Virtual Campus in HTML5

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Declaration

I, Salako Oluwatimilehin, confirm that this work submitted for assessment is my own and is expressed in my own words. Any uses made within it of the works of other authors in any form (e.g., ideas, equations, figures, text, tables, programs) are properly acknowledged at any point of their use. A list of the references employed is included.

Signed: ..................................................................

Date: .....................................................................
Abstract

There have been various efforts to integrate 3D technologies in web browsers. Some of these technologies involved rendering with plug-ins while some involved rendering without plug-ins. There would be no need to install a plug-in to view 3D models on the web if 3D technologies were readily integrated in web browsers. HTML5 is both a single specification and a whole set of technologies proposed recently for the web. X3DOM is a scalable architecture proposed for the integration of HTML5 and X3D. This architecture aims to integrate and update declarative X3D content directly in the HTML Document Object Model (DOM) tree. In this project, we explore the HTML5 support for 3D graphics on the web.

Three Heriot Watt virtual campus models exist in Virtual Reality Markup Language (VRML). We aimed at producing a virtual campus from these VRML models viewable in any HTML5-compliant web browser without any plug-in using iterative development and prototyping.

A total of nine buildings were remodeled manually in X3D with primitive shapes (boxes) to replace extrusion nodes which is not supported in X3DOM. The first prototype was tested with users and the feedback obtained was used to improve and develop a second prototype in HTML5. The prototypes’ performance evaluation was also carried out using some HTML5-compliant browsers on Windows, Linux and Mac Operating systems.

The difference in the number of polygons rendered in the virtual campus scene for the first prototype (566KB in size) and second prototype (1.731MB in size) led to a significant reduction in the models’ average frame rates. The varied timing of the testing in order to vary the effect of network latency also produced a slight reduction in the average frame rates for the HTML5 prototypes.
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1. Introduction

Virtual environments with 3D models on the web can give web users a sense of presence in such an environment. If this is achieved, users for instance, would know what a university campus looks like without being physically present there. There have been various efforts to integrate 3D technologies in web browsers. Some developers have tried to implement this using various software technologies. Some of these technologies involved rendering with plug-ins while some involved rendering without plug-ins [1]. Most of these systems and standards disappeared, some survived but none has a prevalence rate that makes it relevant and known to most people who use the web daily (see section 2.3 of this report for more details). There would be no need to install a plug-in to view 3D models on the web if 3D technologies were readily integrated in web browsers.

HTML5 is both a single specification and a whole set of technologies proposed recently for the web [2]. Although it is a technology being deployed now, HTML5 is not yet a finished standard. It has a number of capabilities as mentioned in section 2.3.4. Among its capabilities is its support for 3D graphics. Web browsers can be tested and scored to know how well they support HTML5 [3]. In this project, we explore the HTML5 support for 3D graphics on the web. Three Heriot Watt University campus model exists in VRML. The aim of this project is to produce a campus model viewable in any HTML5 compliant browser without any plug-in.

The main objectives of this project include the following three aspects;

i. Produce an X3D version of the existing VRML campus models

ii. Incorporate the X3D model into HTML5 pages

iii. Establish the usability and performance of the HTML5 model

Chapter 2 contains a literature review where we discuss virtual environments, significance of 3D graphics, history and development of 3D graphics on the web, HTML5 support for 3D graphics and some earlier work done on virtual campus models. In Chapter 3, we discuss the requirement analysis for this project. This chapter contains the mandatory and optional requirements. Chapter 4 contains the project methodology. Here, we discuss key stages in the development of the first prototype. This includes prior investigation into X3DOM and HTML5, the VRML campus models, the choice of the VRML model used the development
of the first prototype, users’ evaluation and performance evaluation of the first prototype. In Chapter 5, we further discuss the second prototype development, performance evaluation of the second prototype, some further findings with other building models and our project results. In Chapter 6, we outline the achievements of the project, the shortcomings and possible extensions for future work on the project.
2. Literature Review

2.1 Why Virtual Environments?

Virtual Environments can be used to give its users a sense of presence. Also, some interactions can be made possible in virtual environments. An example of such interactions is navigation by walking or flying around in the virtual environment. Virtual environments also try to reproduce effects such as sound and touch among others which are things actually experienced in the real world.

2.2 Significance of having 3D graphics

3D models have been useful in various areas. The web has also further helped to achieve a wider coverage and faster accessibility for viewing 3D models. Recently, Web Applications that provide real-time 3D support and run platform independently on smart phones, tablets and on desktop computers are being developed for virtual museums using web technologies like HTML5, CSS3, DOM scripting and Ajax [4] (see section 2.3 for more details about these technologies). This can be used to give visitors and also experts such as curators the possibility to examine virtual heritage objects and also interact with the 3D models. Also, [5] explains the integration of HTML, X3DOM and PHP technologies as a carrier for bringing 3D content of cultural heritage to end-users of the web as shown in figures 1 and 2 below.

![Figure 1: Irish Lighthouse 3D Model visualized using X3DOM](image-url)
Virtual environments and 3D graphics have been applied also to web commerce. Also on the web, prospective buyers can view and try clothes on in virtual fitting rooms [6]. The fashion and design industry too now incorporates interactive virtual visualization of their exhibitions [7]. Google maps also can be used to locate, view and navigate places [8].

Google Earth [9] is a tool created by Google in which users can take a virtual journey to any location in the world. Users can explore terrains, 3D buildings, imagery, places, cities and also local businesses. Figure 3 shows an example of a 3D building that was viewed in Google Earth.
2.3 History and development of 3D graphics on the web

2.3.1 Virtual Reality Markup language (VRML)

The history, capabilities, usefulness and technological capabilities of VRML (Virtual Reality Markup Language) is explained in [10]. Labyrinth, a prototype 3D interface for the web was developed in 1994. After this, VRML evolved in its development with the production of VRML 1, VRML 2, VRML 97, VRML 200X. Later, X3D was developed.

VRML is an HTML-like language [11]. It is described as a hierarchical scene description language that defines the geometry and behavior of a 3D scene or world [10]. It allows viewers to manipulate objects, walk and fly around landscapes, and interact with virtual environments consisting of 3D shapes, colors, textures, and sounds. It requires a standalone application or web browser plug-in to be viewed. It is described as an interpreted language because commands written in text are interpreted by the browser and displayed on the viewer’s monitor [10].

Figure 3: Google Earth 3D view of Cathedral of St. John the Divine, New York [9]
Many technologies are supported by VRML in order to add 3D objects, lights, animation and sound [12]. Some of these technologies include textures (JPEG, GIF, PNG and MPEG1, Flash, Real Media, AVI), sound (WAVE, MIDI), lighting, special nodes (background, switch, hyperlink (anchor), animation, billboard and fog, sensors, scripting (JavaScript, Java), modular (references external textures, models, scenes and scripts).

### 2.3.2 Rendering with Plug-ins

Plug-in-based systems have not been successful over the years [1]. One of the reasons for this is that they are not installed by default on most systems. This leaves users having to deal with plug-in installation, security and browser or OS compatibility issues. Adobe Flash until its Version 10 release in 2008 [13] had no real-time support for 3D graphics [1]. This update includes simple 3D transformations and objects but are very limited and designed only for 3D composite and GUI effects. Microsoft Silverlight is a programmable web browser plug-in developed by Microsoft as an alternative to Flash. Until their Version 3.0 was released in 2009, Silverlight did not have native 3D support.

O3D [14] is another graphics API for creating rich interactive 3D applications within a browser. It was made for JavaScript programmers who need the flexibility of a low-level graphics API. Though O3D used a relatively standard scene-graph model, its content cannot be defined in a declarative way. It was also found to be slower in implementation.

X3D was developed after VRML200X [10]. It was developed so as to enable a new generation of simulation & modeling applications develop, emerge, and interoperate. X3D is described as a component-based architecture that has the ability to support applications ranging from a simple non-interactive animation to streaming or rendering applications [11]. It also provides compatibility with existing VRML content and browsers. It was produced as a result of years of development by the Web 3D Consortium's X3D Task Group [15]. X3D is also an International Organization for Standardization (ISO) standard XML-based file format as shown in figure 4 that is used to represent 3D computer graphics. It has various internal and external APIs and a full runtime, event and behavior model as shown in the figure below.
Other technologies like MPEG-4 and Collada have not been successful for web-application. MPEG-4 has a 3D subset but none of the major MPEG-4 players supports 3D content at all. Collada is designed as an intermediate format which can be used in the creation pipeline with a final deployment format like X3D. GoogleEarth [16] uses Collada data files directly to define content for their runtime-environment [1].

**Figure 4**: X3D data-encodings and programming language bindings [1]
2.3.3 Rendering without Plug-ins

The effort to render 3D content without plug-ins is in an early development state and not standardized presently. The current proposals available today utilize existing internal 2D browser techniques in order to implement something similar to what occurs in 3D pipelines. They also try to provide an abstraction for the 3D hardware directly to the web-application developer without any additional plug-in.

Browser techniques like CSS [17], Canvas [18], and SVG [19] do not support 3D at all. SVG-VML-3D [19], tree-builder and the latest Google chrome experiment [20] are examples of improvement in browser and JavaScript performance over the last years. Apple also added some 3D CSS transformations [21] to their webkit engine but when compared with X3D is still not up to the full 3D scene setup.

2.3.4 HTML5

HTML5 is described as an enhanced web specification for equipping web developers and giving users new capabilities [2]. HTML5 is both a single specification and a whole set of technologies. HTML5 include new versions of the markup language itself and its associated standard for accessing and manipulating HTML documents, Cascading Style Sheets (CSS) and the JavaScript scripting language. It is used more broadly as a term to include application programming interfaces (APIs) [22] such as those that enable new browser-based graphics, geolocation, local storage and video capabilities. It is described as a developer-friendly standard and a technology with tighter specifications for web browsers.

The Document Object Model (DOM) is said to be a platform- and language-neutral interface that will allow programs and scripts to dynamically access and update the content, structure and style of documents [23]. These documents can then be further processed and the results of that processing incorporated back into the presented page. HTML DOM is described as a standard way for accessing and manipulating HTML documents [24]. Figure 5 below shows the HTML DOM tree. The way 3D content on the web can be created,
modified and shared like text, images, audio and video is by direct integration in DOM tree [1].

![HTML DOM Tree](image)

**Figure 5: HTML DOM Tree [24]**

X3DOM is a scalable architecture proposed for the integration of HTML5 and X3D [25]. This architecture aims to integrate and update declarative X3D content directly in the HTML DOM tree. It provides a single declarative interface to application developers and at the same time support of various back ends through a powerful fallback-model. This would help application developers to describe what the program written should accomplish rather than describing how to go about accomplishing it. Figure 6 below shows the proposed X3DOM architecture.
This architecture is described in [5]. The architecture is made up of three building blocks which are the User Agent (UA), the X3D runtime (X3DR) and the connector (CON). The UA is the actual web browser responsible for holding the DOM tree. It contains a URI resolver used to download images, video files, sounds and other data the scene contains. The X3DR block builds and updates the X3D scene and also handles user’s input related to navigating and point clicking in 3D space. The CON connects the DOM-tree held by the UA with the X3DR thus updates like an addition, a removal or an attribute change in an object are forwarded in both directions.

In their work, [26] describe the use of images and explicit binary container for delivery of declarative 3D Scenes on the web. For real world applications with large 3D data sets, integrating the 3D data into HTML DOM leads to huge HTML documents (see figure 8). This causes unpleasant, non-interactive user experience due to long loading times and non-responsive web pages. This is because Web Browsers are not built to parse DOM attribute data sets beyond several megabytes in size. This binary compression method has been used to visualize large 3D scanned data sets up to 4 million polygons in real time [27]. This compression was done for a collection of historical objects on the web for a museum. Figure 7 below (right images) shows one of such historical objects.
A Sequential Image Geometry (SIG) approach was used for the mesh data encoding. In this approach, the image is used to store unlinked vertex data such as coordinates and normals and all vertex data is stored in an indexed array.

**Figure 7:** Models visualized with X3DOM in the Web Browser. Left: architectural walkthrough model of Hall 11 of the Fair of Frankfurt – represented and rendered using sequential image geometry (SIG) approach for fast content delivery and data compression on the Web. Right: 3D-scanned historical object rendered as triangle mesh and as point set using SIG approach [26].

**Figure 8:** Example of declarative 3d structure and data held by DOM [26].
Another solution to achieve a pleasant interactive experience for users viewing large 3D models on the web was also proposed [26]. This is to divide lightweight, structured information from the heavy unstructured data. Lightweight structured information includes transformation groups and materials that usually make up less than five percent of the entire file size. Also, unstructured data being referred to are not only images but vertex attributes. Their research therefore has two goals. First is to improve the structuring of 3D documents on the web due to clear externalization of unstructured data away from the scene-graph and the (X)3D application. This is beneficial for human-readability and browsers, since parsers will not have to wade through heavy chunks of binary data within XML documents. It also improves the loading time and affects the overall user experience. The second goal is to stream large geometries to users instantaneously in a specific ordering with little effort using the new geometry container format proposed.

2.4 Some earlier work done on virtual campus models

The Nanyang Technological University Virtual Campus was built in VRML which inspired putting the model on the web [28]. Digital photos of the campus taken were converted to texture images. A lot of polygon reduction was done to find a compromise between realism and the size of their model. The whole Nanyang Technological University virtual campus including VRML models of the land, interiors, buildings, avatars and images was finally stored in only about 15 megabytes of files on the web. Figure 9 below shows scenes from the virtual campus.
VRML was also used to design a virtual reality model of the Avcilar Campus of Istanbul University [10]. The virtual campus was developed to be placed on the web. Figure 10 below shows a view of the virtual campus.
Figure 10: View of the Engineering and Veterinary Medicine Faculty of the virtual Avcilar campus [10].

The University of Sargodha virtual campus was also designed using VRML [29]. Various buildings and other places such as lecture rooms and laboratories on the campus were modeled. Figure 11 below shows a view of the virtual campus.
Figure 11: Exterior view of the Computer Science and IT department of the University of Sargodha virtual campus [29].
3. Requirements Analysis

Sections 3.1 and 3.2 explain the mandatory and optional requirements of this project.

### 3.1 Mandatory requirements

<table>
<thead>
<tr>
<th>Mandatory requirements</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Model Conversion</strong></td>
<td>The campus model in VRML will be converted first to X3D. After this, the X3D model will be incorporated into an HTML5 page.</td>
</tr>
<tr>
<td>Model conversion</td>
<td></td>
</tr>
<tr>
<td>Geometry</td>
<td>If the model is eventually partitioned or its resolution is reduced, the geometry of the campus model should be managed as much as possible in order to obtain a realistic appearance of the Heriot Watt virtual campus.</td>
</tr>
<tr>
<td>Textures</td>
<td>Textures that are missing or absent in the model initially and during conversion will be replaced. Textures that are not too large in size will be used to ensure that the entire size of the model is minimized as far as possible.</td>
</tr>
<tr>
<td><strong>2. Performance</strong></td>
<td>The frame rate of the model should be kept above 20fps so that it is acceptable to be viewed by users.</td>
</tr>
<tr>
<td>Frame rate</td>
<td></td>
</tr>
<tr>
<td>Network Latency</td>
<td>Network latency in loading and interacting with the model should be kept as low as possible in order to give the users a good experience</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>

### 3. Users

<table>
<thead>
<tr>
<th>Loading the model</th>
<th>Users of the model when trying to load the model incorporated into HTML5 page will be told if they can load the model or not. This is because only browsers that score high on HTML5 [3] particularly with its canvas requirement specification will be able to load the model successfully</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction</td>
<td>An intuitive navigation for the model incorporated in HTML5 page will be chosen so that users do not have difficulty with interacting with the model</td>
</tr>
</tbody>
</table>
3.2 Optional requirements

The optional requirement is to enhance the model for user experience to be established via iterative prototyping (if time permits)

In the evaluation of this project, we would therefore design a questionnaire to evaluate these requirements with the prototype we developed. Also, users will be asked to test the prototype. Their experience and comments with testing the prototype would be observed and noted. This could help to bring up issues we need to consider that were not thought of earlier in this project (see sections 4.4 for more details).
4. Methodology and Development of First Prototype

An earlier research propose a model-driven iterative development of 3D Web-Applications using SSIML, X3D and JavaScript [30]. In this project, we used Iterative development and prototyping. The Boehm’s spiral methodology [31] was chosen. This is because it combines the features of the prototyping and the waterfall model [32]. The waterfall model would not be suitable because it does a sequential development and once our model is in its testing phase, it would be difficult to go back to change something we did not think of in our concept stage. Also, this model has a high amount of risk and uncertainty involved in its use.

We would first try to incorporate a small part of the model, for example, a single building into an HTML5 web page. We will next evaluate its performance and usability. After this will be the identification of errors and issues that may arise from the feedback we get for improvement in the next iteration. Our methodology therefore involves usability and performance evaluation together as we proceed with the project.

4.1 Prior Investigations

This section describes key stages in the development of the first prototype. The project diary contains the full details of activities done for the project in chronological order (see Appendix 4). It also contains URLs to the prototypes and other resources accessed which are all available via the World Wide Web.

HTML5 and X3DOM
Prior investigation was done as to how an X3D file can be incorporated into an HTML5 web page. This can be done by embedding the X3D codes within HTML codes [34] (see Appendix 1 for a sample code). The document is then saved with the .xhtml file extension.
The VRML Campus Models

Three earlier developed Heriot Watt University campus models in VRML were considered (hwu, hwu1, hw2). (see Appendix 4 - Project Diary dates 3/5/2013 and 6/5/2013 for full details). The structures of these models are illustrated in the figures below (see also Appendix 2 for VRML model snapshots).

Figure 12: The structure of the hwu VRML campus model
Figure 13: The structure of the hwu1 VRML campus model (see Appendix 8 for the codes)
4.2 Choice of VRML model to be used

The hwu2 VRML campus model was initially selected to be used for the development of the HTML5 prototypes. This was because it has a single main file in which all the VRML codes were written. Also, it has a map for location guide which could make the viewing of specific locations on campus easier for the users when testing our HTML5 prototype without having to navigate the entire campus model. The codes were converted to X3D, incorporated and evaluated in HTML5 incrementally (see Appendix 4 – Project Diary dates 6/5/2013 to 21/5/2013 for full details). However, due to the discovery that the ProximitySensor and TouchSensor nodes are not supported by X3DOM, the map would not work. Furthermore, the Extrusions not supported by X3DOM would be replaced by primitive shapes (boxes) which are well supported in X3DOM. The hwu1 model was then chosen because it has a structure that would enable working on a decomposed bit of the model (buildings) individually to replace the extrusions with boxes manually (as seen in figure 13 above). This would be difficult to do using the hwu2 model which has a single main file containing all VRML campus model codes.
4.3 First Prototype Development

Workflow Diagram

The general workflow involved in the development of our prototypes is shown in figure 15 below.

Figure 15: Workflow Involved in the development of the HTML5 virtual campus prototype
The actions carried out in the manual remodeling of the extrusion nodes and their replacement with boxes (the process highlighted in black background in figure 15 above) are listed in sequential order below:

For a well structured model such as the hwu1 VRML campus model having a main file that loads sub files (representing each building), after the buildings have been converted to X3D:

i. Examine each sub file (building) in Octaga player and identify the simple buildings whose geometry could be easily replaced by boxes
ii. Identify the extrusion nodes
iii. Identify which part of the building the extrusion nodes represent (the walls or the roof for instance)
iv. Remove the extrusion node and replace with boxes that fit into the building appropriately by positioning the boxes rightly in the xyz-plane in X3D maintaining the look of the initial building as much as possible.

v. Ensure that the appearance of the textures applied to the boxes as applied to the extrusions replaced are suitable. Make readjustments to the texture mapping if need be
vi. Proceed to the more complex buildings and repeat steps (ii) to (v).

Using the newly chosen hwu1 VRML campus model, its main VRML file and some of its sub files 56-vegetation.wrl and 55-lamp.wrl including the ground and some trees were successfully incorporated into an HTML5 page. Also, two simple buildings, 4-launderette.wrl and 14-medisstudio.wrl were worked upon following the steps described in the workflow diagram above (see Appendix 4 – Project Diary dates 23/5/2013 to 31/5/2013 for full details). The extrusion nodes which were not supported in X3DOM formed the walls and doors of the buildings. Two extrusions were replaced with two boxes for the launderette building and one extrusion was replaced with two boxes for the medisstudio
building. The extrusion nodes replaced in X3D and the new nodes for one of the buildings (launderette) is given below.

**Extrusion nodes replaced**

```xml
<Shape>
  <Appearance>
    <Material diffuseColor='0.6 0.4 0.2'/>
    <ImageTexture url='"image/wall.jpg"'/>
    <TextureTransform scale='40 40'/>
  </Appearance>
  <Extrusion solid='false' creaseAngle='1.57' crossSection='0.001 0.25 -0.001 0.25 -0.001 -0.25 0.001 -0.25 0.001 0.25 -0.001 -0.25 0.25' spine='22.831 -0.25 10.825 23.46 -0.25 11.297 24.438 -0.25 9.993 23.809 -0.25 9.522 22.831 -0.25 10.825' />
</Shape>

<Shape>
  <Appearance>
    <Material diffuseColor='0.6 0.4 0.2'/>
    <ImageTexture url='"image/door14.jpg"'/>
    <TextureTransform scale='2 2'/>
  </Appearance>
  <Extrusion solid='false' creaseAngle='1.57' crossSection='0.0021 0.25 -0.0021 0.25 -0.0021 -0.25 0.0021 -0.25 0.0021 0.25 -0.0021 -0.25 0.25' spine='22.92 -0.25 10.7 23 -0.25 10.48 23 -0.25 10.64 22.92 -0.25 10.7'/>
</Shape>
```

![Figure 16: A view of the launderette building in X3D modeled with extrusions](image)
Replacement with primitive shape (boxes)

<Transform rotation='0 1 0 0.935' translation='23.5805 -0.25 10.39'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.6 0.4 0.2'/>
      <ImageTexture url="image/wall.jpg"/>
      <TextureTransform scale='40 40'/>
    </Appearance>
    <Box size='1.58 0.529 0.640'/>
  </Shape>
</Transform>

<Transform rotation='0 1 0 0.935' translation='23.18 -0.25 10.39'>
  <Shape>
    <Appearance>
      <Material diffuseColor='0.6 0.4 0.2'/>
      <ImageTexture url="image/door14.jpg"/>
      <TextureTransform scale='1 1'/>
    </Appearance>
    <Box size='0.25 0.519 0.01'/>
  </Shape>
</Transform>

**Figure 17:** A view of the launderette building in X3D remodeled with boxes
The ground, trees, vegetation, lamp posts at the reception, launderette building and
medisstudio building made up the first prototype (see Appendix 3 for snapshot of the first
prototype overview).

4.4 Performance Evaluation and Users’ Evaluation of the First Prototype

HTML5 Browser Test Scores

The HTML5 test website [3] was used to test how well some browsers support HTML5.
They were awarded a score out of a total of 500 points and also given some bonus points.
The details of the testing on Windows, Linux and Mac Operating Systems (OS) are given
below.

Windows Operating System

A computer system in the MACS G.46 laboratory with a Windows 7 professional OS and
the browsers on the system were used for the HTML5 browser score testing. It was also
used for performance evaluation on Windows OS as later explained in this section. Below
is the configuration for the system used and HTML5 test results.

System Configuration

Operating system: Windows 7 Professional 64-bit (6.1, Build 7601)
Processor: Pentium (R) Core (TM) i7-2600 CPU @ 3.40Ghz (8 CPUs)
Memory: 8192MB RAM
Page File: 2323MB used. 13947MB available
DirectX version: DirectX 11
Display Adapter – NVIDIA GeForce GT 520
<table>
<thead>
<tr>
<th>Browser</th>
<th>HTML5 Test Score (points out of 500)</th>
<th>Selected (Yes/No)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Chrome Version  27.0.1453.94m</td>
<td>463 and 13 bonus points</td>
<td>Yes</td>
</tr>
<tr>
<td>Mozilla Firefox 19.0.2</td>
<td>393 and 10 bonus points</td>
<td>Yes</td>
</tr>
<tr>
<td>Windows Internet Explorer 9 version 9.0.8112.16421</td>
<td>138 and 5 bonus points</td>
<td>No</td>
</tr>
<tr>
<td>Safari 5.1.5</td>
<td>319 and 9 Bonus points</td>
<td>No</td>
</tr>
</tbody>
</table>

**Table 1: Some Windows OS Browsers and their HTML5 Test Scores**

**Linux Operating System**

A computer system in the EM2.50 laboratory with a Linux 10 CentOS and the browsers on the system were used for the HTML5 browser score testing. It was also used for performance evaluation on Linux OS as later explained in this section. Below is the configuration for the system used and HTML5 test results.

**System Configuration**

Linux 10 CentOS

Release 6.4 (Final)

GNOME 2.28.2

Memory: 3.6GiB

Processor 0: Intel (R) Core(TM) 2 Duo CPU E8400 @ 3.00GHz

Processor 1: Intel (R) Core(TM) 2 Duo CPU E8400 @ 3.00GHz

**Graphics Card Information**

Graphics Processor: GeForce GT 520

Cuda Cores: 48

VBIOS Version: 75.19.1b.00.00

Bus Type: PCI Express X16 Gen2
<table>
<thead>
<tr>
<th>Browser</th>
<th>HTML5 Test Score (points out of 500)</th>
<th>Selected (Yes/No)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>463 and 13 bonus points</td>
<td>Yes</td>
</tr>
<tr>
<td>Mozilla Firefox 22.0</td>
<td>410 and 10 bonus points</td>
<td>Yes</td>
</tr>
<tr>
<td>Opera version 12.15 Build 1748</td>
<td>404 and 9 bonus points</td>
<td>No</td>
</tr>
<tr>
<td>SeaMonkey version 2.17.1</td>
<td>394 and 10 Bonus points</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Table 2: Some Linux OS Browsers and their HTML5 Test Scores**

**Mac Operating System**

A laptop computer system with a Mac OS and the browsers on the system were used for the HTML5 browser score testing. It was also used for performance evaluation on Mac OS as later explained in this section. Below is the configuration for the laptop computer system used and HTML5 test results.

**System Configuration**

Mac OS  
Version 10.6.8  
Processor: 2.4GHz Intel Core 2 Duo  
Memory: 2GB 1067 MHz DDR3

**Graphics Card Information**

Graphics Processor: GeeForce GT 520  
CUDA Cores: 48  
VBIOS Version: 75.19.1b.00.00  
Total Memory: 1024MB  
Memory Interface: 64-bit  
Bus Type: PCI Express X16 Gen2
<table>
<thead>
<tr>
<th>Browser</th>
<th>HTML5 Test Score (points out of 500)</th>
<th>Selected (Yes/No)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>463 and 13 bonus points</td>
<td>Yes</td>
</tr>
<tr>
<td>Mozilla Firefox 21.0</td>
<td>399 and 10 bonus points</td>
<td>Yes</td>
</tr>
<tr>
<td>Safari 5.1.7</td>
<td>319 and 9 bonus points</td>
<td>No</td>
</tr>
</tbody>
</table>

**Table 3: Some Mac OS Browsers and their HTML5 Test Scores**

The browsers that have high HTML5 scores for the different operating systems on which the virtual campus prototype could be viewed were selected for further prototype testing (marked Yes in tables 1, 2 and 3 above). The prototype could not be viewed on the others (marked No in tables 1, 2, and 3 above).

**Performance Evaluation of the First Prototype**

The performance of the first prototype developed (as explained in section 4.3) in terms of the frame rate measurement was tested on the selected operating systems and browsers above. The total size of the first prototype together with its textures occupied 566 Kilobytes on the web. The URL of the prototype

(http://www2.macs.hw.ac.uk/~oss30/hwu1/FirstPerformanceEvaluation.xhtml) was accessed on the web (see figure 18 below for a snapshot taken from the evaluation). The testing was done early in the morning and in the afternoon in order to achieve the varied effect of network latency (load on the network) on the prototype. In all cases, the prototype was moved around slightly with the mouse left key held down and readings of the X3DOM frame rates were recorded (see section 5.3 for the details of the results). The frame rate readings produced by X3DOM varied as the number of polygons that was rendered in the scene varied. The frame rates recorded were estimated frame rates.
Testing with users

The first prototype developed (as explained in section 4.3) was tested with 8 users. At this early development stage of the campus model in HTML5, qualitative data in terms of users’ comments on their experience while testing the first prototype would be helpful and valuable. An evaluation consent form was filled in and signed by users. An evaluation questionnaire was designed with questions channeled towards what the system users would interact with and the campus model itself. An observed performance note was also prepared along sides to take personal notes of users’ comments and experiences while testing the prototype. This was done so as to note comments, observations and any other experiences of the users as they may not remember to point these out while filling in their comments in the questionnaire (see Appendices 5, 6 and 7)
The evaluation questionnaire in the system section contains questions about how responsive the system was to actions, the rating of users’ visual experience and what they thought was the best and worst thing about the system. The Campus model section contains questions on the rating of the buildings’ appearance, the rating of the ground’s appearance, the rating of the vegetation’s appearance and what users thought was the best or worst thing about the campus model.

Of the 8 users that tested the first prototype, 6 were students at Heriot Watt University and 2 were not. All the users tested using a laptop computer system with Windows 7 Operating system (32-bit). This laptop was used primarily because of its portability as users were tested in various locations. Users were logged on to the URLs of the first prototype on a Heriot Watt web space. The web browser used to access the web space was Google Chrome Version 28.0.1500.72 m. 7 different viewpoints of the campus were created to start users off from particular views on the campus model. This would prevent users from having to navigate the entire vast space on the model before a particular building could be reached and examined for instance (see Appendix 4 Project Diary Date 10/6/2013).

Users were asked to navigate around the virtual campus views to examine the vegetation, ground and the two buildings. They were told how to use the laptop touchpad for navigating the virtual campus. The left key was used to move forwards and the right key was used to move backwards. The multi-touch touchpad when used with the left and right keys was used to move left, right, upwards or downwards.

Here is a summary of the observations noted while the users tested the prototype and the comments written and suggestions from the users after testing (see Appendices 7 for full details).
Observed Performance Notes

- Users did not find the navigation easy. Some kept moving forwards when their intention was to move sideways. Some delved into the ground
- Some users walked through the buildings
- A user suggested maps would help to locate and visit locations faster on the virtual campus

Positive comments

- The ground, garden, plants and trees have a nice appearance
- The idea of creating a virtual campus is good
- Viewing the 3D model of the campus makes it look more realistic
- The textures are sharp and detailed and it makes the objects look more realistic

Negative Comments

- The navigation is quite difficult to control
- The navigation controls are quite sensitive
- There is no control over navigation speed
- Walking through walls and plants did not give a realistic experience
- The buildings looked basic and the appearance needs to be improved
- The ground is uniform all through the virtual campus.

Suggestions

- The controls are sensitive and it would be better to use the arrow keys on the keyboard for navigation
- It would be good to be able to fly over the entire campus to have an overview
- Fixing windows and doors on them will make them look more realistic
- It would be good to see what the inside of the buildings look like
- The ground can be improved with the addition of the paths and roads
Overall this was quite a good evaluation. The quality of the feedback was very valuable and the issues pointed out would be looked into for improvement in the development of the second prototype.
5. Second Prototype Development

Not much could be done with the issues with navigation and the system controls as pointed out by the users. The navigation used was that available for the HTML5 technology and perhaps navigation using a mouse could make the navigation controls easier. Walking through buildings was also investigated and this might be an issue with collision detection in HTML5. Also, due to TouchSensor and ProximitySensor nodes not supported by X3DOM as earlier discovered, maps cannot be implemented.

As observed by some of the users, the two buildings in the first prototype looked basic. This was improved by the addition of windows and doors to the two buildings (Laundrette and Medisstudio) to give them a more realistic look. Also, the base IndexedFaceSets of the buildings representing the floor from which the initial extrusions were projected were removed. This also gave the two buildings a better appearance.

As more buildings were manually remodeled in X3D, more skill was developed in remodeling the buildings. 7 more complex buildings (15-s1.wrl, 33-purchasingoffice.wrl, 36-printingservices.wrl, 10-pentlandhouse.wrl, 11-linlithgowhouse.wrl, 24-medicalcenter.wrl and 12-midlothianhouse.wrl) were worked upon and incorporated into HTML5 web pages following the workflow earlier described in figure 15 above (see Appendix 4 Project Diary dates 20/6/2013 to 29/6/2013 for full details). Six different viewpoints were created for the second prototype as was done for the first prototype. Table 4 below shows the nodes replaced after conversion to X3D and the replacements in X3D.
<table>
<thead>
<tr>
<th>VRML Building</th>
<th>Nodes replaced after conversion to X3D</th>
<th>Replacements in X3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-s1.wrl</td>
<td>2 Extrusions (walls)</td>
<td>6 boxes</td>
</tr>
<tr>
<td>33-purchasingoffice.wrl</td>
<td>2 Extrusions (walls)</td>
<td>2 boxes</td>
</tr>
<tr>
<td>36-printingservices.wrl</td>
<td>2 Extrusions (walls)</td>
<td>2 boxes</td>
</tr>
<tr>
<td>10-pentlandhouse.wrl</td>
<td>7 Extrusions (walls)</td>
<td>30 boxes</td>
</tr>
<tr>
<td>11-linlithgowhouse.wrl</td>
<td>7 Extrusions (walls)</td>
<td>39 boxes</td>
</tr>
<tr>
<td>24-medicalcenter.wrl</td>
<td>1 Extrusion (walls)</td>
<td>3 boxes</td>
</tr>
<tr>
<td>12-midlothianhouse.wrl</td>
<td>7 Extrusions (walls)</td>
<td>52 boxes</td>
</tr>
</tbody>
</table>

**Table 4**: Table showing the 7 additional buildings in the second prototype, the nodes replaced and their replacements in X3D

Figures 19 and 20 below show the improved buildings of the first prototype viewed in octaga player 4.0. Figures 21 to 34 show the other seven buildings worked upon in the second prototype. The snapshots also taken in octaga player version 4.0 show their initial appearance modeled with extrusions and their new appearance after they were remodeled with boxes. Figure 35 shows a snapshot of the second prototype overview (see Appendix 3 for more snapshots).
Figure 19: Laundrette building’s appearance improved with the addition of windows

Figure 20: Medisstudio building’s appearance improved with the addition of windows and doors
Figure 21: *s1 building initially modeled with extrusions*

Figure 22: *s1 building in X3D remodeled with boxes*
Figure 23: Purchasing Office VRML building initially modeled with extrusions

Figure 24: Purchasing Office building in X3D remodeled with boxes
Figure 25: Printing Services VRML building initially modeled with extrusions

Figure 26: Printing Services building in X3D remodeled with boxes
Figure 27: Pentlandhouse VRML building initially modeled with extrusions

Figure 28: Pentlandhouse building in X3D remodeled with boxes
Figure 29: Linlithgowhouse VRML building initially modeled with extrusions

Figure 30: Linlithgowhouse building in X3D remodeled with boxes
Figure 31: Medical Center VRML building initially modeled with extrusions

Figure 32: Medical Center building in X3D remodeled with boxes
Figure 33: Midlothianhouse VRML building initially modeled with extrusions

Figure 34: Midlothianhouse building in X3D remodeled with boxes
5.1 Performance Evaluation of the Second Prototype

The performance of the second prototype developed in terms of the frame rate measurement was tested on the selected operating systems and browsers above. The total size of the second prototype together with its textures occupied 1.731 Megabytes on the web. The URL of the prototype
was accessed on the web (see figure 36 below for a snapshot taken from the evaluation). The testing was also done early in the morning and in the afternoon in order to achieve the varied effect of network latency (load on the network) on the prototype. For all the cases, navigation between two points (starting from the lamp posts at the reception moving towards the buildings behind the trees in the distance as seen in figure 36) was done and readings of the X3DOM frame rates were recorded (see section 5.3 for the details of the results). The frame rate readings produced by X3DOM varied as the number of polygons that was rendered in the scene varied. The frame rates recorded were also estimated frame rates.
5.2 Further findings with other building models

To further explore the HTML5 support for building models, some buildings of the Chester model in X3D were examined (See Appendix4 Project Diary dates 4/7/2013 and 8/7/2013). A building (TownHall.X3d) was tested following the workflow explained in section 4.3. The size of the building together with its textures was 1.48MB. It was modeled using IndexedFaceSets nodes and the USE and DEF tags. The building was modeled using large chunks of coordinate point descriptions (similar to that described earlier in the highlighted area in figure 8).

Figure 36: Snapshot from Second Performance Evaluation
Evaluation in X3D and HTML5

The model was viewed on a computer system in the G.46 laboratory. The textures loaded well in Octaga player and level of detail was implemented for the textures. However, it could not display on the canvas when incorporated in an HTML5 web page. A node was present in the model containing texCoordIndex which as earlier discovered with the VRML hw2 campus model does not work in HTML5 (see Appendix 4 Project Diary Date 21/5/2013). When this node was removed, there were some changes in the X3DOM canvas. This was also the case for the other Chester building models.

Further investigation was carried out to know why this was so. The observation was posted on an X3DOM forum (at http://forum.instantreality.org/index.php). An administrator in the forum was of the opinion that this was caused by some self closing tags used with the nodes.

Other VRML virtual campus model and building files that have been produced earlier (as seen in section 2.4) were sought for on the web. These include the Nanyang Technological University Virtual Campus, the virtual Avcilar campus and the University of Sargodha virtual campus among others. Some of the Nanyang Technological University Virtual Campus files were eventually found and downloaded (available at http://cospace.sce.ntu.edu.sg/vircampus/). The VRML files contained binary data and could not be viewed in any text editor. For the other searches carried out on the web, virtual campus model VRML files were neither found nor accessible.
5.3 Results

A summary of the various model conversions done in the project and the results observed in X3D and HTML5 for all the models worked with is given below:

<table>
<thead>
<tr>
<th>Model/Building</th>
<th>X3D Conversion</th>
<th>HTML5 incorporation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hwu2 VRML campus model</td>
<td>Conversion of whole model</td>
<td>Extrusion, ProximitySensor,</td>
</tr>
<tr>
<td></td>
<td>successful</td>
<td>TouchSensor and node containing texCoordIndex not</td>
</tr>
<tr>
<td></td>
<td></td>
<td>supported</td>
</tr>
<tr>
<td>Hwu1 VRML campus model</td>
<td>Conversion of its files</td>
<td>Incorporation successful with the replacement of</td>
</tr>
<tr>
<td></td>
<td>successful</td>
<td>extrusions with boxes for the 9 buildings</td>
</tr>
<tr>
<td>Chester X3D building models (01-TownHall.X3D, 04-BellTower.X3D, 02-AbbeyGateway.X3D, 03-AbbeySquare.X3D)</td>
<td>-</td>
<td>The buildings contained nodes with texCoordIndex which</td>
</tr>
<tr>
<td></td>
<td></td>
<td>does not work in HTML5 as earlier discovered</td>
</tr>
</tbody>
</table>

**Table 5**: A summary of the various model conversions done in the project and the results observed in X3D and HTML5 for all the models worked with

The results for the performance evaluation (frame rate measurement in frames per second - fps) of the first and second prototypes are given below. An average of the observed estimated range is calculated as the frame rate varied on viewing and interacting with the prototypes.
<table>
<thead>
<tr>
<th>Operating System</th>
<th>Browser</th>
<th>Frame Rate Range (fps)</th>
<th>Average frame rate (fps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows OS</td>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>48.31 – 57.40</td>
<td>52.86</td>
</tr>
<tr>
<td></td>
<td>Mozilla Firefox 19.0.2</td>
<td>45.27 – 63.39</td>
<td>54.33</td>
</tr>
<tr>
<td>Linux OS</td>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>59.69 - 61.76</td>
<td>60.73</td>
</tr>
<tr>
<td></td>
<td>Mozilla Firefox 22.0</td>
<td>46.89 – 58.13</td>
<td>52.51</td>
</tr>
<tr>
<td></td>
<td>SeaMonkey version 2.17.1</td>
<td>52.42 – 57.98</td>
<td>55.20</td>
</tr>
<tr>
<td>Mac OS</td>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>55.78 – 58.21</td>
<td>57.00</td>
</tr>
<tr>
<td></td>
<td>Mozilla Firefox 21.0</td>
<td>43.99 – 49.62</td>
<td>46.81</td>
</tr>
</tbody>
</table>

**Table 6: First Prototype (Early morning testing)**

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Browser</th>
<th>Frame Rate Range (fps)</th>
<th>Average frame rate (fps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows OS</td>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>55.28 – 60.05</td>
<td>57.67</td>
</tr>
<tr>
<td></td>
<td>Mozilla Firefox 19.0.2</td>
<td>50.35 – 57.74</td>
<td>54.05</td>
</tr>
<tr>
<td>Linux OS</td>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>47.91 – 58.42</td>
<td>53.17</td>
</tr>
<tr>
<td></td>
<td>Mozilla Firefox 22.0</td>
<td>50.66 – 60.12</td>
<td>55.39</td>
</tr>
<tr>
<td></td>
<td>SeaMonkey version 2.17.1</td>
<td>51.87 – 59.43</td>
<td>55.65</td>
</tr>
<tr>
<td>Mac OS</td>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>40.08 – 45.08</td>
<td>42.58</td>
</tr>
<tr>
<td></td>
<td>Mozilla Firefox 21.0</td>
<td>41.25 – 44.59</td>
<td>42.92</td>
</tr>
</tbody>
</table>

**Table 7: First Prototype (Afternoon testing)**
<table>
<thead>
<tr>
<th>Operating System</th>
<th>Browser</th>
<th>Frame Rate Range (fps)</th>
<th>Average frame rate (fps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows OS</td>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>29.13 – 29.95</td>
<td>29.54</td>
</tr>
<tr>
<td></td>
<td>Mozilla Firefox 19.0.2</td>
<td>26.53 – 28.89</td>
<td>27.71</td>
</tr>
<tr>
<td>Linux OS</td>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>21.98 - 23.19</td>
<td>22.59</td>
</tr>
<tr>
<td></td>
<td>Mozilla Firefox 22.0</td>
<td>16.68 – 18.02</td>
<td>17.35</td>
</tr>
<tr>
<td></td>
<td>SeaMonkey version 2.17.1</td>
<td>15.73 – 17.13</td>
<td>16.43</td>
</tr>
<tr>
<td>Mac OS</td>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>14.12 – 14.26</td>
<td>14.19</td>
</tr>
<tr>
<td></td>
<td>Mozilla Firefox 21.0</td>
<td>10.19 – 10.73</td>
<td>10.46</td>
</tr>
</tbody>
</table>

**Table 8: Second Prototype (Early morning testing)**

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Browser</th>
<th>Frame Rate Range (fps)</th>
<th>Average frame rate (fps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows OS</td>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>27.17 – 28.30</td>
<td>28.74</td>
</tr>
<tr>
<td></td>
<td>Mozilla Firefox 19.0.2</td>
<td>21.94 – 25.89</td>
<td>23.92</td>
</tr>
<tr>
<td>Linux OS</td>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>18.70 – 20.33</td>
<td>19.52</td>
</tr>
<tr>
<td></td>
<td>Mozilla Firefox 22.0</td>
<td>16.57 – 17.65</td>
<td>17.11</td>
</tr>
<tr>
<td></td>
<td>SeaMonkey version 2.17.1</td>
<td>17.33 – 19.01</td>
<td>18.17</td>
</tr>
<tr>
<td>Mac OS</td>
<td>Google Chrome Version 27.0.1453.94m</td>
<td>15.39 – 15.63</td>
<td>15.51</td>
</tr>
<tr>
<td></td>
<td>Mozilla Firefox 21.0</td>
<td>11.04 – 11.76</td>
<td>11.40</td>
</tr>
</tbody>
</table>

**Table 9: Second Prototype (Afternoon testing)**
Charts

The Charts below show results for Google Chrome Version 27.0.1453.94m web browser which scored highest in the HTML5 test (see section 4.4).

Figure 37: Results for the performance evaluation of the prototypes on Windows OS for Google Chrome Version 27.0.1453.94m web browser
**Figure 38:** Results for the performance evaluation of the prototypes on Linux OS for Google Chrome Version 27.0.1453.94m web browser

**Figure 39:** Results for the performance evaluation of the prototypes on Mac OS for Google Chrome Version 27.0.1453.94m web browser
Comparing the two prototypes for the three operating systems, as seen in figures 37, 38 and 39 above, there was a significant reduction in the average frame rate. In Windows OS for instance, the average frame rate for the first prototype reduced from 52.86fps to 29.54fps for the morning measurement.

Also, as seen in figures 37, 38 and 39 above, the varying of measurement times (early morning and afternoon) to vary the effect of network latency in the three operating systems (as a result of load on the network) produced slight changes in the average frame rates except for that observed in the testing of the first prototype on Mac OS. In Linux OS for example, there was a slight reduction in the average frame rate by 7.56fps for the first prototype and 3.07fps for the second prototype.

The difference in the number of polygons rendered in the virtual campus scene for the first prototype (566KB in size) and second prototype (1.731MB in size) led to a significant reduction in the models’ average frame rates. The varied timing of the testing in order to vary the effect of network latency also produced a slight reduction in the average frame rate for the prototypes.

In this project, we have been able to

i. convert some VRML models to X3D using an online X3D encoding converter
ii. Incorporate the X3D files into HTML5 web pages
iii. Identify some nodes that are partially supported (Text) or not supported (Extrusion, ProximitySensor, TouchSensor, ROUTE and nodes containing texCoordIndex) by X3DOM in the X3D files
iv. Manually remodel the building extrusions in X3D with boxes (a primitive basic shape) supported by X3DOM
v. Build a first prototype consisting of the ground, 2 buildings, trees, other vegetation and lampposts at the reception which was tested with users and the performance in terms of frame rate evaluated
vi. Modify the first prototype to develop a second prototype consisting of a total of 9 buildings whose performance was also evaluated in HTML5 measuring the frame rate
6. Conclusions

6.1 Achievements

I. Project

The achievements of the project (numbered i – vi above) are matched with the earlier stated aims, objectives and initial requirements for this project.

We were able to make some part of the Heriot Watt University campus model that existed earlier in VRML viewable in an HTML5 compliant browser without any plug-in. X3D versions of the VRML models were produced. The online X3D encoding converter used (see Appendix 4 date 6/5/2103 in Project Diary) was able to convert all the VRML files that needed to be converted to X3D successfully.

However, the fact that all the three Heriot Watt campus models in VRML were modeled using mostly extrusions was not properly investigated. The further discovery that HTML5 did not support extrusions gave rise to another aspect in the project, the replacement of the extrusions with boxes. This development was the major contributing factor to our final decision of using the hwu1 VRML model has explained in section 4.2. Therefore, each building had to be remodeled one after the other in X3D by hand starting from the simple basic buildings to the more complex ones. This was carefully done so as to maintain the look of the earlier modeled buildings and textures and thus was time consuming.

The main file in VRML together with other VRML files it loads had to be individually converted to X3D and next to HTML5 one after the other. Individual evaluation in X3D, incorporation into an HTML5 webpage and evaluation of the HTML5 model had to be done as each of the files is loaded from a new main file in X3D. This led to only a total of 9 buildings incorporated into HTML5 pages together with the ground, lampposts at the reception, trees, and other vegetation. This does not represent the entire Heriot Watt Campus model but as stated in our mandatory requirements, the geometry of the campus model and look was managed as much as possible to maintain the realistic appearance of the campus. Some textures found missing in the earlier developed model was replaced
with suitable ones that were not large so as to minimize the entire size of the model as much as possible.

We were also able to perform both user evaluation and performance evaluation of our developed prototypes. The first prototype was tested with users. Though some users pointed out navigation and collision detection issues with our HTML5 prototype, not much could be done about this as these are issues with the HTML5 technology but improvement was made to the appearance of the buildings as also suggested by some users. Performance evaluation of the first and second prototypes was done on different operating systems and web browsers measuring the frame rates also as required. The average frame rates observed and network latency was also acceptable unless for that observed in Mac operating system that dropped to as low as 14.19fps for the second prototype testing. This is below the over 20fps frame rate measurement for acceptable viewing for 3D models as stated in our mandatory requirement.

II. Skills learnt

Previous knowledge before the start of this project include modeling objects in X3D using primitive shapes (box, sphere and cone) and web page design in HTML. The new skills learnt embarking on this project are modeling concepts in VRML, X3D and HTML5 (their node types and syntax) and modeling buildings in X3D by hand using Submarine and Octaga Player. Also, skills in creating HTML5 web pages with embedded X3DOM scene and working with X3D building models in X3D Edit were learnt. Project management skills involving planning, risk management and project evaluation were also acquired embarking on this project.

6.2 Shortcomings

The project tended towards remodeling buildings which was not initially envisaged and this was time consuming. It is believed that those that earlier modeled the hwu, hwu1 and hwu2 Heriot Watt Campus models chose to use Extrusions for certain reasons. However, the discovery that the HTML5 technology does not support the Extrusion node gave this project a different turn. The decision to overcome this problem was to replace the extrusions with
boxes (primitive shape). Also, the hwu2 VRML campus model that was chosen and initially worked upon for a period of time had to be changed to the hwu1 VRML model.

The HTML5 technology and the nodes it did not support gave this project some restrictions. Asides the Extrusion issue with the buildings, maps and tour guide could not be implemented in the prototypes because HTML5 did not support it.

Also, users pointed out during the first prototype evaluation that there was difficulty with the navigation controls that was used. All users navigated the virtual campus with the laptop touchpad made available to them. As stated earlier in the mandatory requirements for this project, the navigation system chosen should not be difficult to use in order to make users have a good experience in a virtual environment. The use of a mouse for the navigation controls could have made navigation of the prototype easier for the users.

Time had to the allotted to evaluation with users and also performance evaluation of the first and second prototype. Therefore, only a total of nine buildings together with the trees, garden, lamp posts at the reception and some vegetation on the campus were able to be incorporated in HTML5. This does not represent the entire Heriot Watt Virtual Campus as earlier modeled in VRML.

### 6.3 Possible extensions

In this project, some of the tasks carried out include converting of some VRML building models to X3D using an online X3D encoding converter, incorporating the X3D files into HTML5 web pages and identifying the nodes that are partially supported (Text) or not supported by X3DOM in the X3D files (such as the Extrusion, ProximitySensor, TouchSensor, ROUTE and nodes containing texCoordIndex). Also, remodeling of the affected buildings was done in X3D by the manual replacement the extrusions with boxes (a primitive shape) supported in HTML5. Next, these reconstructed buildings were reincorporated into HTML5 web pages.

A project could be set up to automate the workflow of activities highlighted above. This system would have a VRML model fed into it to produce an HTML5 compatible 3D model. If there are nodes that are not supported in HTML5 during the conversion process, the
system would identify such nodes for the user and possibly make suggestions as to what needs to be done to produce an HTML5 compatible model.

Another project could look into automating how buildings modeled with extrusions could be remodeled with primitive shapes (boxes for example) still maintaining the look of such a building model as was done manually in X3D in this project.
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Appendices

Appendix 1 – Preliminary investigation of HTML5

Available at view-source:http://x3dom.org/x3dom/example/x3dom_helloWorld.xhtml

<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
  "http://www.w3.org/TR/xhtml1/DTD/xhtml1strict.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
  <head>
    <meta http-equiv="X-UA-Compatible" content="chrome=1" />
    <meta http-equiv="Content-Type" content="text/html;charset=utf-8" />
    <title>Hello World</title>
    <link rel="stylesheet" type="text/css" href="x3dom.css" />
    <script type="text/javascript" src="x3dom.js"></script>
  </head>
  <body>
    <h1>XHTML Hello World</h1>
    <p>
      With X3D-namespace and case sensitive element/node names. Works with self-closing tags (e.g. Viewpoint and Material)
    </p>
    <X3D xmlns="http://www.web3d.org/specifications/x3d-namespace" showStat="false" showLog="false" x="0px" y="0px" width="400px" height="400px" altImg="helloX3D-alt.png">
      <Scene>
        <Viewpoint position='0 0 10' />
        <Shape>
          <Appearance>
            <Material diffuseColor='0.603 0.894 0.909' />
          </Appearance>
          <Box DEF="box" />
        </Shape>
      </Scene>
    </X3D>
  </body>
</html>
A view of the VRML hwu model

view of the VRML hwu1 campus model
A view of the VRML hwu2 campus model

The VRML hwu2 campus model showing a map for location guide
Appendix 3 – Prototype development (Screen shots)

First prototype development (Extrusions not supported in HTML5)

Final first prototype with vegetation, ground, reception lamp posts and two buildings
Second Prototype Reception view
Second prototype - closer view on some of the buildings
Second Prototype Sunken Garden View

Heriot Watt Virtual Campus

Second Prototype – View of the Printing services and Purchasing office buildings
Appendix 4 – Project Diary

06/02/2013 Conversion of the hwu model in VRML to X3D using X3D edit version 3.3
My supervisor has earlier sent me a link (http://www.macs.hw.ac.uk/~ruth/campus-models/) containing three different files which are three earlier developed campus models in VRML (hwu, hwu1, and hwu2). I downloaded and worked with the hwu model for early investigation. The main.wrl and main-old.wrl files were imported into X3DEdit and converted to main.X3d and main-old.X3d files respectively. Download of textures also from Ruth Aylett’s (My supervisor’s) website and put in the same folder as the main.X3d and main-old.X3d

07/02/2013 Octaga Player could not load some textures
Some textures were missing in the original files on Ruth’s website. These textures were referenced in the main programs. Octaga player gave warnings about these missing textures. The campus model was able to load and be viewed in octaga player in the MACS G.46 laboratory. Some flickering was observed in the model.

The model could not load and be viewed on my computer system (laptop). This could be because the G.46 lab’s computer system had more processing power and had more components installed to view large 3D models.

My laptop Configuration
Operating system: Windows 7 starter 32-bit (6.1, Build 7601)
Processor: Pentium (R) Dual-Core CPU T4500 @ 2.30Ghz (2 CPUs)
Memory: 2048MB RAM
Page File: 1657MB used, 2294MB available
Direct X Version: DirectX 11

Lab System Configuration
Operating system: Windows 7 Professional 64-bit (6.1, Build 7601)
Processor: Pentium (R) Core (TM) i7-2600 CPU @ 3.40Ghz (8 CPUs)
Memory: 8192MB RAM
Page File: 2323MB used. 13947MB available
DirectX version: DirectX 11

13/02/2013 Replacing the missing textures with similar textures
This is done to ensure that there are no bugs before this X3d file is incorporated into an html5 web page. The next stage will be to try taking a small section or part of the model to incorporate into an HTML5 page as a first prototype.

25/02/2013 – Project Report write up for Research Methods and Project Planning (F21RP)
Weekly meeting with my project supervisor for the project write up and subsequent progress with the project. Also was able to investigate how X3D codes could be incorporated into an HTML5 web page.
02/05/2013 Meeting with supervisor
I had a meeting with Ruth. The way to incorporate X3D codes into an HTML5 page is to embed the X3D codes within the HTML codes. Haven investigated HTML5 and how it works with X3D, the next step will be to find a way to partition the large model. Also, I will need to create a web page for my project for

1. My supervisor to view my progress with the project (partitioning the model and developing the prototypes in stages).
2. Users who will evaluate the prototype subsequently would be logged on to this web pages

My Heriot watt web space would be used for this (http://www2.macs.hw.ac.uk/~oss30/). Logging on to this web site would also be like accessing the intended virtual campus model on the web.

03/05/2013 Investigating the campus models for partitioning
The link Ruth has three different campus models that were coded in VRML (hwu, hwu1 and hwu2). They contained textures and wrl files. It was therefore necessary to examine these models to know which one will be easier to partition so as to subsequently incorporate it into an HTML5 page in stages. The other folders (hwu1 and hwu2) and their contents have to be download and all examined properly.

05/05/2013 Download of the folder hwu1 and all the files it contains

06/05/2013 Partitioning the model

The three virtual campus models are studied to know which will be most suitable for partitioning the model and incremental incorporation into an HTML5 page. Properties of like the sizes of the models and their contents were considered. hwu2 was selected to be partitioned because it has a size of 4.72MB and it also has a navigation guide.

Early investigation into HTML5 showed that it has a 5MB web storage limit and hwu2 is not as large as that. Also, the navigation and map the hwu2 campus model has could be useful subsequently to help users that will evaluate the prototype navigate the virtual campus more easily in an HTML5 page.

The main file in VRML (main.wrl) and other textures of hwu2 were downloaded and main.wrl was converted to X3D using the X3D encoding converter at http://doc.instantreality.org/tools/x3d_encoding_converter/

This X3D encoding converter will subsequently be used for the conversion of the VRML files (.wrl) to X3D files (.x3d).

Evaluation of the X3D file produced

The X3D model was viewed in Octaga player on a system in the G.46 MACS Computer lab. There were some warnings about missing textures and files which to which reference was made in the model. The model still loaded and could be viewed successfully. Most of the textures loaded well. However, some flickering was observed as the model was interacted with.

At this developmental stage, we are concerned primarily about scaling down the model to incorporate a small part into an HTML5 page so the flickering and missing textures could be looked into later in the project.
Work on the incremental scaling of the X3D model could be done on my laptop computer system while the laboratory system would be used to view larger models and also to access and test the model on my Heriot Watt web space.

07/05/2013 Scaling up of the model through incremental top-down running of the X3D codes

Submarine X3D Version 2.0 and an open source X3D Graphics Authoring software, X3D-Edit 3.3 installed on my laptop computer system were used for this.

In X3D – Edit, one could view the whole scene graph separated into nodes (Groups, Transforms and Scripts). Octaga player in Submarine X3D was used to view the extracted nodes copied bit by bit from X3D – Edit.

The new X3D model (main.X3d) is made up of 7,803 lines of code in X3D – Edit. Block of codes (Nodes) from line 1 will then be next viewed independently in Submarine X3D to see what they represent in the real model as a bit and also test incorporating them into an HTML5 page from time to time to see if it loads.

The nodes were copied and viewed in groups (lines 1-169, 170-183, 184-191, 200 -209 till line 540). They consisted of Shape nodes with IndexedListFaceSet, Extrusions and textures. This was the model background and a few buildings which worked and loaded in HTML5.

The viewpoints and positions of the objects in the model so far was maintained as changing it would affect the relative positions of each building/polygon and distort the overall campus model.

This would be the first stage in the development of the first prototype.

Model Evaluation in HTML5

The X3D codes (lines 1 to 540 altogether) was saved as an XHTML web page with X3D codes embedded within HTML codes using X3D-Edit. The textures loaded correctly. However, some parts of the buildings loaded (the walls and its textures) which were visible in X3D are missing in HTML5. The reason for this has to be investigated before any further progress could be made.

09/05/2013 Joined Instantlabs InstantReality 2.0 Forum

Further investigation pointed out that the nodes containing extrusions were not visible in HTML5. I joined the Instant reality forum at http://forum.instantreality.org/index.php to find a way around this.

The options that came up were

- To convert the extrusions and every other parametric 3D objects e.g. Spheres and text to IFS.
- Export the model fromm3ds max to xhtml. X3d exporter can export extrusions as IndexedListFaceSets.

Further investigation was made into this but these did not work out

14/5/2013 X3D- Edit points out HTML5 does not support Extrusions, ProximitySensor and TouchSensor
The X3D model was exported as an XHTML page in X3DOM scene in X3D-Edit. X3DOM pointed out the nodes that were not supported in HTML5 which are

- Extrusion
- Proximity Sensor
- Touch Sensor

16/5/2013 Further incremental development

The next decision was to continue with the model development to discover what other parts of the model will work and those that would not in HTML5. The nodes in lines 541 to 7803 will next be tested incrementally.

17/5/2013 Lines 541 to 679 tested and worked

19/5/2013 Lines 680 to 699 is tested.
It loads initially in Octaga player version 4.0 on my laptop computer system but crashes when the model is interacted with.

21/05/2013 The model loaded well in Octaga player version 3.0 on the G. 46 lab computer
The textures were fine and interaction was easy with the model. Interaction was now possible with the model to examine the buildings.
Lines 700 to 719 was tested. It worked in HTML5.
This would be the second stage in the development of the first prototype.
Lines 720 to 752 when added to all the initial codes did not work. This had to be investigated.
The following were suspected:

- Size of the model had reached the 5MB HTML5 limit
- Texture mapping that occurred within the block of code made it not to work

It was later discovered that the block of codes contained texCoordIndex which is not supported by the X3DOM scene in HTML5.

Lines 753 to 762 and 763 to 798 did work when added and tested in HTML5.

22/05/2013 Meeting with my Supervisor (Ruth Aylett) and Second Reader (Andrew Ireland)
I got feedback on my project report and we discussed on the progress the project. Ruth advised I find a way around implementing the extrusions by replacing the entire walls of the buildings with basic shapes (for example rectangles) which would be textured the same way as the extrusions. Another suggestion was I deal with the model building by building to solve this problem. This way, it will be necessary to look all through the whole model to see which buildings were modeled with extrusions and which were not. The buildings with extrusions will then be remodeled replacing the extrusions with rectangles. Almost all the buildings were modeled with extrusions.

The hwu2 model chosen to be worked with earlier has a single main file (main.wrl) in which all the codes were written all together top-down. It contained 7803 lines of VRML code. Though it was well commented in VRML, converting it to X3D left out the comments. In X3D therefore, it will not be easy to know what each group of code mapped to in the actual overall campus model. The earlier approach was to run the codes incrementally in bits a chunk at a time which worked until it was discovered that the X3D extrusions were not supported in HTML5.
It would now be better to use the hwu1 model. This is because it is not top down straight coding like the hwu2 model. It is modular having a main.wrl file that links to other VRML files using INLINE linkage tag. Most of the other wrl files linked to are the campus model buildings. They could therefore now be considered in isolation one after the other. Working on them individually and then linking to them from a main X3D file will be the way out.

The INLINE tag would link the main file to the other VRML (.wrl) files representing the buildings and other parts of the campus model.

23/5/2013  Working on the component wrl files in the hwu1 campus model

All .wrl files in the hwu2 model were inspected and their models viewed. It would be better to work on the simple basic buildings to first replace the extrusions (walls) with rectangles before moving on to the more complex buildings. The following wrl files that their walls could be replaced by boxes were shortlisted.

4-launderette.wrl
10-pentlandhouse.wrl
11-linlithgowhouse.wrl
12-midlothianhouse.wrl
14-medisstudio.wrl
15-s1.wrl
24-medicalcenter.wrl
33- purchasingoffice.wrl
36-printingservices.wrl
45-n1.wrl
46-n2.wrl

The approach will be to convert them to X3D and then replace the extrusions with boxes with the same textures. Each would subsequently be tested to know if it can be incorporated into HTML5. If so, it will then be linked from a main file in X3D.

The file named 56-vegetation.wrl was converted to X3D using the X3D encoding converter earlier mentioned above and it worked fine.

It also works fine when incorporated in an HTML5 page.

The following now has to be investigated:

- If X3D supports inline as VRML so the main.wrl that links other wrl files in VRML will be converted to X3D and now link the other files which also will be converted to X3D
- If X3DOM supports inline because the new main X3D file will be incorporated into an HTML5 page making calls to other X3D files

X3D supports inline. Xhtml page with X3DOM embedded supports inline using the DEF statement.

The main.wrl file links other wrl files in the hwu1 campus model. The wrl files it loads are commented out and added in one after the other to be tested.
Conversion to HTML5
The new main X3D file was opened in X3DEdit 3.3 Editor suite and exported as an XHTML page with embedded X3DOM scene.

X3D conversion Evaluation
The trees and the floor texture loads successfully. Some flickering occurred in the model. The reception building with its floor textures loads well at some time and does not sometime. X3D loaded the wrl files with the INLINE tags. These include the lamp at the reception and the avatar with its sound and animation. They worked fine in X3d.

Evaluation in X3DOM
X3DOM reported some unsupported and partially supported nodes

Unsupported nodes found

• ProximitySensor
• ROUTE
• TouchSensor

Partial Support

• Text

X3DOM did not load the .wrl files (reception, avatar, vegetation and lamp) referenced using INLINE like X3D.
The possible solutions would be to either

• Convert the wrl files to X3d and load them in X3DOM using the INLINE tag or
• Convert the wrl files to X3D and embed the lines directly in X3DOM

Converting the wrl files to X3D and loading them using the INLINE tag within the main X3D file embedded in X3DOM works.
The files vegetation.X3d and 55-lamp.x3d loads well in X3DOM.

25/5/2013 Investigate Incorporation of the Reception and other buildings
texCoordIndex was not supported in X3DOM as earlier suspected. X3DOM only supports IndexedFaceSet with CoordIndex.

26/05/2013 Replacing the extrusions in the buildings with basic shapes (boxes)
This would be done carefully to ensure that the respective position of each building in the overall model is maintained. The same textures on the extrusions will also be used on the boxes to try to obtain the realistic appearance of the buildings in the virtual campus.

Work was done on launderette.wrl. This was first converted to X3D using the online converter earlier mentioned. In X3D, 2 extrusions were replaced by 2 boxes. It was ensured the boxes fitted rightly in the xyz-plane under the roof.

31/05/2013 Work on building medisstudio.wrl
It was converted to X3D. It had 1 extrusion for its wall. This was replaced by 2 boxes given the
same texture as the extrusion. Haven incorporated 2 buildings in addition to the ground, vegetation, trees and lamp at the reception this would all be tested with users as the first prototype.

2/6/2013 Design of Evaluation questionnaire and consent form

3/6/2013 Browsers’ HTML5 test on Windows and Linux Operating Systems

For the Windows operating system test, a computer in the MACS G.46 laboratory was used. The browsers tested are Google Chrome 27, Mozilla Firefox 19.0.2, Internet Explorer 9 version 9.0.8112.16421 and Safari 5.1.5.

For the Linux operating system test, a computer in the Linux lab 2.50 was used. The browsers tested are Google Chrome 27, Mozilla Firefox 21, Opera version 12.15 and SeaMonkey version 2.17.1.

Meeting with supervisor (Ruth Aylett)
What would be evaluated in the model was discussed. It would also be better to make use of viewpoints to get the users close to the two buildings, trees and vegetation to be evaluated. Users would not have to navigate the entire large model more so there is not much on the virtual campus at this level.

Ruth observed a wall texture not placed well. This would also be fixed before testing the virtual campus first prototype.

6/6/2013 The wall texture which was wrongly rotated was fixed

7/6/2013 7 different viewpoints where created to show various views to start users off for navigating the model

8/6/2013 Performance evaluation of the virtual campus prototype

Investigation into how the Performance evaluation of the prototypes would be carried out. This includes how to test network and internet latency (lag) in network on Windows, Linux and Mac operating systems.

An approach is to perform a ping test to determine the latency in accessing the model on my web space. The link to my web space (http://www2.macs.hw.ac.uk/~oss30/) could not be accessed with the ping test.

9/6/2013 Browsers’ HTML5 test on Mac Operating System

A computer system with Mac OS running on it had to be sought for because this was not available in the MACS laboratories in the university.

A laptop computer system was eventually sourced to be used having the following configuration:

System Configuration
Mac OS
Version 10.6.8
Processor: 2.4GHz Intel Core 2 Duo
Memory: 2GB 1067 MHz DDR3
The browsers tested were Google Chrome 27, Mozilla Firefox 21.0, and Safari 5.1.7.

10/6/2013 User testing and evaluation of the first prototype with questionnaire and observed performance note taking. The URLs for the 7 different viewpoints created for the model are:

http://www2.macs.hw.ac.uk/~oss30/hwu1/TheReceptionView.xhtml
http://www2.macs.hw.ac.uk/~oss30/hwu1/TheAvenueView.xhtml
http://www2.macs.hw.ac.uk/~oss30/hwu1/SunkenGardenView.xhtml
http://www2.macs.hw.ac.uk/~oss30/hwu1/SouthWestResidenceView.xhtml
http://www2.macs.hw.ac.uk/~oss30/hwu1/EdinburghBusinessSchoolView.xhtml
http://www2.macs.hw.ac.uk/~oss30/hwu1/RiccartonLochView.xhtml
http://www2.macs.hw.ac.uk/~oss30/hwu1/OverviewFromSouthWest.xhtml

12/6/2013 User testing finishes with the last 3 users out of a total of 8. The project documentation also commences. My supervisor (Ruth) is away from the university. Further communication on the progress of the project would be via email

16/6/2013 Typing of my project write up begins

17/6/2013 Users evaluation and prototype modification
Under listed are the key observations and suggestions of the users that tested the first prototype that would help to improve the model:

- Walking through the two buildings
- The graphics, textures and door look dated
- The buildings looked basic. There is need for them to be enhanced
- The quality of the buildings need improvement
- The roof needs improvement in its symmetry
- Errors occurred moving close to the buildings
- The walls of the buildings became transparent on getting too close to the walls

From these observations and suggestions, the following needs to be looked into for improvement

- Collision detection and boundaries for the building
- Antialiasing
- Windows and doors needs to be placed on the buildings to make them look more realistic.

Though the two buildings in the initial model did not have windows and doors fixed, this has to be done to further improve the prototype.

Investigating the Collision Detection

It was discovered that X3DOM supports the collision node. The collision detection and boundaries worked fine in X3D. It seems like the collision detection and boundaries works initially in X3DOM
because the walls of the buildings repel but eventually give way after much persistence on trying to walk through them.

**Implementing the map and tour guide**

The hwu1 model has a map and tour guide pointing to various locations of the virtual campus. It was earlier projected that this could be used to achieve easier user navigation in the virtual campus prototype incorporated in HTML5. This would not be possible because X3DOM does not support the ProximitySensor and TouchSensor nodes.

**Investigating Antialiasing**

Investigation into how antialiasing could be implemented in X3D and/or X3DOM was carried out. A way around this could not be found. Further work will be done to improve the quality and appearance and quality of the buildings.

**19/6/2013 Fixing Windows and doors on the buildings**

Windows and doors were fixed on the 2 buildings (launderette.x3d and medisstudio.x3d). This was done by the addition of more boxes which were given a window and door texture taken from images in the hwu1 model.

**20/6/2013 Work on other buildings**

Work was done on the 15-s1.wrl building. It was converted to X3D using the X3D encoding converter website mentioned earlier.

**Evaluation in X3D**

It was okay in X3D.

2 extrusions representing the walls and the roof were replaced by 6 boxes on which textures that were applied to the extrusions were applied.

The building 33-purchasingoffice.wrl was also converted to X3D as above.

**Evaluation in X3D**

It was okay in X3D.

The building consists of 2 extrusions representing the walls. These extrusions were replaced with two boxes textured similarly as the extrusions.

**22/6/2013 Work on building 36-printingservices.wrl**

The building 36-printingservices.wrl was converted to X3D using the X3D encoding converter website.

**Evaluation in X3D**

It was okay in X3D.

2 extrusions representing the walls were replaced by 2 boxes textured similarly as the extrusions.

The 5 buildings worked on so far would be incorporated and tested in HTML5. They were loaded into the existing developed prototype using the INLINE tag. They all load successfully in HTML5.

The IndexedFaceSet (flat surface obtained from plotted points in the xyz-plane from which the
building is projected upwards) that are not textured can now be deleted haven served as a guide to place the boxes in the right position under the roof for the building. This approach would then be used similarly for subsequent buildings worked upon.

24/6/2013 Work on building 10-pentlandhouse.wrl
The building 10-pentlandhouse.wrl was converted to X3D using the X3D encoding converter website.

Evaluation in X3D
It was okay in X3D.

It consists of 7 extrusions and 2 IndexedFaceSet. These were replaced by 30 boxes which were given the same textured as the extrusions and IndexedFaceSet that were replaced.

Flickering earlier observed
The flickering in X3D observed in the hwu2 model worked on earlier (See above on 06/05/2013) could be caused by the IndexedFaceSet on top of the buildings that were not textured. Such IndexedFaceSet if found in any building would subsequently be textured or deleted to avoid flickering in the developed prototype.

27/6/2013 Work on building 11-linlithgowhouse.wrl
The building 11-linlithgowhouse.wrl was converted to X3D using the X3D encoding converter website.

Evaluation in X3D
It was okay in X3D.

The building is made up of 7 extrusions and 2 IndexedFaceSet. This is replaced by 39 boxes on which the same textures applied to the extrusions and IndexedFacesets were applied.

The X3D files for pentlandhouse and linlithgowhouse were next incorporated into HTML5. This was done using the INLINE tag.

The 2 buildings load well in HTML5. A texture rotated wrongly was fixed.

28/6/2013 Work on building 24-medicalcenter.wrl
The building 24-medicalcenter.wrl was converted to X3D using the X3D encoding converter website.

Evaluation in X3D
It was okay in X3D.

The building is made up of 1 extrusions and 2 IndexedFaceSet. This is replaced by 3 boxes on which the same textures applied to the extrusions and IndexedFacesets were applied.

29/6/2013 Work on building 12-medlothianhouse.wrl
The building 12-medlothianhouse.wrl was converted to X3D using the X3D encoding converter website.

Evaluation in X3D
It was okay in X3D.
The building is made up of 7 extrusions and 2 IndexedFaceSet. This is replaced by 52 boxes on which the same textures applied to the extrusions and IndexedFaceSets were applied.

Developments till this point would be our second prototype with the addition of seven more buildings. Viewpoints for the second prototype were created like that of the first prototype. The URLs to these on Heriot Watt web space are:

http://www2.macs.hw.ac.uk/~oss30/hwu1/SecondPrototypeLeonardHornerHallView.xhtml
http://www2.macs.hw.ac.uk/~oss30/hwu1/SecondPrototypeOverview.xhtml
http://www2.macs.hw.ac.uk/~oss30/hwu1/SecondPrototypeReceptionView.xhtml
http://www2.macs.hw.ac.uk/~oss30/hwu1/SecondPrototypeRiccartonLochView.xhtml
http://www2.macs.hw.ac.uk/~oss30/hwu1/SecondPrototypeSWResidenceView.xhtml
http://www2.macs.hw.ac.uk/~oss30/hwu1/SecondPrototypeSunkenGardenView.xhtml

1/7/2013 First prototype Performance Evaluation
X3DEdit as earlier mentioned can enable export of an X3D file as an XHTML page with an embedded X3DOM scene.

The first prototype is basically made up of a main.X3d file that loads 2 buildings (laundrette.X3d and medisstudio.X3d), vegetation.X3d and lampposts at reception (55-lamp.X3d) using the INLINE tag. All the codes of these X3d files is loaded directly into main.X3d without using the INLINE tag so that X3DEdit loads just one X3D file (main.X3d) which contains all that is in the first prototype. This single file (main.X3d) is then opened in X3DEdit 3.3 and exported as an XHTML page with embedded X3DOM scene and saved. This way, X3DOM would make the frame rate and all other parameters involved in viewing the model visible. The web page is then put into my web space (see 2/05/2013). This would be used for the first prototype performance evaluation.

3/7/2013 Project write up

4/7/2013 Meeting with Supervisor
We discussed about the progress with the second prototype and performance evaluation. This would include the measurement of frame rates.

It would be better to navigate the model moving from one point to the other and then observe and record the frame rate. It is expected the higher the number of polygons rendered and the more the load on the network, the lower the frame rate.

The frame rates we obtained with the first prototype were okay.

Further test with a different model – Chester building models
It would be good to further test a higher polygon model to know its performance in HTML5.
We would test some buildings of the Chester model.
Ruth sent a link to view some of these models. (http://www.macs.hw.ac.uk/~ruth/vrml-examples)
8/07/2013 Work on the Chester Model Buildings (01-TownHall.X3d)
Size of the model with textures – 1.48MB
The building 01-TownHall.X3d consists of large chunks of IndexedFaceSet Descriptions. Also, it was modeled with the use of DEF and USE nodes.

X3D Evaluation
It was viewed in the MACS lab room G.46 on one of the computer systems. The textures load well. Viewable and can be interacted with in X3D using Octaga player. Level of detail was observed as the model loaded the textures only when it is close to the viewer.

X3DOM Evaluation
All the nodes seem to be supported by X3DOM but nothing is visible on the canvas. These nodes are Appearance, Coordinate, Group, Image Texture, IndexedFaceSet, LOD, Material, NavigationInfo, Normal, Shape, TextureCoordinate and WorldInfo.

9/7/2013  Project Writeup

10/7/2013 Meeting with Supervisor
The structure of the project write up was discussed. It would be also good to know why the TownHall building did not work in HTML5.

12/7/2013 Second Performance Evaluation
The second performance evaluation was done just as the first performance evaluation (see at 1/7/2013). The codes for 7 additional buildings (s1.x3d, pentlandhouse.x3d, midlothianhouse.x3d, printingservices.x3d, purchasingoffice.x3d, medicalcenter.x3d and linlithgowhouse.x3d) were directly into the main file (main.x3d).

13/7/2013 Testing the other Chester model buildings
Work was done to try to incorporate other Chester buildings (04-BellTower.x3d, 02-AbbeyGateway.X3d, 03-AbbeySquare.x3d) which are X3d files into HTML5. They all load in X3D but do not in HTML5.
A single shape node in 02-AbbeyGateway.X3d was tested to see if this small bit would work. It was observed that all the buildings had a node which did not work as earlier discovered in the project (see date 21/5/2013). This has to do with some texture mapping (nodes containing texCoordIndex).
This observation was posted on the instant reality forum I earlier joined (see date 9/5/2013). An administrator of the forum was of the opinion that this was due to the use of self closing tags in the code and this does not work in HTML.

15/7/2013 Performance Evaluation continued
It would be good to test the performance of the first and second prototype without the influence of the internet because of the effect of network lag. This can be done by testing the performance of the prototypes offline locally on a computer system. This would not be done because the textures would did not load while viewing the prototypes this way. The performance evaluation will therefore be done online to load the textures as the textures are important in the prototypes. The prototypes would be put on my web space and tested and accessed.

The total size of the first and second prototype including their textures was recorded.
First prototype - 667kB size on disk
Second prototype - 1.73MB size on disk

Meeting with Supervisor
The performance evaluation would be done at 2 different times in the university

- Early in the morning (when the load on the network is not much) and
- In the afternoon (when there could be more load on the network)

Subsequent work will be a not too in-depth investigation into other building models available to know what works and what does not.

19/7/2013 Performance evaluation of the first and second prototypes
This was done on the selected browsers on Windows, Mac and Linux operating systems. Estimated frame rates were recorded at the two different test times (early morning and afternoon).

20/7/2013 Performance evaluation testing of the first and second prototype was done on a laptop with Mac OS. The procedure followed was the same as done on the Linux and Windows OS.

21/7/2013 Project Writeup
Appendix 5 – Evaluation Consent Form

Form of Consent: Virtual Campus in HTML5

I, Salako Oluwatimilehin, formally request your participation to the evaluation of my project: Virtual Campus in HTML5.

A Heriot Watt University virtual campus model exists in Virtual Reality Markup Language (VRML). The aim of this project is to make it viewable in any HTML5 compliant browser without any plug-in.

- First, you will be logged on to the developed campus model URL (http://www2.macs.hw.ac.uk/~oss30/hwu1/) using an HTML5 compliant browser. Seven different viewpoints of the campus are provided on this page.
- You will then navigate around the virtual campus views to examine the vegetation, ground and the two buildings
- Finally you will complete a questionnaire commenting about what you thought of your experience

You are free to stop the experiment and leave at any time if you wish, without having to give any reason.

The questionnaire data and other records obtained from you in this evaluation will be kept private and anonymous for the purpose of this research.

By signing below you agree to the conditions aforementioned:

Name: ……………………………………………………………………
Date: ………………………………………………………………………
Signature:
### Evaluation Questionnaire

#### I. The System

<table>
<thead>
<tr>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>How responsive was the system to your actions?</td>
</tr>
<tr>
<td>How would you rate your visual experience?</td>
</tr>
<tr>
<td>What is the best or worst thing about the system?</td>
</tr>
</tbody>
</table>

#### II. The Campus Model

<table>
<thead>
<tr>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>How would you rate the buildings’ appearance?</td>
</tr>
<tr>
<td>How would you rate the ground’s appearance?</td>
</tr>
<tr>
<td>How would you rate the vegetation’s appearance?</td>
</tr>
<tr>
<td>What is the best or worst thing about the campus model?</td>
</tr>
<tr>
<td>Feature</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>System responsiveness to user’s actions</td>
</tr>
<tr>
<td>Visual Experience</td>
</tr>
<tr>
<td>Buildings’ appearance</td>
</tr>
<tr>
<td>Ground’s appearance</td>
</tr>
<tr>
<td>Vegetation’s appearance</td>
</tr>
<tr>
<td>Other features not listed above</td>
</tr>
</tbody>
</table>
### Evaluation Questionnaire

<table>
<thead>
<tr>
<th>Feature</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>How responsive was the system to your actions?</td>
<td>Not easy to close to the item (maybe not fixed yet)</td>
</tr>
<tr>
<td>How would you rate your visual experience?</td>
<td>Building 1 too dim</td>
</tr>
<tr>
<td>What is the best or worst thing about the system?</td>
<td>I like the tree!</td>
</tr>
</tbody>
</table>

### The Campus Model

<table>
<thead>
<tr>
<th>Feature</th>
<th>Comment/observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>System responsiveness to user's actions</td>
<td>There are issues with navigating in the environment for the user. She does not find it easy going around.</td>
</tr>
<tr>
<td>Visual Experience</td>
<td>All the scenery looks great inside the appearance of buildings</td>
</tr>
<tr>
<td>Buildings' appearance</td>
<td>Keep away from buildings, people could walk through (meditation)</td>
</tr>
<tr>
<td>Ground's appearance</td>
<td>The all green ground emphasis the river. Inclusivity roads will be helpful</td>
</tr>
<tr>
<td>Vegetation's appearance</td>
<td>Trees/wood vegetation are good and detailed</td>
</tr>
<tr>
<td>Other features not listed above</td>
<td>People sitting under the tree</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feature</th>
<th>Comment/observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>How would you rate the buildings' appearance?</td>
<td>Sometimes there is some error in view, particularly when the camera is very close to the building</td>
</tr>
<tr>
<td>How would you rate the ground's appearance?</td>
<td>Small some areas, e.g. roads with others, look</td>
</tr>
<tr>
<td>How would you rate the vegetation's appearance?</td>
<td>Small! Shows some level of detail in the trees</td>
</tr>
<tr>
<td>What is the best or worst thing about the campus model?</td>
<td></td>
</tr>
</tbody>
</table>

---

Appendix 7 – Filled Questionnaires and observed performance notes
**Evaluation Questionnaire**

<table>
<thead>
<tr>
<th>I. The System</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>How responsive was the system to your actions?</td>
<td>Difficult to turn left and right, I would implement separated controls for &quot;moving&quot; and &quot;turn around your head&quot;.</td>
</tr>
<tr>
<td>How would you rate your visual experience?</td>
<td>70-75%</td>
</tr>
<tr>
<td>What is the best or worst thing about the system?</td>
<td>The controls</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. The Campus Model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>How would you rate the buildings' appearance?</td>
<td>They were OK</td>
</tr>
<tr>
<td>How would you rate the ground's appearance?</td>
<td>It could be improved with paths etc.</td>
</tr>
<tr>
<td>How would you rate the vegetation's appearance?</td>
<td>Some trees looked with low resolution</td>
</tr>
<tr>
<td>What is the best or worst thing about the campus model?</td>
<td>Some trees were quite good.</td>
</tr>
</tbody>
</table>

**Observed Performance Notes**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Comment/observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>System responsiveness to user's actions</td>
<td></td>
</tr>
<tr>
<td>Visual Experience</td>
<td></td>
</tr>
<tr>
<td>Buildings' appearance</td>
<td></td>
</tr>
<tr>
<td>Ground's appearance</td>
<td>Not bad, some details but okay.</td>
</tr>
<tr>
<td>Vegetation's appearance</td>
<td>Are okay, very good. Little bit of adjustment to some plant base: More resolution</td>
</tr>
<tr>
<td>Other features not listed above</td>
<td>Navigation: Always moving forwards. Perhaps arrow keys would help.</td>
</tr>
</tbody>
</table>
### Evaluation Questionnaire

<table>
<thead>
<tr>
<th>I. The System</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>How responsive was the system to your actions?</td>
<td>The response is OK, however, it is a bit slow and it also takes much time to turn around.</td>
</tr>
<tr>
<td>How would you rate your visual experience?</td>
<td>The textures are sharp and detailed.</td>
</tr>
<tr>
<td>What is the best or worst thing about the system?</td>
<td>The best thing is that all the objects look quite realistic.</td>
</tr>
</tbody>
</table>

| II. The Campus Model | |
| How would you rate the buildings' appearance? | Very good 3D models, which look realistic, however, it is possible to go through the walls. |
| How would you rate the ground's appearance? | The grass is displayed very well. |
| How would you rate the vegetation's appearance? | The images are quite realistic, but again, it is possible to go through all the plants. |
| What is the best or worst thing about the campus model? | The worst thing is that it is possible to go through the objects. |

### Observed Performance Notes

<table>
<thead>
<tr>
<th>Feature</th>
<th>Comment/observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>System responsiveness to user’s actions</td>
<td>The system is a bit slow. User will love to walk faster.</td>
</tr>
<tr>
<td>Visual Experience</td>
<td></td>
</tr>
<tr>
<td>Buildings’ appearance</td>
<td></td>
</tr>
<tr>
<td>Ground’s appearance</td>
<td></td>
</tr>
<tr>
<td>Vegetation’s appearance</td>
<td>They don’t look like the university trees. The user is used to paths in the university.</td>
</tr>
<tr>
<td>Other features not listed above</td>
<td>User seems to be fast on navigation moving up and down.</td>
</tr>
</tbody>
</table>
### Evaluation Questionnaire

<table>
<thead>
<tr>
<th>I. The System</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>How responsive was the system to your actions?</td>
<td>The system responded faster than expected at first which made it a little difficult to control.</td>
</tr>
<tr>
<td>How would you rate your visual experience?</td>
<td>Realistic at slow walking speed, speed/pushing mode very useful for overview.</td>
</tr>
<tr>
<td>What is the best or worst thing about the system?</td>
<td>Best: realistic plants + trees.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. The Campus Model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>How would you rate the buildings' appearance?</td>
<td>Buildings had shed-like appearance, windows + doors would look more realistic. Would like to enter inside.</td>
</tr>
<tr>
<td>How would you rate the ground's appearance?</td>
<td>Grass is unrealistically uniform.</td>
</tr>
<tr>
<td>How would you rate the vegetation's appearance?</td>
<td>Realistic from a far but blurry when walking through vegetation.</td>
</tr>
<tr>
<td>What is the best or worst thing about the campus model?</td>
<td>Best: trees + plants. Worst: want to be able to navigate inside buildings.</td>
</tr>
</tbody>
</table>

### Observed Performance Notes

<table>
<thead>
<tr>
<th>Feature</th>
<th>Comment/observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>System responsiveness to user's actions</td>
<td></td>
</tr>
<tr>
<td>Visual Experience</td>
<td></td>
</tr>
<tr>
<td>Buildings' appearance</td>
<td>Lepet building should repel at walls.</td>
</tr>
<tr>
<td>Ground's appearance</td>
<td></td>
</tr>
<tr>
<td>Vegetation's appearance</td>
<td>Uniformity of the zone. The arrangement looked highly organized.</td>
</tr>
<tr>
<td>Other features not listed above</td>
<td>Navigation is quite difficult. Not much control.</td>
</tr>
</tbody>
</table>
# Evaluation Questionnaire

<table>
<thead>
<tr>
<th>I. The System</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>How responsive was the system to your actions?</td>
<td>It works but at some points it behaves unexpectedly.</td>
</tr>
<tr>
<td>How would you rate your visual experience?</td>
<td>Overall it looks very basic, it does provide the idea of environment and perspective but it is quite scanty.</td>
</tr>
<tr>
<td>What is the best or worst thing about the system?</td>
<td>Best - simple navigation. Worst - I am not sure about the properties of models as it is not fully completed.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. The Campus Model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>How would you rate the buildings' appearance?</td>
<td>Good for basic idea, to let the user to imagine the appearance. Negative - it comes too close, the walls became transparent.</td>
</tr>
<tr>
<td>How would you rate the ground's appearance?</td>
<td>It serves the purpose but it does not look very realistic.</td>
</tr>
<tr>
<td>How would you rate the vegetation's appearance?</td>
<td>OK.</td>
</tr>
<tr>
<td>What is the best or worst thing about the campus model?</td>
<td>The best thing I like is the appearance of the vegetation from a distance. Worst - if viewing from closer, you can see the rough texture and lineworks.</td>
</tr>
</tbody>
</table>

# Observed Performance Notes

<table>
<thead>
<tr>
<th>Feature</th>
<th>Comment/observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>System responsiveness to user's actions</td>
<td>Comments about not familiar with the campus</td>
</tr>
<tr>
<td>Visual Experience</td>
<td></td>
</tr>
<tr>
<td>Buildings' appearance</td>
<td>Transparency in the building. The details of buildings are not noticeable from a distance.</td>
</tr>
<tr>
<td>Ground's appearance</td>
<td>The trees change from different angles.</td>
</tr>
<tr>
<td>Vegetation's appearance</td>
<td>The garden should be worked on. It looks artificial and all similar. Make it more random.</td>
</tr>
<tr>
<td>Other features not listed above</td>
<td>Navigation is too sensitive. The control is sensitive to movements and directions. It is quite unstable.</td>
</tr>
</tbody>
</table>
### Evaluation Questionnaire

<table>
<thead>
<tr>
<th>I. The System</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>How responsive was the system to your actions?</td>
<td>It's easier to use the arrow keys to navigate.</td>
</tr>
<tr>
<td>How would you rate your visual experience?</td>
<td>You have to improve the quality of the buildings.</td>
</tr>
<tr>
<td>What is the best or worst thing about the system?</td>
<td>The navigation.</td>
</tr>
</tbody>
</table>

| II. The Campus Model                                                        |                                                                           |
| How would you rate the buildings' appearance?                              | You can improve the quality and the symmetry (roof).                     |
| How would you rate the ground's appearance?                                | Very well.                                                               |
| How would you rate the vegetation's appearance?                            | Very well.                                                               |
| What is the best or worst thing about the campus model?                    | Best thing: the ground. Worst thing: Quality of the building.            |

### Observed Performance Notes

<table>
<thead>
<tr>
<th>Feature</th>
<th>Comment/observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>System responsiveness to user's actions</td>
<td></td>
</tr>
<tr>
<td>Visual Experience</td>
<td></td>
</tr>
<tr>
<td>Buildings' appearance</td>
<td>Long walls of buildings. Improve the doors. Probably they could be modelled in details instead of textured.</td>
</tr>
<tr>
<td>Ground's appearance</td>
<td></td>
</tr>
<tr>
<td>Vegetation's appearance</td>
<td></td>
</tr>
<tr>
<td>Other features not listed above</td>
<td>Navigation will be easier with arrow keys. It's quite difficult to navigate with these.</td>
</tr>
</tbody>
</table>
### Evaluation Questionnaire

<table>
<thead>
<tr>
<th>I. The System</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>How responsive was the system to your actions?</td>
<td>Quite sluggish. Slow walking is possible with only users for 'immediate news'.</td>
</tr>
<tr>
<td>How would you rate your visual experience?</td>
<td>Reasonable, considering the technology and hardware.</td>
</tr>
<tr>
<td>What is the best or worst thing about the system?</td>
<td>Best: kicks. Worst: speed of walking.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. The Campus Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>How would you rate the buildings' appearance?</td>
</tr>
<tr>
<td>How would you rate the ground's appearance?</td>
</tr>
<tr>
<td>How would you rate the vegetation's appearance?</td>
</tr>
<tr>
<td>What is the best or worst thing about the campus model?</td>
</tr>
</tbody>
</table>

### Observed Performance Notes

<table>
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<tr>
<th>Feature</th>
<th>Comment/observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>System responsiveness to user's actions</td>
<td></td>
</tr>
<tr>
<td>Visual Experience</td>
<td></td>
</tr>
<tr>
<td>Buildings' appearance</td>
<td></td>
</tr>
<tr>
<td>Ground's appearance</td>
<td></td>
</tr>
<tr>
<td>Vegetation's appearance</td>
<td>Trees look quite good</td>
</tr>
<tr>
<td>Other features not listed above</td>
<td>Google maps like kind of map would help. Arrows on a map would help. More also.</td>
</tr>
</tbody>
</table>
### Evaluation Questionnaire

<table>
<thead>
<tr>
<th>I. The System</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>How responsive was the system to your actions?</td>
<td>It could be more responsive, it is hard to initially navigate. Perhaps an alternate system could be built for the &quot;cheese&quot; keys (just like a FPS game).</td>
</tr>
<tr>
<td>How would you rate your visual experience?</td>
<td>Good overall, although the graphics may be dated. The textures could be brought up to date.</td>
</tr>
<tr>
<td>What is the best or worst thing about the system?</td>
<td>The glitches weren't great. Overall, though, the idea was the best.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. The Campus Model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>How would you rate the buildings' appearance?</td>
<td>Generally good. The brick wall texture looks good. It captures a look of the campus.</td>
</tr>
<tr>
<td>How would you rate the ground's appearance?</td>
<td>Again, it looks dated.</td>
</tr>
<tr>
<td>How would you rate the vegetation's appearance?</td>
<td>Trees look fine, there could be more variety though.</td>
</tr>
<tr>
<td>What is the best or worst thing about the campus model?</td>
<td>The idea is the best. It may be another useful addition to a prospective student to use, in order to get a feel of the campus as a whole.</td>
</tr>
</tbody>
</table>

### Observed Performance Notes

<table>
<thead>
<tr>
<th>Feature</th>
<th>Comment/observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>System responsiveness to user's actions</td>
<td>Arrow keys could help with navigation.</td>
</tr>
<tr>
<td>Visual Experience</td>
<td>Graphics look dated and texture also.</td>
</tr>
<tr>
<td>Buildings' appearance</td>
<td></td>
</tr>
<tr>
<td>Ground's appearance</td>
<td></td>
</tr>
<tr>
<td>Vegetation's appearance</td>
<td></td>
</tr>
<tr>
<td>Other features not listed above</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 8:  hwu1 virtual campus model code after conversion to X3D

<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "ISO//Web3D//DTD X3D 3.0//EN" "http://www.web3d.org/specifications/x3d-3.0.dtd">
<X3D xmlns:xsd='http://www.w3.org/2001/XMLSchema-instance' profile='Full' version='3.0'
xsd:noNamespaceSchemaLocation='http://www.web3d.org/specifications/x3d-3.0.xsd'>
  <Scene DEF='scene'>
    <WorldInfo info='"(C) Copyright 2004 Shuang Zhao"' title='Heriot -Watt Virtual University'/>
    <NavigationInfo avatarSize='0.5 0.5 0.5' speed='0.2' type='"WALK"'/>
    <Viewpoint description='University and Edinburgh Conference Centre Visitor Reception' orientation='0 1 0 -5.1' position='66 0.3 -23.9'/>
    <Viewpoint DEF='avenue' description='The Avenue' orientation='0 1 0 2.25' position='94 0.2 -51'/>
    <Viewpoint DEF='edinburgh_business_school' description='Edinburgh Business School' orientation='0 1 0 -1.7' position='52 0.3 -17.1'/>
    <Viewpoint DEF='sunken_garden' description='Sunken Garden' orientation='0 1 0 0.62' position='37.867 0.6 -18.467'/>
    <Viewpoint DEF='sports_center' description='Sports Center' orientation='0 1 0 4.4' position='62.4 0.3 -23.9'/>
    <Viewpoint DEF='students_union' description='Students Union ' orientation='0 1 0 -1' position='64.004 0.5 -42.837'/>
    <Viewpoint DEF='riccarton_loch' description='Riccarton Loch' orientation='0 1 0 1.2' position='66.3453 0.3 -47.7873'/>
    <Viewpoint DEF='academic_building' description='Academic Buildings' orientation='0 1 0 0.3' position='45.3034 0.3 -50.019'/>
    <Viewpoint DEF='accommodation1' description='Flats (Linlithgow,Midlothian,Pentland,Caddon,Ettrick,Yarrow)' orientation='0 1 0 -0.15' position='50.3133 0.3 -38.7603'/>
    <Viewpoint DEF='leonard_horner' description='Leonard Horner Hall ' orientation='0 1 0 1.5' position='76 0.3 -37'/>
    <Viewpoint DEF='accommodation2' description='Southwest Residence(Lord Thomson, George Burnett, Robin Smith)' orientation='0 1 0 -0.5' position='9.832 0.5 2.833'/>
    <Viewpoint description='Robert Bryson Hall' orientation='0 1 0 2.8' position='46.92 0.3 -10.57'/>
  </Scene>
</X3D>
<Shape/>
</Transform>
</Transform>

<Transform DEF='right_arm' translation='0 1.5 0'>
<Transform scale='0.08 0.7 0.1' translation='0.14 -0.35 0'>
<Shape USE='arms'/>
</Transform>
</Transform>

<Transform translation='0 0.875 0'>
<Shape>
<Appearance>
<ImageTexture url="skirt.jpg"/>
</Appearance>
<Cone bottomRadius='0.25' height='0.5'/>
</Shape>
</Transform>

<Transform DEF='left_leg' translation='0 0.75 0'>
<Transform scale='0.1 0.75 0.1' translation='-0.1 -0.375 0'>
<Shape USE='arms'/>
</Transform>
</Transform>

<Transform DEF='right_leg' translation='0 0.75 0'>
<Transform scale='0.1 0.75 0.1' translation='0.1 -0.375 0'>
<Shape USE='arms'/>
</Transform>
</Transform>

<TouchSensor DEF='walk'/>

<Viewpoint DEF='tour' description='Tour' orientation='0 1 0 1.57' position='0.6 0.3 0' fieldOfView='0.959931'/>
<Anchor url="main.wrl#tour">
  <Transform>
    <Shape>
      <Appearance>
        <Material ambientIntensity='0' shininess='0' transparency='0.376'/>
      </Appearance>
      <IndexedFaceSet solid='false' coordIndex='0 1 2 3 0 -1'>
        <Coordinate point='0 0.8 2.5 0.8 2.5 -0.2 0 0 -0.2 0'/>
      </IndexedFaceSet>
    </Shape>
    <Shape>
      <Appearance>
        <Material ambientIntensity='0' shininess='0'/>
      </Appearance>
      <Text string=""Tour">
        <FontStyle justify="RIGHT"/>
      </Text>
    </Shape>
  </Transform>
</Anchor>

<Anchor parameter="target=_blank" url="help.htm">
  <Transform translation='0 -1 0'>
    <Shape>
      <Appearance>
        <Material ambientIntensity='0' shininess='0' transparency='0.376'/>
      </Appearance>
      <IndexedFaceSet solid='false' coordIndex='0 1 2 3 0 -1'>
        <Coordinate point='0 0.8 2.5 0.8 2.5 -0.2 0 0 -0.2 0'/>
      </IndexedFaceSet>
    </Shape>
  </Transform>
</Anchor>
</ indexedface>  
</ shape>  
</ shape>  
</ appearance>  
< material ambientIntensity='0' shininess='0'/>  
</ appearance>  
< text string='"Help"'>  
< fontstyle justify='"RIGHT"'/>  
</ text>  
</ shape>  
</ transform>  
</ anchor>  
</ transform>  
< transform rotation='0 1 0 1.58' scale='0.2 0.2 0.2' translation='62 0 -24.9'>  
< inline url='"avatar/nana_1.1.wrl"'/>  
</ transform>  
< background groundAngle='0.9 1.5 1.57' groundColor='0 0.333 0 0.4 0 0.5 0 0.62 0.67 0.6' skyAngle='0.9 1.5 1.57' skyColor='0.21 0.18 0.66 0.2 0.44 0.85 0.51 0.81 0.95 0.77 0.8 0.82'/>  
< pointLight location='50 60 50' radius='150'/>  
< inline url='"1-lampcontrol.wrl"'/>  
< transform translation='0 -0.1 0'>  
< shape DEF='Meadow'>  
< appearance>  
< material/>  
< imagetexture url='"image/grass1.jpg"'/>  
< texturetransform scale='500 500'/>  
</ appearance>  
< indexedface solid='false' coordIndex='0 1 2 3 0'>  
< coordinate point='0 0 100 0 10 0 100 0 -100 0 0 -100'/>

105
<Transform translation='7.776 0 -5.296'>
<Billboard USE='Tree'/>
</Transform>

<Transform translation='8.262 0 -5.627'>
<Billboard USE='Tree'/>
</Transform>

<Transform translation='8.748 0 -5.958'>
<Billboard USE='Tree'/>
</Transform>

<Transform translation='9.234 0 -6.289'>
<Billboard USE='Tree'/>
</Transform>

</Group>

<Group DEF='entranceTrees2'>
<Transform rotation='0 1 0 0.06' translation='84.9924 0.35 -42.676'>
<Transform>
    <Billboard USE='Tree'/>
</Transform>

<Transform translation='0.486 0 -0.331'>
    <Billboard USE='Tree'/>
</Transform>

<Transform translation='0.972 0 -0.662'>
    <Billboard USE='Tree'/>
</Transform>

<Transform translation='1.458 0 -0.993'>
    <Billboard USE='Tree'/>
</Transform>

<Transform translation='1.944 0 -1.324'>
    <Billboard USE='Tree'/>
</Transform>
</Group>
<Billboard USE='Tree'/>
</Transform>
<Transform translation='2.43 0 -1.655'>
 <Billboard USE='Tree'/>
</Transform>
<Transform translation='2.916 0 -1.986'>
 <Billboard USE='Tree'/>
</Transform>
<Transform translation='3.402 0 -2.317'>
 <Billboard USE='Tree'/>
</Transform>
<Transform translation='3.888 0 -2.648'>
 <Billboard USE='Tree'/>
</Transform>
<Transform translation='4.374 0 -2.979'>
 <Billboard USE='Tree'/>
</Transform>
<Transform translation='4.86 0 -3.31'>
 <Billboard USE='Tree'/>
</Transform>
<Transform translation='5.346 0 -3.641'>
 <Billboard USE='Tree'/>
</Transform>
<Transform translation='5.832 0 -3.972'>
 <Billboard USE='Tree'/>
</Transform>
<Transform translation='6.318 0 -4.303'>
 <Billboard USE='Tree'/>
</Transform>
<Text string=""Reception"">
  <FontStyle spacing='0.5' size='0.5'/>
</Text>
</Shape>
<Shape>
  <Appearance>
    <Material transparency='0.9'/>
  </Appearance>
  <IndexedFaceSet solid='false' coordIndex='0 1 2 3 0 -1'>
    <Coordinate point='0 0.5 0 12 0.5 0 12 -0.5 0 0 -0.5 0'/>
  </IndexedFaceSet>
</Shape>
</Anchor>
</Transform>
<TouchSensor DEF='Reception'/>
<Transform translation='-2 2.5 0'>
  <Anchor url=""main.wrl#sports_center"">
    <Shape>
      <Appearance>
        <Material ambientIntensity='0.06' diffuseColor='0.24 0.1 0.22' shininess='0.13' specularColor='0.31 0.39 0.39'/>
      </Appearance>
      <Text string=""Sports Centre"">
        <FontStyle spacing='0.5' size='0.5'/>
      </Text>
    </Shape>
  </Anchor>
</Transform>
</TouchSensor>
<Transform translation='-2 2.5 0'>
  <Anchor url=""main.wrl#sports_center"">
    <Shape>
      <Appearance>
        <Material transparency='0.9'/>
      </Appearance>
      <Text string=""Sports Centre"">
        <FontStyle spacing='0.5' size='0.5'/>
      </Text>
    </Shape>
  </Anchor>
</Transform>
<Shape>
  <Appearance>
    <Material transparency='0.9'/>
  </Appearance>
  <IndexedFaceSet solid='false' coordIndex='0 1 2 3 0 -1'>
    <Coordinate point='0 0.5 0 12 0.5 0 12 -0.5 0 0 -0.5 0'/>
  </IndexedFaceSet>
</Shape>

</Shape>
</Anchor>
</Transform>

<TouchSensor DEF='Accommodation1'/>
<Transform translation='-2 -1.5 0'>
  <Anchor url='"main.wrl#accommodation2"'>
    <Shape>
      <Appearance>
        <Material ambientIntensity='0.06' diffuseColor='0.24 0.1 0.22' shininess='0.13' specularColor='0.31 0.39 0.39'/> 
      </Appearance>
      <Text string='"Accommodation 2"'>
        <FontStyle spacing='0.5' size='0.5'/>
      </Text>
    </Shape>
  </Anchor>
</Transform>

<Shape>
  <Appearance>
    <Material transparency='0.9'/>
  </Appearance>
  <IndexedFaceSet solid='false' coordIndex='0 1 2 3 0 -1'>
    <Coordinate point='0 0.5 0 12 0.5 0 12 -0.5 0 0 -0.5 0'/>
  </IndexedFaceSet>
</Shape>
<ROUTE fromNode='left_turnround' fromField='value_changed' toNode='right_leg' toField='set_rotation'/>

<ROUTE fromNode='right_turnround' fromField='value_changed' toNode='left_leg' toField='set_rotation'/>

<ROUTE fromNode='walk' fromField='touchTime' toNode='clock2' toField='set_startTime'/>

<ROUTE fromNode='clock2' fromField='fraction_changed' toNode='path' toField='set_fraction'/>

<ROUTE fromNode='path' fromField='value_changed' toNode='guide' toField='set_translation'/>

<ROUTE fromNode='PROX2' fromField='position_changed' toNode='Sub_menu' toField='set_translation'/>

<ROUTE fromNode='PROX2' fromField='orientation_changed' toNode='Sub_menu' toField='set_rotation'/>

</Scene>

</X3D>
Appendix 9: HTML5 Code for Second Prototype Developed

```html
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
 "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
  <head
    <meta http-equiv="X-UA-Compatible" content="chrome=1" />
    <meta http-equiv="Content-Type" content="text/html;charset=utf-8" />
    <title>Virtual Campus in HTML5</title>
    <link rel="stylesheet" type="text/css"
      href="http://www.x3dom.org/download/x3dom.css">
    <script type="text/javascript"
      src="http://www.x3dom.org/download/x3dom.js">
    </script>
  </head>
  <body>
    <h1>Heriot Watt Virtual Campus</h1>
    <p>Second Prototype</p>
    <X3D xmlns="http://www.web3d.org/specifications/x3d-namespace" showStat="false" showLog="false"
      x="0px" y="0px" width="1200px" height="800px" altImg="helloX3D-alt.png">
      <Scene DEF='scene'>
        <WorldInfo info='"(C) Copyright 2004 Shuang Zhao"' title='Heriot -Watt Virtual University'/>
        <NavigationInfo avatarSize='0.5 0.5 0.5' speed='0.2' type='"WALK"'/>
        <Viewpoint description='University Overview from Southwest' orientation='0 1 0 -0.5' position='17 6 8'/>
        <Viewpoint DEF='avenue' description='The Avenue' orientation='0 1 0 2.25' position='94 0.2 -51'/>
    </Scene>
  </body>
</html>
```
<Text string=""Tour"">
  <FontStyle justify="RIGHT"/>
</Text>
</Shape>
</Transform>
</Anchor>
<Anchor parameter=""target= _blank"" url=""help.htm"">
  <Transform translation='0 -1 0'>
    <Shape>
      <Appearance>
        <Material ambientIntensity='0' shininess='0' transparency='0.376'/>
      </Appearance>
      <IndexedFaceSet solid='false' coordIndex='0 1 2 3 0 -1'>
        <Coordinate point='0 0.8 0.8 2.5 0.8 0.8 0 2.5 -0.2 0 0 -0.2 0'/>
      </IndexedFaceSet>
    </Shape>
    <Shape>
      <Appearance>
        <Material ambientIntensity='0' shininess='0'/>
      </Appearance>
      <Text string=""Help"">
        <FontStyle justify="RIGHT"/>
      </Text>
    </Shape>
  </Transform>
</Anchor>
</Transform>
</Transform>
<Background groundAngle='0.9 1.5 1.57' groundColor='0 0.333 0 0 0.4 0 0 0.5 0 0.62 0.67 0.6' skyAngle='0.9 1.5 1.57' skyColor='0.21 0.18 0.66 0.2 0.44 0.85 0.51 0.81 0.95 0.77 0.8 0.82'/>

<PointLight location='50 60 50' radius='150'/>

<Inline url='"1-lampcontrol.x3d"'/>

<Transform translation='0 -0.1 0'>
  <Shape DEF='Meadow'>
    <Appearance>
      <Material/>
      <ImageTexture url='"image/grass1.jpg"'/>
      <TextureTransform scale='500 500'/>
    </Appearance>
    <IndexedFaceSet solid='false' coordIndex='0 1 2 3 0'>
      <Coordinate point='0 0 10 100 0 10 100 0 -100 0 0 -100'/>  
    </IndexedFaceSet>
  </Shape>
</Transform>

<Transform rotation='1 0 0 3.14'>
  <Collision bboxCenter='50 -1 40' bboxSize='100 0 80'>
    <Inline containerField='children' url='"laundrette.x3d"'/>
    <Inline containerField='children' url='"55-lamp.x3d"'/>
      <Inline containerField='children' url='"medisstudio.x3d"'/>
      <Inline containerField='children' url='"s1.x3d"'/>
    <Inline containerField='children' url='"printingservices.x3d"'/>
    <Inline containerField='children' url='"purchasingoffice.x3d"'/>
      <Inline containerField='children' url='"pentlandhouse.x3d"'/>
      <Inline containerField='children' url='"linlithgowhouse.x3d"'/>
      <Inline containerField='children' url='"midlothianhouse.x3d"'/>
      <Inline containerField='children' url='"medicalcenter.x3d"'/>
  </Collision>
</Transform>
<Inline url=""vegetation.x3d""/>
<Group DEF='entranceTrees'>
  <Transform rotation='0 1 0 0.06' translation='83.7739 0.35 -44.1273'>
    <Billboard DEF='Tree'>
      <Shape>
        <Appearance>
          <ImageTexture url="image/tree6.gif"/>
        </Appearance>
        <Box size='0.7 0.8 0.001'/>
      </Shape>
    </Billboard>
  </Transform>
  <Transform translation='0.486 0 -0.331'>
    <Billboard USE='Tree'/>  
  </Transform>
  <Transform translation='0.972 0 -0.662'>
    <Billboard USE='Tree'/>  
  </Transform>
  <Transform translation='1.458 0 -0.993'>
    <Billboard USE='Tree'/>  
  </Transform>
  <Transform translation='1.944 0 -1.324'>
    <Billboard USE='Tree'/>  
  </Transform>
  <Transform translation='2.43 0 -1.655'>
    <Billboard USE='Tree'/>  
  </Transform>
  <Transform translation='2.916 0 -1.986'>
    <Billboard USE='Tree'/>  
  </Transform>
</Group>
<Billboard USE='Tree'/>
</Transform>
<Transform translation='3.402 0 -2.317'>
<Billboard USE='Tree'/>
</Transform>
<Transform translation='3.888 0 -2.648'>
<Billboard USE='Tree'/>
</Transform>
<Transform translation='4.374 0 -2.979'>
<Billboard USE='Tree'/>
</Transform>
<Transform translation='4.860 0 -3.31'>
<Billboard USE='Tree'/>
</Transform>
<Transform translation='5.346 0 -3.641'>
<Billboard USE='Tree'/>
</Transform>
<Transform translation='5.832 0 -3.972'>
<Billboard USE='Tree'/>
</Transform>
<Transform translation='6.318 0 -4.303'>
<Billboard USE='Tree'/>
</Transform>
<Transform translation='6.804 0 -4.634'>
<Billboard USE='Tree'/>
</Transform>
<Transform translation='7.290 0 -4.965'>
<Billboard USE='Tree'/>
</Transform>
<Transform translation='7.776 0 -5.296'>
   <Billboard USE='Tree'/>
</Transform>

<Transform translation='8.262 0 -5.627'>
   <Billboard USE='Tree'/>
</Transform>

<Transform translation='8.748 0 -5.958'>
   <Billboard USE='Tree'/>
</Transform>

<Transform translation='9.234 0 -6.289'>
   <Billboard USE='Tree'/>
</Transform>
</Group>

<Group DEF='entranceTrees2'>
   <Transform rotation='0 1 0 0.06' translation='84.9924 0.35 -42.676'>
      <Transform>
         <Billboard USE='Tree'/>
      </Transform>
   </Transform>
   <Transform translation='0.486 0 -0.331'>
      <Billboard USE='Tree'/>
   </Transform>
   <Transform translation='0.972 0 -0.662'>
      <Billboard USE='Tree'/>
   </Transform>
   <Transform translation='1.458 0 -0.993'>
      <Billboard USE='Tree'/>
   </Transform>
   <Transform translation='1.944 0 -1.324'>
      <Billboard USE='Tree'/>
   </Transform>
</Group>