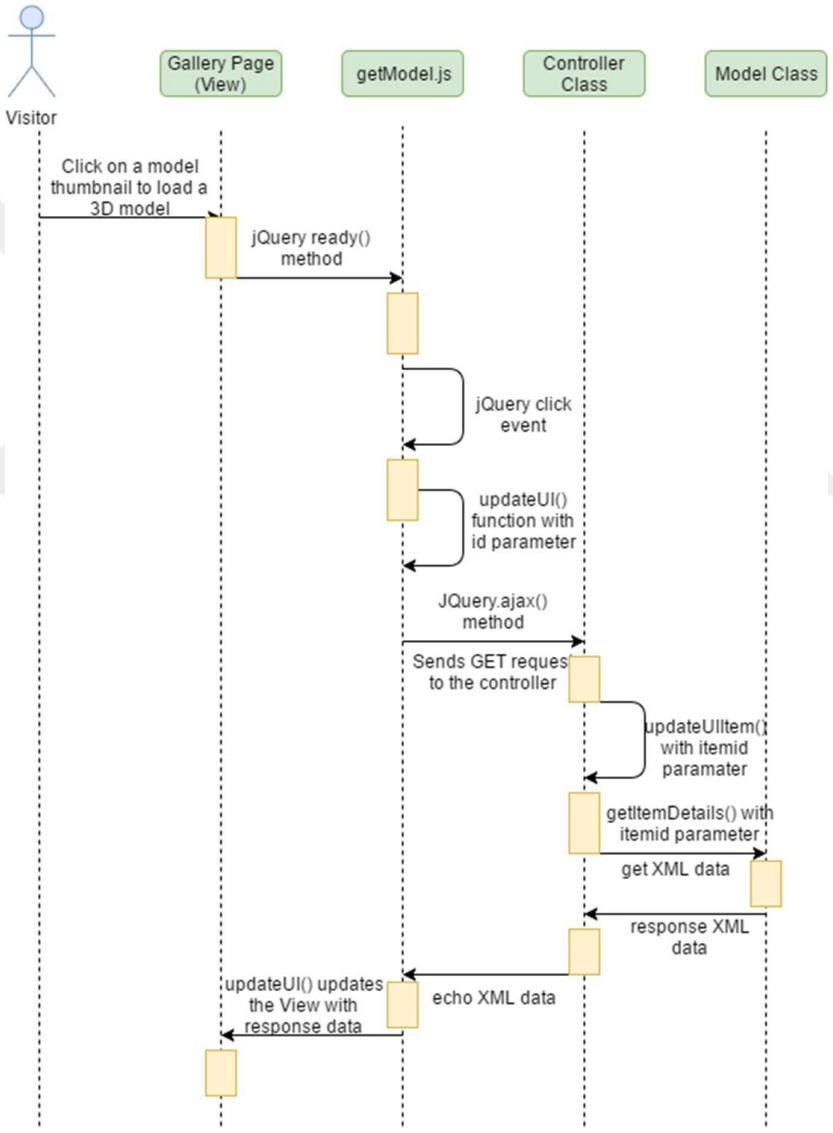

Figure 3: AJAX Sequence Diagram

3.1.4. MVC Framework

The MVC design pattern was first proposed by Trygve Reenskaug in 1970 at Xerox Parc. According to him, the MVC design pattern aims to bridge the gap between user model and digital model in computer system [19]. In years, it was realized that the MVC design pattern could provide many benefits in developing modular applications [2]. Isolating the functional units as much as possible

made it easier for application developers to work without having to know everything about the whole design [20]. The MVC design pattern is divided into 3 main tasks to ensure effective collaboration. These main tasks are development, design and integration [2].

The development task is undertaken by the software responsible for the application logic. They are responsible for data query, processing, validation and other tasks. Designers are responsible for user-friendly application and appearance. They display the data supplied from the developers [13]. The MVC design pattern is especially well suited for developing web applications because in such applications, more than one technology is often used in different layers [1].

The figure below shows the MVC components and the relations between them for a website design.

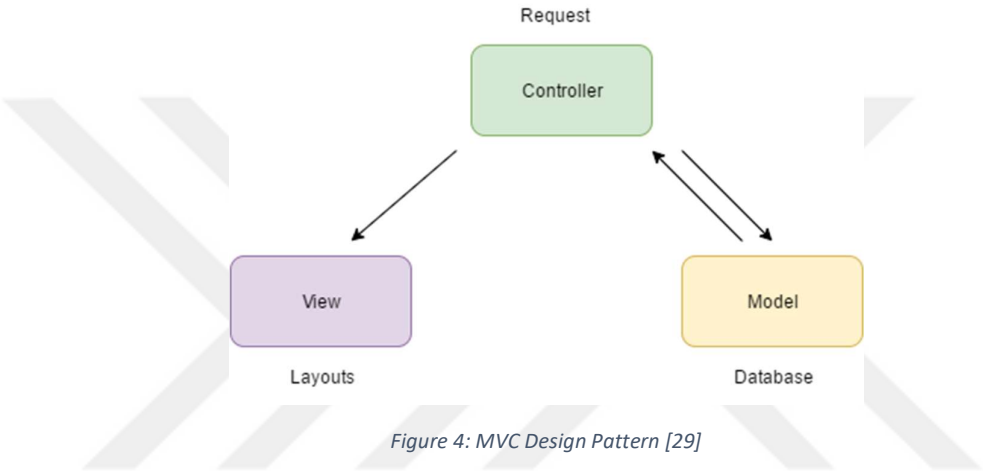

Figure 4: MVC Design Pattern [29]

Model

The model is the part of the system that manages everything related to data, validation, control and structure of data source. The model section reasonably reduces the complexity of code that software developers need to write [22]. The model is responsible for the business logic of the software. This business logic accesses the data and creates a reusable class.

View

View is responsible for the graphical interface in which the user interacts directly. It includes forms, buttons, visual elements, and all HTML elements. Separation of the application design into logical sections in this way, reduces the possibility of human error when a change has to be made in the user interface [2]. In other words, in an application that is divided into logical sections with MVC design pattern, user interface (the view) can be designed and managed much more easily.

A view usually called the web design part or template of the application. View controls how the fetched data is displayed and how the user interacts with it. View also allows to receive data from the user. In general, a view should not contain elements related to application logic. Otherwise, designers need to have knowledge about them and can work with these elements.

Controller

The controller is responsible for managing events that are performed by users interacting with the application. A controller receives the incoming request and prepares the corresponding data in a specific format to respond. It communicates with the model to fetch the requested data and generates the View. When a request arrives at the server, the MVC framework sends it to a method in the controller according to the URL [32]. The controller contains the application logic in it, collaborating with the model functions and the user interface in the view. It is used for fetching data from the View.

It provides a path to be followed for system operation [2]. The controller accesses the model function and shapes the received data to show in the View. Error handling is also performed by the controller [9].

To summarize, a controller arranges communication between View and Model layers. All of the data processing must be done at the controller level. It responds to user requests, and takes the data from the model, process it and sends to the view layer. In the View layer, the data from the controller is inserted into the interface and displayed to the user.

3.1.5. Utilised Technologies

CSS

To achieve responsive mobile web page design, CSS3's media query technique was utilised. Two different media queries, one for mobile and one for tablet layouts, are created in the format.css file and CSS properties located into these media queries for different screen resolutions. The points where these distinctions are, is called breakpoint [30]. In this study, two different breakpoints are defined as 500 pixels and 1024 pixels.

- Mobile layout: @media (max-width: 500px): Page design for browsers with a maximum width of 500 pixels (mobile devices). This field specifies the display of objects in devices with small widths from this resolution.
- Tablet layout: @media (min-width: 501px) and (max-width: 1024px): For devices between 501 and 1024 pixels wide, the styles specified here apply. This part is usually for tablets.
- Other than these two media queries, the sections also specify properties for browsers with a larger resolution than 1024 pixels.

When designing for these three target screens, it should be started from the mobile layout first and then the tablet and desktop layouts should be updated respectively. This allows the page to be displayed faster on small devices [30].

The design structure of the website consists of 3 separated pages. These are Homepage (index.html), Gallery (gallery.php) and About (about.html) pages. The most comprehensive part of the site is the gallery page where the models are presented. For this reason, the homepage and about sections have been left with the html extension, and the gallery has been converted to PHP for asynchronous updating of the page using the MVC framework. So, the MVC framework is designed on the gallery section.

Document Object Model (DOM)

The Document object model is a platform and language independent interface where programs and scripts can dynamically access and update content. Documents can be processed, and the results of the processes can be included in to the displayed page again. The combination of HTML, stylesheets, and scripts that can modify documents is referred as 'Dynamic HTML'. In this study DOM was used to manipulate the models on the page and to update the gallery content dynamically [8]. When a web page is uploaded, the browser creates the Document object model of that page, which can be used to make pages dynamic with the aid of JavaScript [14]. X3DOM technology is also composed from the combination of X3D and DOM technologies [36].

PHP

PHP is a server scripting programming language that allows for the design of interactive and dynamic pages. It is a free and effective language widely used on web sites [27]. There are several alternatives server scripting languages such as Microsoft ASP and JSP (allows to use Java codes in web pages); but PHP is preferred because it is free and open source.

3.2. Methodology

Different development methodologies are followed during the development of computer software systems. A software development methodology specifies the framework to be followed during the software development process. The software is planned, managed and controlled according to this framework [13]. A software development methodology is known as the Software Development Life Cycle (SDLC) and is also used for several other engineering branches besides Computer Science [31]. Waterfall, incremental, spiral, agile software development and rapid prototyping are some examples of current methodologies. All SDLC models have basically similar features. These are the steps that the designer must follow and take some conclusions accordingly. As a result of these steps the final product is shaped [2]. This project was developed based on Waterfall model, which is one of the first SDLC models. The waterfall model consists of 5 consecutive steps. These are requirements, design, implementation, verification (testing) and maintenance. Following the sequence of these steps is important. During the development process, following sections have been followed.

3.2.1. Requirement Analysis

In the first part of the Waterfall model, a detailed description of the software to be developed is made. The project manager communicates with stake holders to determine functional and non-functional requirements. Functional requirements include purpose, scope, function, perspective, interface, use characteristics and database. Along with this, non-functional requirements represent criteria, limitations, constraints and software performance [3].

3.2.2. Design

In this section the user's requirements are divided into logical fragments for implementation. Then, software and hardware requirements, algorithms and diagrams are designed accordingly. Along with interface design; algorithm design, architectural structure of software, concept design and database are created in this section. System design is helpful for hardware identification and definition of general system architecture [2].

3.2.3. Implementation

This is the step where sector requirements and system design are turned into applications. In this section, the actual coding is done. The database and other needs acquired in the Design step are compiled into a functioning application. If the software is being developed by a team, the development phase is divided into modular parts for Teamwork. This is also the longest part of the SDLC because the main goal in this stage is developing the software [28].

3.2.4. Testing

In this section, it is checked whether the software conforms to the previously determined requirements and objectives. It is also named verification or validation. This step is a process which allows to evaluate the software at the end of the development or during the development phase [24]. Apart from this, bugs and unwanted behaviours are detected at this stage [2].

3.2.5. Maintenance

In this step, after the software is completed and deployed, errors are eliminated, performance and quality are improved. In addition, maintenance can be done to improve the reliability of the software, such as environmental adaptation, adapting to the needs of new users [2].

4. Implementation

In this section, screenshots of final version of the system is shown. After the system design was completed, and the finalized version of the system was deployed to the web space, screenshots were taken on Firefox browser in various window sizes to portray the user journey for different screen sizes.

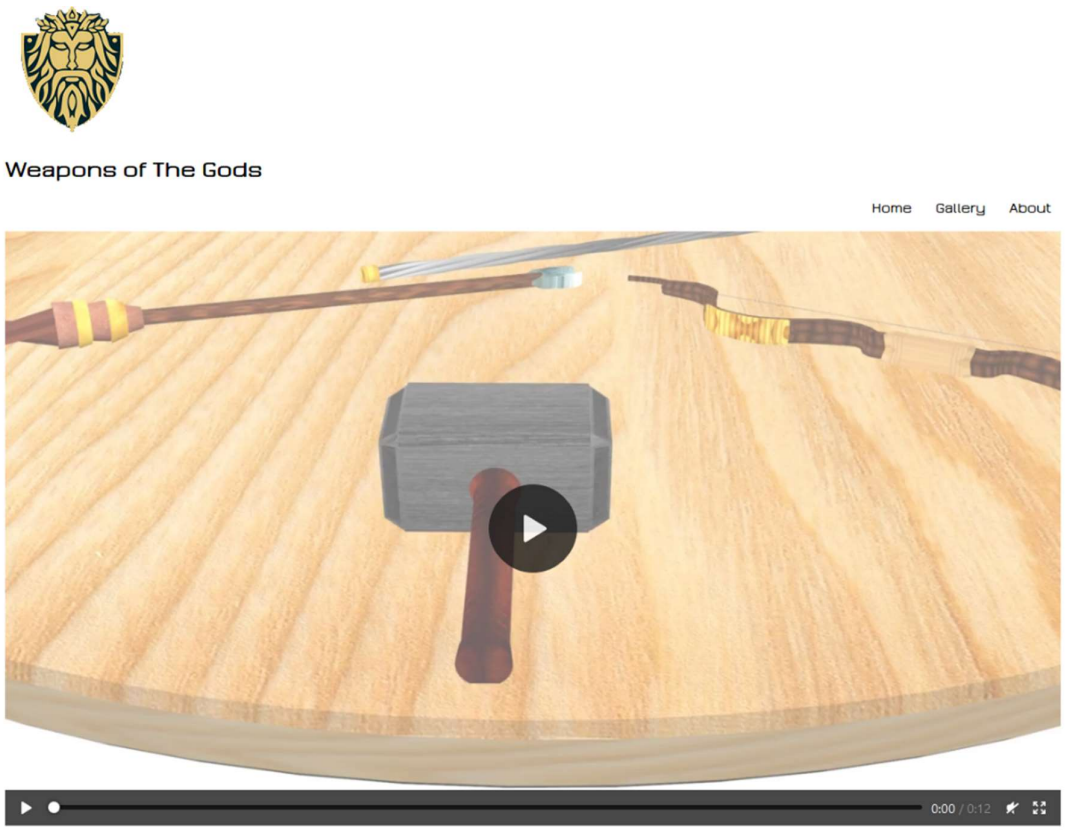

Figure 5: Homepage Desktop View

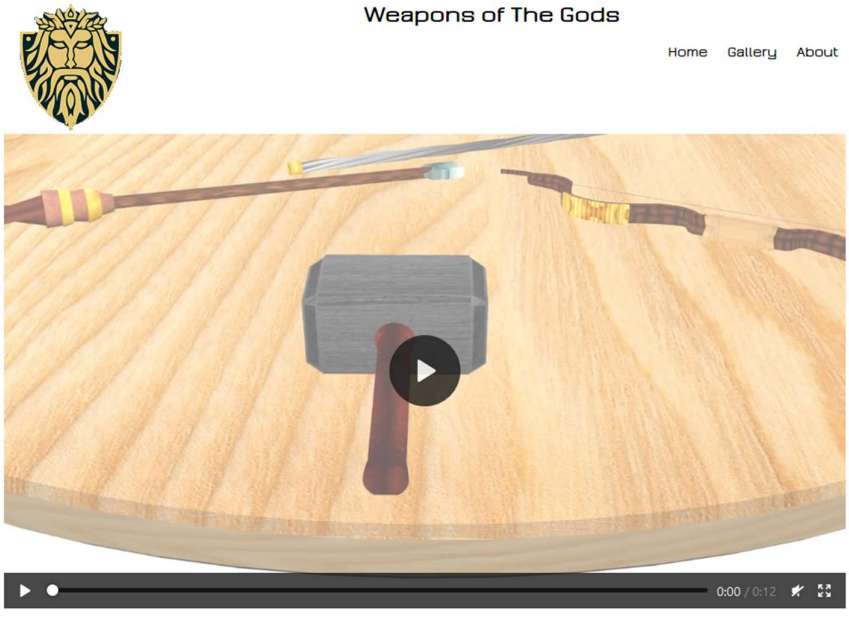

Figure 6:Homepage Tablet View

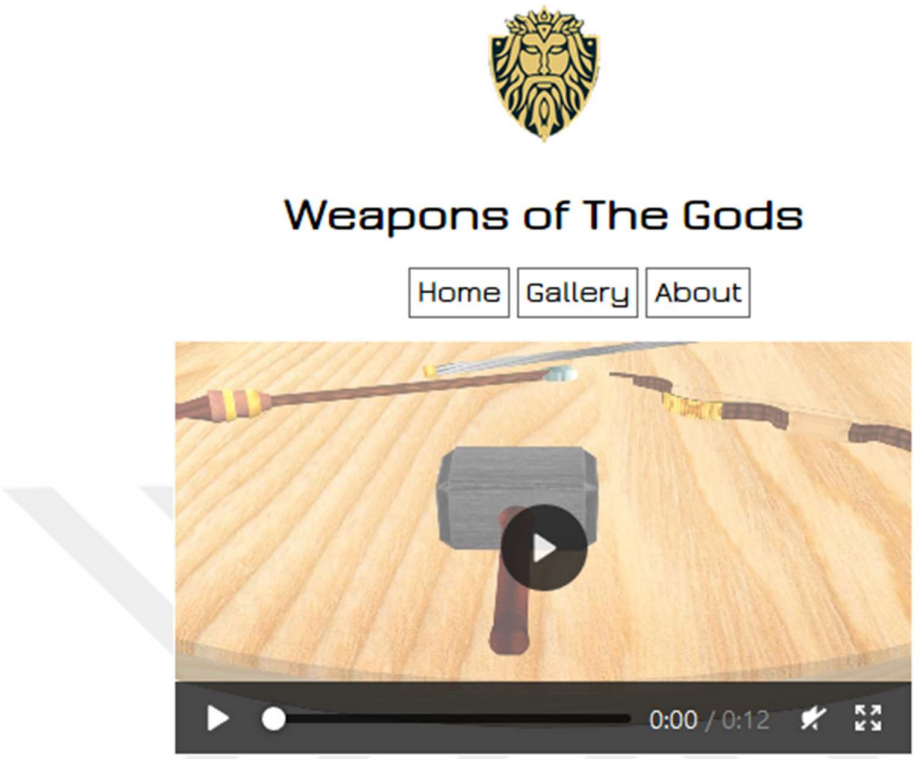

Figure 7: Homepage Mobile View

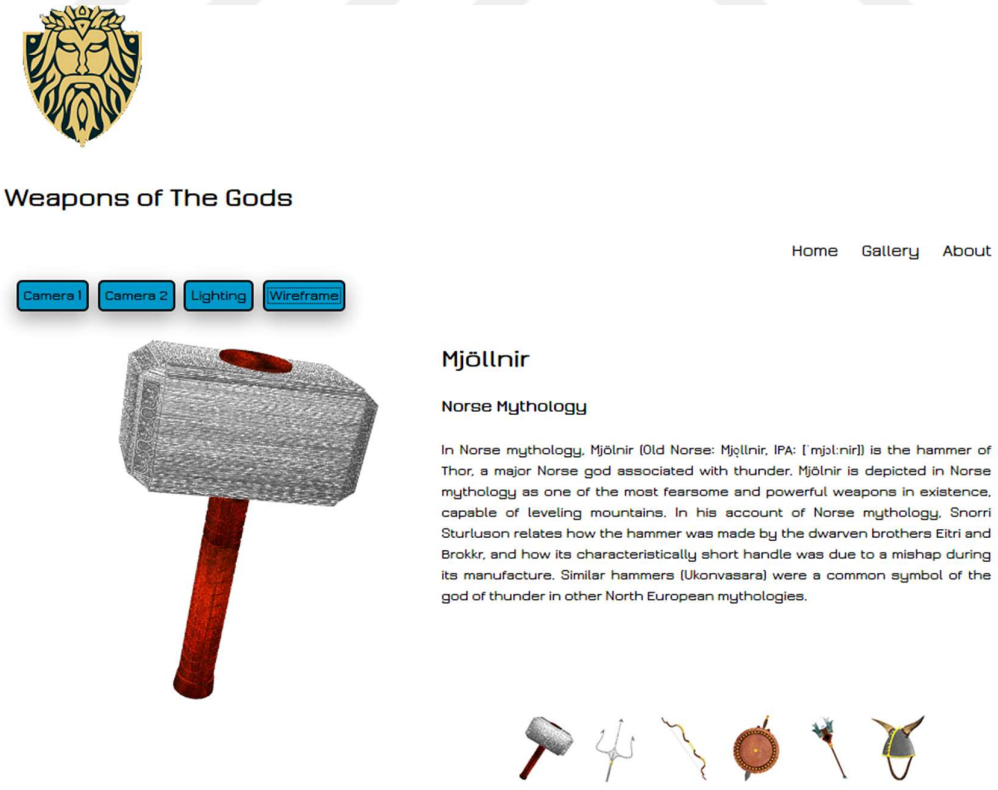

Figure 8:Gallery Desktop View

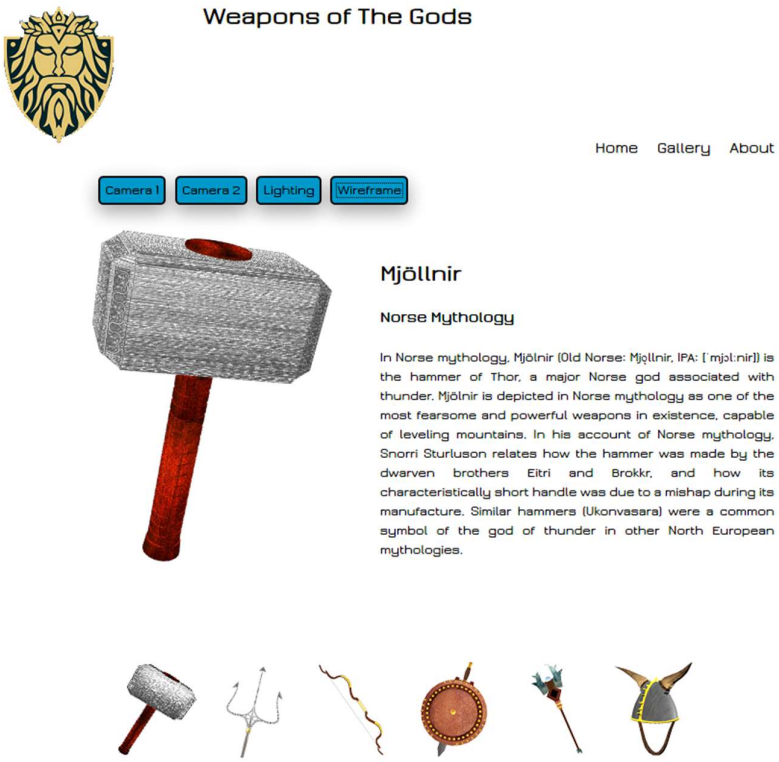

Figure 9: Gallery Tablet View

Figure 10: Gallery Mobile View

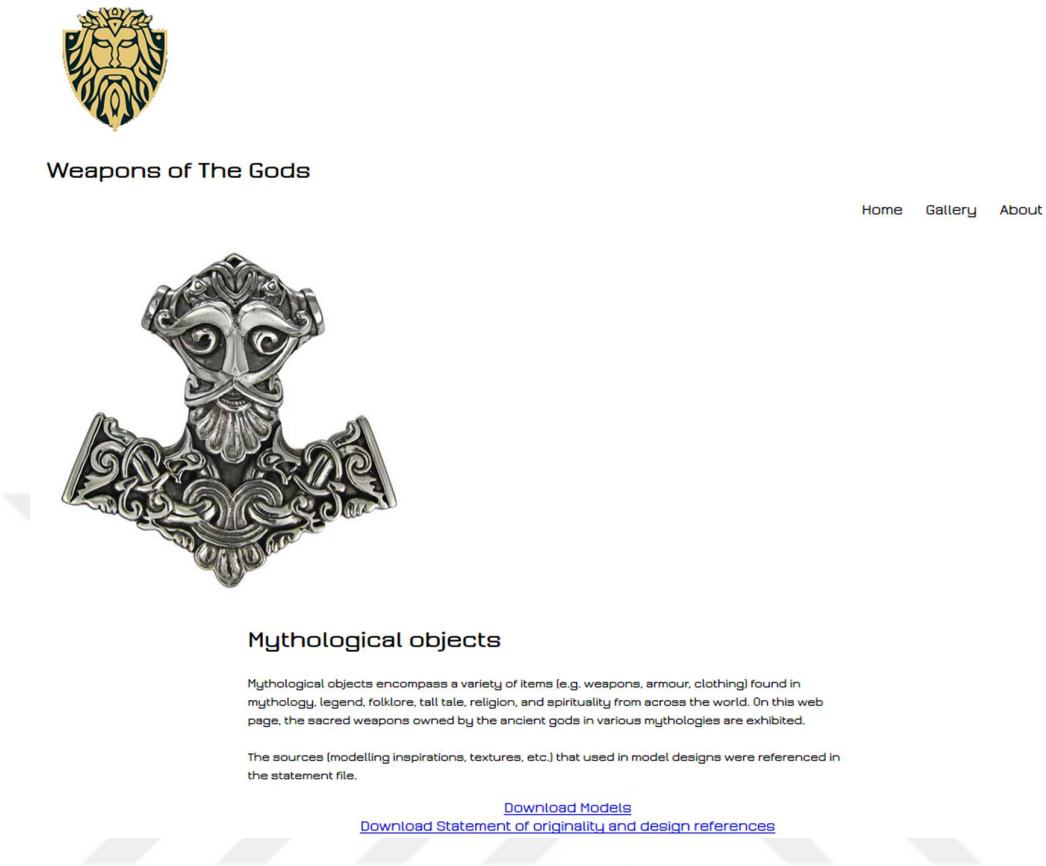

Figure 11: About Page Desktop View

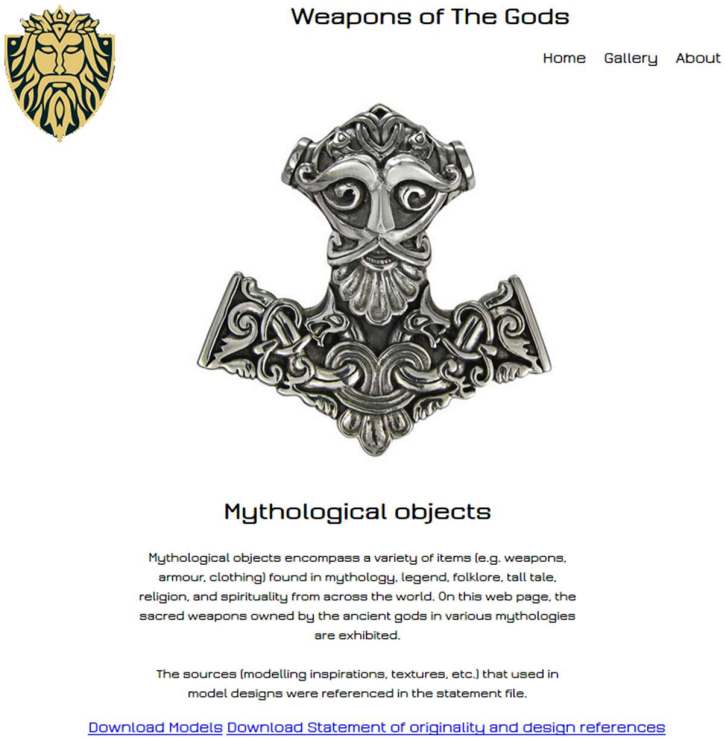

Figure 12: About Page Tablet View

Figure 13: About Page Mobile View

5. Test and Evaluation

Software testing is a phase of software development which aims to detect unexpected behaviours by executing the system [36]. It is often perceived as cleaning the software from bugs, but it is a much more comprehensive and important stage of software development life cycle. Software testing is the determination of whether a software system can run in the expected environment to meet the provided specifications. Running the system, distinguishes testing from reading and analysing the code by developers or other people. However, testing requires an executable system [35].

Tests should be planned and documented. Testing specifications are the critical points that support testing. A test case should include the test inputs, preconditions, test purpose, expected outputs post

conditions and a testing execution history [36]. The specifications are the critical points that support testing. By identifying the right behaviour, it is easier to distinguish when the system behaves incorrectly. In some cases, software may provide anticipation but may not be able to adapt to environmental conditions, such as occupying too much memory, executing too slowly, etc [35].

Some formal software testing methods have been classified as,

- **Unit Tests** are used to test a specific part of the system.
- **Integration tests** test multiple components of the system. It aims to test the communication between components.
- **System test** tests a collection of the components in the system that can provide a deliverable output.
- **Acceptance test** are customer approved tests.

Apart from these formal testing methods, there are also informal testing methods of validation and verification. These are called informal because they are more qualitative than quantitative.

In this work testing was performed in two phases: First testing setup is based on ad-hoc (user verified) testing with documentation and performed at the end of the development, and the second testing was performed by using Chrome's developer tools during development phase. Especially, on debugging JavaScript and jQuery errors, it was benefited from Google Chrome's developer tools. WampServer is also used to test PHP files in web browser without uploading them on a real server. This small free software allows to manage web applications easily on Windows devices. Along with these, at the end of the main section designs, the entire system was deployed to the Sussex Web Space and tested on the server. It can be accessed from the following URL: http://users.sussex.ac.uk/~ed286/project_d/index.html

On ad-hoc testing, different pre-conditions with highest possibilities are determined, and test cases are executed consecutively. Basically, the major features of the system were manually tested. All cases noted with their post condition. This testing method also represents the black-box testing method.

Table 4: Ad-hoc (User verified) testing documentation

Test	**Ability of Responsive page design**			
Precondition	Web Browser: Chrome	Web Browser: Firefox	Web Browser: Mobile Safari	Web Browser: Android Chrome
Steps	On a 1920 * 1080 resolution displayed computer, website visited and starting from the full screen size, the width of the browser frame has been narrowed down and enlarged respectively.	On a 1920 * 1080 resolution displayed computer, website visited and starting from the full screen size, the width of the browser frame has been narrowed down and enlarged respectively.	The webpage is visited from Safari on a 1334 x 750 pixels screen mobile phone (iOS device).	The webpage is visited from Chrome on an 800 x 1280 pixels screen tablet Amazon Fire 8 HD (Android based Fire OS device).
Post Condition	1. GUI behaves as expected. All elements are displayed correctly on Chrome on a	1. GUI behaves as expected. All elements are displayed correctly on Firefox on a	GUI behaves as expected. Website loaded in mobile form.	GUI behaves as expected. Website loaded in tablet form.

	Windows Computer. 2. When too many tabs are open in Chrome, the browser window does not shrink after a certain point, and the design cannot go to mobile form. However, this problem is not a bug, it is caused by the browser.	Windows Computer. 2. The problem experienced in Chrome hasn't been observed. When the page is shrunk, all view forms are changed as expected.		

Test	**Ability of X3DOM inline node**			
Precondition	Web Browser: Chrome Device: Computer	Web Browser: Firefox Device: Computer	Web Browser: Mobile Safari Device: Mobile Phone (iOS)	Web Browser: Android Chrome Device: Tablet (Android Fire OS)
Steps	The gallery page was visited, interacted with the loaded X3D model randomly for a period.	The gallery page was visited, interacted with the loaded X3D model randomly for a period.	The gallery page was visited, interacted with the loaded X3D model randomly for a period.	The gallery page was visited, interacted with the loaded X3D model randomly for a period.
Post Condition	The X3DOM inline node fulfilled all commands.	The X3DOM inline node fulfilled all commands.	The X3DOM inline node fulfilled all commands.	The X3DOM inline node fulfilled all commands.

Test	**Ability of interaction buttons**			
Precondition	Web Browser: Chrome Device: Computer	Web Browser: Firefox Device: Computer	Web Browser: Mobile Safari Device: Mobile Phone (iOS)	Web Browser: Android Chrome Device: Tablet (Android Fire OS)
Steps	Each interaction button was randomly clicked at least once, and manipulation of the 3D model was observed.	Each interaction button was randomly clicked at least once, and manipulation of the 3D model was observed.	Each interaction button was randomly clicked at least once, and manipulation of the 3D model was observed.	Each interaction button was randomly clicked at least once, and manipulation of the 3D model was observed.
Post Condition	Manipulation buttons performed the commands correctly.	Manipulation buttons performed the commands correctly.	Manipulation buttons performed the commands correctly.	Manipulation buttons performed the commands correctly.

Test	Ability of loading new models			
Precondition	Web Browser: Chrome Device: Computer	Web Browser: Firefox Device: Computer	Web Browser: Mobile Safari Device: Mobile Phone (iOS)	Web Browser: Android Chrome Device: Tablet (Android Fire OS)
Steps	Model thumbnails clicked randomly for a period. Each model thumbnail image was clicked at least once.	Model thumbnails clicked randomly for a period. Each model thumbnail image was clicked at least once.	Model thumbnails clicked randomly for a period. Each model thumbnail image was clicked at least once.	Model thumbnails clicked randomly for a period. Each model thumbnail image was clicked at least once.
Post Condition	All models were loaded as expected.	All models were loaded as expected.	All models were loaded as expected.	When multiple models are accessed without refreshing the gallery, Chrome crashes. However, this problem was not encountered on any other device and it seems to be caused by memory shortage.

6. Conclusions

In this virtual museum webpage project, a fictional virtual museum was designed by using various web technologies together. Most of the aimed objectives at functionality based on user experience are fulfilled. However, the system infrastructure can be further enhanced or more features added for daily use. Initially, for public use, it would be needed to manage larger amount of metadata and models. Therefore, it would be more appropriate to use an external database technology in a real virtual museum. An admin access section or the user login system could be added. Again, these would be useful for real life use cases.

In this project it is emphasized that, besides the use of virtual museums as replica museums of real exhibits, unreal figures can also be presented with concept designs. With the rapidly developing new technologies such as VR and AR, these concepts can gain popularity in the near future. Such projects facilitate the transfer of cultural heritance by transferring ancient historical information in an attractive way. Therefore, they can be used for educational purposes. Moreover, in the near future, with the VR and AR technologies, it can be more attractive to experience virtual museums which are based on imaginary universes just for hobby purposes only. In both cases, virtual museums offer cultural environments in an entertaining way to their visitors.

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