School of Computing Sciences

FINAL YEAR PROJECT

A Virtual Model of the University of East-Anglia

Jassim Happa

Year 2005/2006

Supervisor: Professor Andy Day (AMD)

Abstract

This report follows the research and development of a third year computing science project from inception to completion. The project involved creating the eastern section of the University of East-Anglia's campus into a virtual model. The model is represented in two ways: A pre-rendered video sequence, and as an interactive application in which users may navigate themselves around campus.

The report begins by introducing the project area of virtual urban modelling in general terms, and moves on to discuss basic techniques applied to this specific project discussing the design and implementation of the virtual model.

It discusses the modelling process of each building, the problems encountered and what has been done to solve these problems. Lastly, the report discusses the possibilities of future work that can be applied to this project. Appendix A contains the video and real-time application this project has produced.

Acknowledgements

This dissertation would not have come into being without the guidance of my supervisor **Prof. Andy Day**. He has been very supportive and his feedback has greatly improved my work. His digital camera has been of great use and I also thank him for directing me to other people involved in creation of virtual urban models; all of whom I have learned much from:

George Lowson from the UEA Estates & Buildings Department, for providing me with the 2D and 3D Computer Aided Design (CAD) files of building plans I have used to import into 3D Studio Max (*3DS Max*) which made creation of virtual models somewhat easier. I also thank him providing roof access for me so I had the opportunity to take overview photographs of the buildings on campus.

Greg Ryder has given me many valuable suggestions, discussions, clarifications and encouragement to this project and has provided me with a cut down version of his rendering program for crowds to work on and import my virtual models into a C++/OpenGL real-time interactive virtual environment.

Geoffrey French from the Norwich Urban Modelling Team has been of great help during the learning process of how to model buildings using *3DS Max* and has provided many tips on effective use of texture mapping for urban models.

Paul Hatton has provided me with a few nice looking textures for my urban models.

Dr. Robert Laycock has given tips on where to find appropriate research material.

Andrew Wallen has been of great help during the writing stages of this project. His advices on report writing have been a good source to learn how to write scientific reports in an appropriate manner.

Jassim Happa
School of Computing Sciences
University of East-Anglia

This paper should be cited as:

J. Happa. "A Virtual Model of the University of East-Anglia." Dissertation. School of Computing Sciences, University of East-Anglia, 2005/2006.

Table of Content

Section 1.0 - Introduction & Objectives - 6

1.1 Overview 6
1.1.1 Aims and objectives – Initial Project Brief 7
1.1.2 Aims and objectives - Alterations to the project aims 8

Section 2.0 - Background & Literature survey - 9

2.1 Background 9

2.2 Literature survey 13
2.2.1 Tools and Techniques used for Urban Modelling 14
2.2.2 Other topics related to Urban Modelling research 21

Section 3.0 - Theory & Design 24

3.1 Definition of problem & solution 24
3.1.1 Addressing the tasks 24
3.1.2 Initial ideas and possibilities 25
3.1.3 Realistic aims and design for project 27

3.2 Resources 28
3.2.1 Hardware 28
3.2.2 Software 30
3.2.3 Documentation 31
3.2.4 Assistance and help 32

Section 4.0 - Implementation, testing & results - 33

4.1 Implementation 33
4.1.1 Using 3DS Max 33
4.1.2 Music Centre 37
4.1.3 Chaplaincy 39
4.1.4 Career Centre 40
4.1.5 Dean of Students' Office 40
4.1.6 Student Counselling Office 41
4.1.7 Waterstone's 41
4.1.8 Old Sports park/Congregation Hall 42
4.1.9 Drama Studio 42
4.1.10 The Street/Shopping Centre 43
4.1.11 Union House 44
4.1.12 Lecture Theatre 44
4.1.13 Old Library 45
4.1.14 New Library 46
4.1.15 Restaurant Building 46
4.1.16 Suffolk Walk 47

4.1.17 Suffolk Terrace 48
4.1.18 Nelson Court 49
4.1.19 UEA Registry 49
4.1.20 Wolfson & Orwell Close 50
4.1.21 Colman House & other new accommodation 50
4.1.22 Height Map/Trees/Campus as a whole 51
4.1.23 Pre-rendered video 52
4.1.24 Real-Time Interactive application 53

4.2 Testing & Problems Encountered 54
4.2.1 Learning 3DS Max 54
4.2.2 Importing .dwg files & problems with CAD files 55
4.2.3 Texturing – adding realism 57
4.2.4 Problems exporting/importing models to C++/OpenGL 57

4.3 Results 59

Section 5.0 - Conclusion and evaluation - 60

5.1 Further work 60
5.1.1 Modelling the north side of campus 60
5.1.2 Improvements of LOD, Textures and Environment detail 60
5.1.3 Interior modelling 60
5.1.4 Vegetation modelling on urban models 60
5.1.5 Vegetation modelling on campus 61
5.1.6 Information system & Guided Tour 61
5.1.7 Maintaining the virtual campus 61
5.1.8 UEA Estate & Building – New Buildings & Plumbing modelling ...61

5.2 Evaluation & Conclusion 62
5.2.1 Report Summary 62
5.2.2 Project Summary 62
5.2.3 Evaluation of performance 62
5.2.4 Final Thoughts 62

Section 6.0 - Glossary, References and List of Figures - 63

6.1 Abbreviation list 63
6.2 References 63
6.3 List of Figures 65

Appendix A: DVD w/files (Final version to be submitted at bench inspection)
Appendix B: Control Manual for real-time application 70
Appendix C: Gantt-Chart illustrating progress of this project 71
Appendix D: Storyboard of pre-rendered video 72

Section 1.0 - Introduction & Objectives

1.1 Overview

The aim of this student project is to create a realistic looking virtual model of the eastern section of the UEA campus (See figure 1). This model is part of the development of a Virtual Model of the entire university. The final product from the research and modelling of the buildings are to be placed in one pre-rendered video sequence and one interactive application in which users may guide themselves around on campus.

Fellow Computing Science student Marc Clare is responsible for modelling the western section of the university campus and each section will be merged together after the bench inspection assessment at the end of the academic year.

This report aims to give a detailed description and documentation of the design and implementation of the virtual model. The rest of this section gives a general introduction to the project.

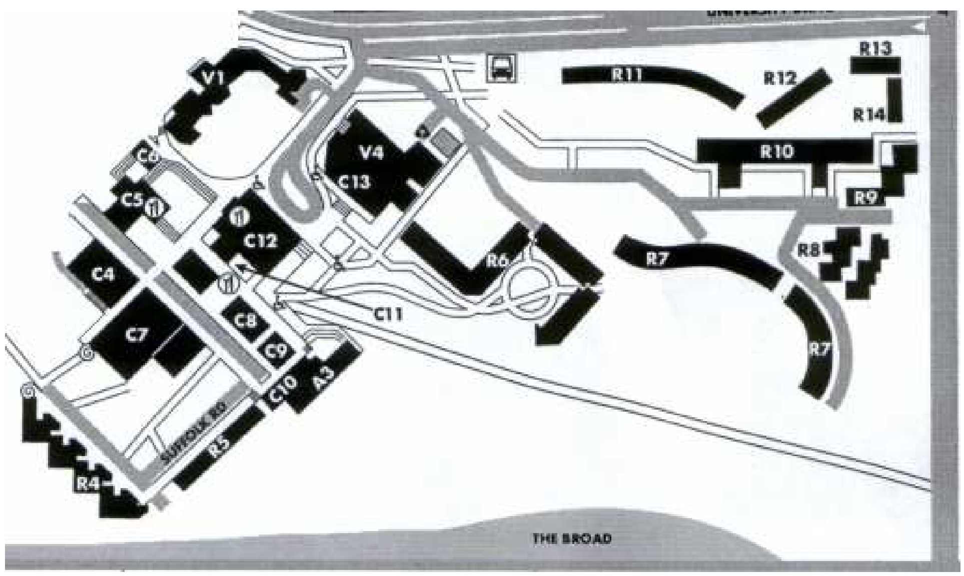

Fig. 1: An image illustrating what has been modelled over the course of this project.

This project's models and virtual environment will be used by several departments of the UEA such as the Admissions Team and the Estates and Buildings department. Furthermore, it may be used as an extension for the UEA Urban Modelling Group's model of Norwich city in the future.

The Admission Team will use the model to promote the university to prospective students. Students who are unable to visit the university, (international students in particular) will be given an opportunity to experience a virtual campus. The UEA Estates & Buildings department aim to use the model for building planning purposes and hope to expand the model to map the plumbing pipes of the university.

Section 2 of this report discusses the background research involved to gain a better understanding of creating urban models for virtual environments. It goes into detail on computer graphics areas such as Computer Aided Design (CAD) files, Constructive Solid Geometry (CSG), L-Systems, Texture Mapping, and Bump Mapping among several other topics that are important in urban modelling.

The Theory and Design of Section 3 discusses the initial ideas on how they have been incorporated according to the information researched in Section 2. It also discusses the main differences between the initial design and the final result of this project.

Section 4 discusses the implementation of the models and describes the problems encountered while modelling each building and environment. It runs through the modelling of each building, discussing each approach, problems encountered and how they have been resolved.

The final section brings a conclusion to this report and gives a summary of the overall project progress and results. Additionally, it also suggests further work that can improve what has already been accomplished.

1.1.1 Aims and objectives – Initial Project Brief

In the text below follows the brief description of the initial aims and objectives for the project given in the list of potential projects. Eventually these aims were altered to benefit a more general purpose of such a project and accordingly to what time allowed. All of these changes were approved by the project supervisor. Furthermore, the altered aims also to focus much more on the graphical quality of the project. Section 1.1.2 discusses these alterations.

Initial brief:
"Produce a realistic populated 3D model of the UEA so that 'visitors' can guide themselves around the place. This project will be carried out in collaboration with the urban modelling group and the UEA admissions team. The complete model (if good enough) will be used by the university [1]*."*

1.1.2 Aims and objectives - Alterations to the project aims

The altered aims for the project are as follows -
Produce two realistic 3D virtual models of the eastern section of the UEA:

1. An interactive application
   → in which users may navigate through campus.

2. A pre-rendered video fly-by of campus
   → giving the users ability to see a much more detailed campus

Appendix C shows a detailed Gantt chart that illustrates the actual progress of the project.

Adding realism and accuracy to each modelled building has been the main focus of this project. Assembling them in a virtual environment that looks like the university campus was also important. Nonetheless, it is important to stress the graphical quality of the buildings was considered more important than the quality of the virtual scenery.

The pre-rendered sequence will not be limited to a polygon count as the video will be rendering for as long as necessary, however the models will be somewhat simplified (and contain less items on the campus ground) for the interactive application to ensure a frame rate of at least 60 frames per seconds.

Limitations will mostly be restricted to removing high polygon trees and plants from the campus as vegetation models often have more polygons than the building models. Nonetheless, the primary priority of this project is the visual quality of the building models. The virtual environment and shine of the campus is the second highest priority.

The polygon count for the interactive application is limited to approximately 500,000 polygons. This ensures that most modern computers today will have no problems of running this application.

Section 2.0 - Background & Literature survey

2.1 Background

In order to gain an appropriate understanding of virtual urban modelling, it is necessary to research existing projects related to urban modelling. There are several academic projects revolved around urban modelling, most notably that of the UEA *Urban Modelling Group's (UMG)* own model of Norwich city (See Fig. 2) and *University of California Los Angeles* (*UCLA*) *Urban Simulation Team's (UST)* model of Los Angeles. Both these projects have a focus on creating realistic re-creations of already existing cities.

The *UMG* project *"specialises in the production of models representing urban environments, incorporating a mixture of manually produced detailed models alongside semi-automatically generated buildings, constructed using in-house software* [2]*."* (See figure 2 for an example)

Fig. 2 – A screenshot from the *UMG* project at the *UEA*

While *"The main focus of the Urban Simulation Team at UCLA is a long-term effort to build a real-time virtual reality model of the entire Los Angeles basin for use by architects, urban planners, emergency response teams, and government entities* [3]*."* See figure 3 for an example of the project.

Fig 3 - Screenshot of the *UST* project at *UCLA*

Much of the research in urban modelling is done by the computer and video games industry. Research in urban modelling is very industry driven, and not as widely spread in the academic world. Computer and video games with realistic computer graphics is more appealing to the end-consumers, while academic researchers focus more on their efforts in efficiency and quality of computer graphics. Overall realism in computer games is what sells the games, which is how computer game developers can get away with many minor approximation/clipping errors, especially in the areas such as collision detection and collision response.

Urban modelling theory is a part of architecture theory and is therefore also a large part of research in architecture.

Grand Theft Auto (GTA, See Fig 4) is an early example of an attempt to visualise a 3 dimensional city. This was achieved using pseudo-3D, giving the illusion of depth into the scene although the controls and computer graphics in the virtual environment is of 2D nature.

Fig 4: Screenshot of the *Grand Theft Auto*, an early example of urban modelling, a PC game released by *DMA Design* (Now *Rockstar North*), 1998.

Syndicate wars (See figure 5) is another early example of a computer game that has urban models in it and using pseudo-3D computer graphics. This game is also an example of a game utilising pre-rendered video sequences to illustrate urban scenery. Using pre-rendered sequences is a way to immerse game players to fairly convincing virtual urban environment. Nonetheless, due to the technical limitations of computers ten years ago *Syndicate Wars* did not use the same models in the videos as during game play.

Fig 5: A small collection of screenshots of *Syndicate Wars*, a PC game released by *Bullfrog productions*, 1996.

Modern computer games have vast areas of urban cities rendered in real-time which the player can navigate through. From a game developer's perspective, maintaining a balance between hardware capabilities and level of detail is crucial for the development of any real-time application, as the aim is to make the environment as realistic as possible with the aimed hardware.

Fig 6: Screenshot of *Grand Theft Auto: San Andreas*. Here; *Los Santos*, a fictional city based on Los Angeles, developed by *Rockstar North*.

While some urban modelling projects are fictional cities, there have been a few examples of games whose aim were to immerse players into real life cities. *Getaway* (London, see figure 7) and *True Crime* (Los Angeles) are just two examples of this.

Fig 7: Screenshot of *Getaway* in which players find themselves in a virtual London, developed by *Team Soho* for *Sony Entertainment*.

Games that incorporate urban modelling do not limit themselves to adventure games where players have to navigate through vast cities. Racing games is also a popular genre with an increasing demand for realistic urban sceneries. Project Gotham Racing (PGR) is an example of a racing game with a large focus on realistic real-life urban environments (See Fig 8). PGR 3 has realistic looking sections of cities such as Tokyo, Las Vegas, New York and London.

Fig 8: A screenshot from the game Project Gotham Racing 3 for the Xbox 360, developed by Bizarre Creations, 2005.

2.2 Literature survey

The purpose of this literature survey is to give a description of research topics related to urban modelling and how they relate to this project. Section 2.2.1 covers topics directly related to the project while section 2.2.2 covers other areas related to other urban modelling research, but is not directly related this project. Section 2.2.2. was deemed appropriate to include in this report to gain a better understanding of urban modelling.

There are many similarities in creating a virtual urban environment to that of creating other virtual environments in computer graphics. Most of the terminology remains the same; however the main differences lie in the high level design of the implementation of the techniques available for creating urban models. Buildings and scenery can be automatically generated or designed by hand, and although some of the high level concepts remain the same the way to apply these techniques are different to one another.

2.2.1 Tools and Techniques used in Urban Modelling

Today there are many tools available for creating urban models for virtual 3D environments. Each has a different approach to modelling and there are several ways of creating the models themselves within these programs. One can use software whose full purpose is only to create models, or use Integrated Development Environments (IDE) that support programming languages like for instance C++ and the OpenGL Application Program Interface (API) and use them to draw a collection of polygons that make up a building. However, they can be used to import already existing models from modelling packages. It is important to state, modelling virtual urban environments is not the primary purpose of programming IDEs, it is only a possibility.

Modelling package tools are used to draft buildings in an accurate manner according to the building specifications by an architect or building designer. Some widely known examples include AutoCAD (See Fig. 9), *3DS Max* (See Fig. 10), Softimage XSI (See Fig. 11) and Maya (See Fig. 12). The latter three are mostly used for computer game development and computer animation as they also include tools for creating character animation, while AutoCAD is more used among architects. This project was designed and implemented from Computer Aided Design files used using AutoCAD supplied from the UEA Estate & Building Department and imported into a *3DS Max* environment.

CAD files are data files that store blue print information of virtual models of real life objects and are used by civil engineers, land developers, architects, mechanical engineers, interior designers and other design professionals [4], [5]. They appear in different computer file formats and support 2D and 3D design.

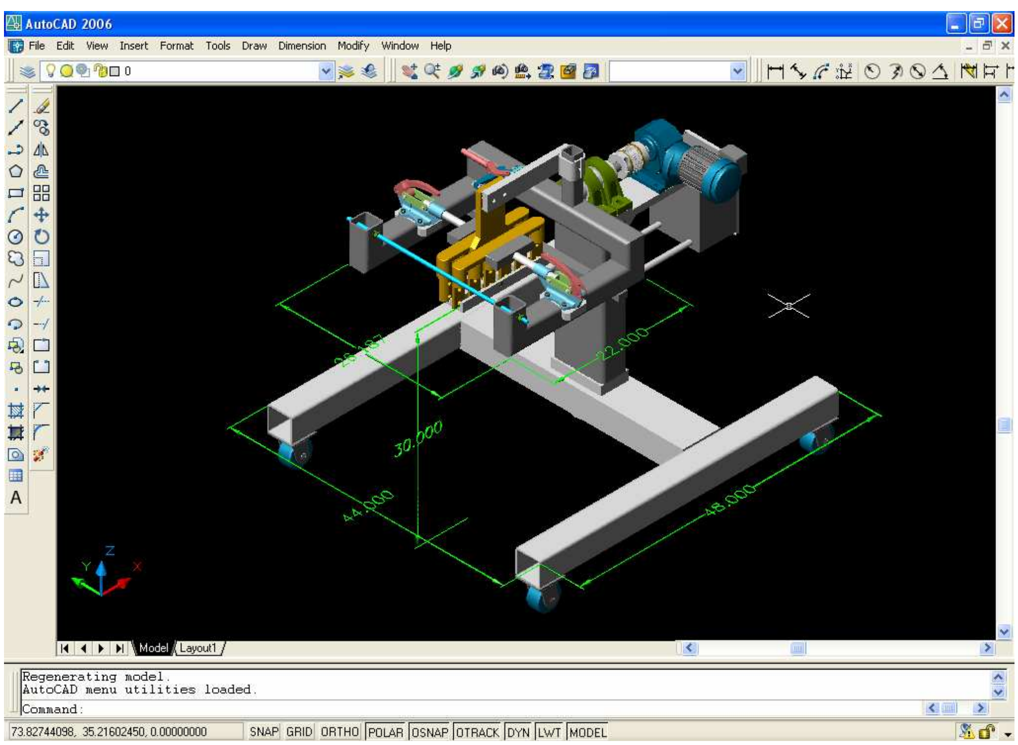

Fig 9: A Screenshot of the *AutoCAD* interface by *Autodesk Inc*.

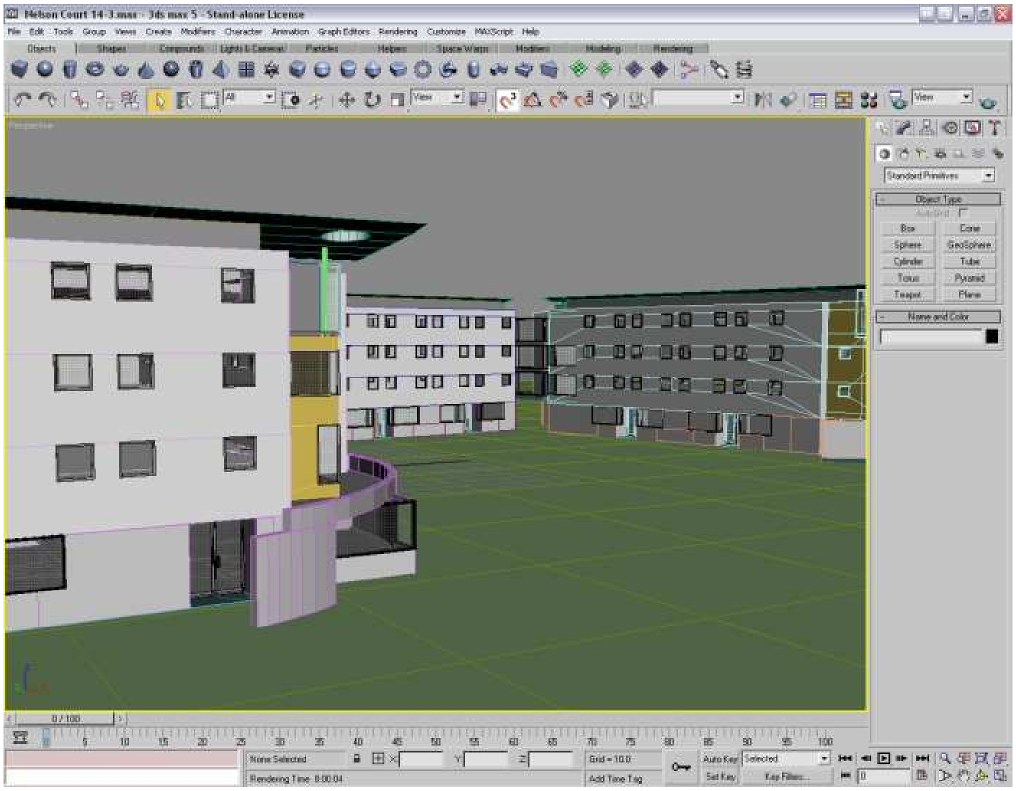

Fig 10: A screenshot of the *3DS Max* interface, here: *Nelson Court*

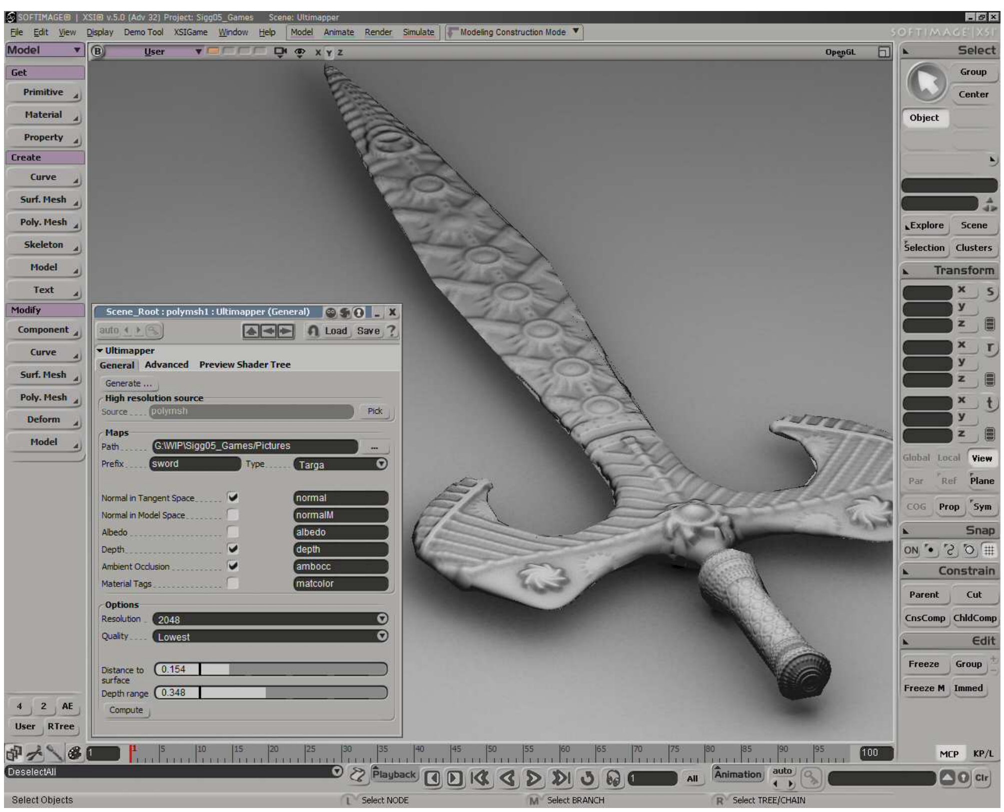

Fig 11: A screenshot of the *Softimage XSI* interface

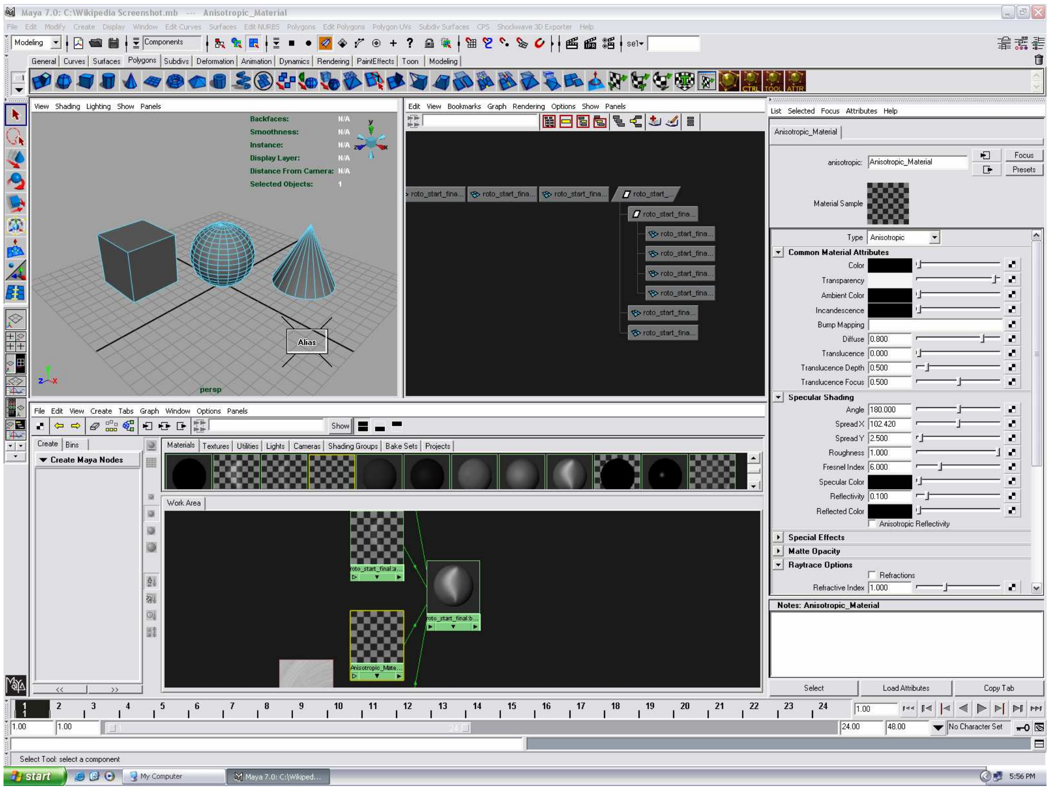

Fig 12: A screenshot of the *Maya* interface

Due to CAD files' accuracy and modifiability it is now the preferable working format over regular blue print documents that architects previously used to design buildings. If the architect made a single mistake on blue prints it could result in the final building looking different according to what the architect envisioned. Working in a virtual environment allows architects to undo mistakes and keep building plans as accurate as possible. It also allows them to make small adjustments without having to draw a blue print over again.

The advantage of using pre-existing CAD files for this project is the accuracy of measurements of the ground plane for each building. As they already have been pre-defined (and assuming they are mathematically correct to the real building) it is possible to get a virtual campus that is very close to the real campus in size.

Over the course of this project existing 2D and 3D CAD files (See Fig 13 & 14) have been used to create models of campus buildings. However as the CAD file archive from the UEA Estates & Building Department is neither not up to date nor complete with the new buildings on campus, it has been necessary to make a few approximate virtual buildings as well. These buildings have been recreated with the use of picture taking on campus.

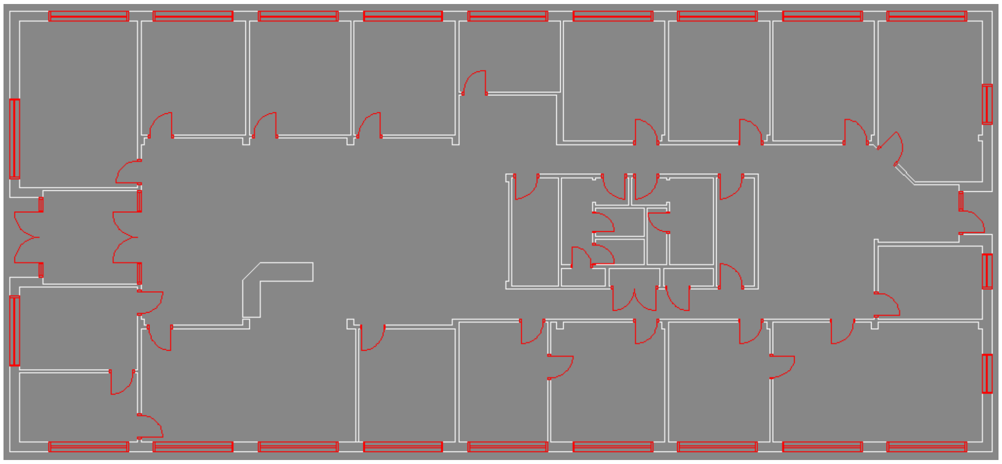

Fig 13: An example of a 2D-CAD file provided by the UEA Estate & Building Department. This is the Dean of Students' office.

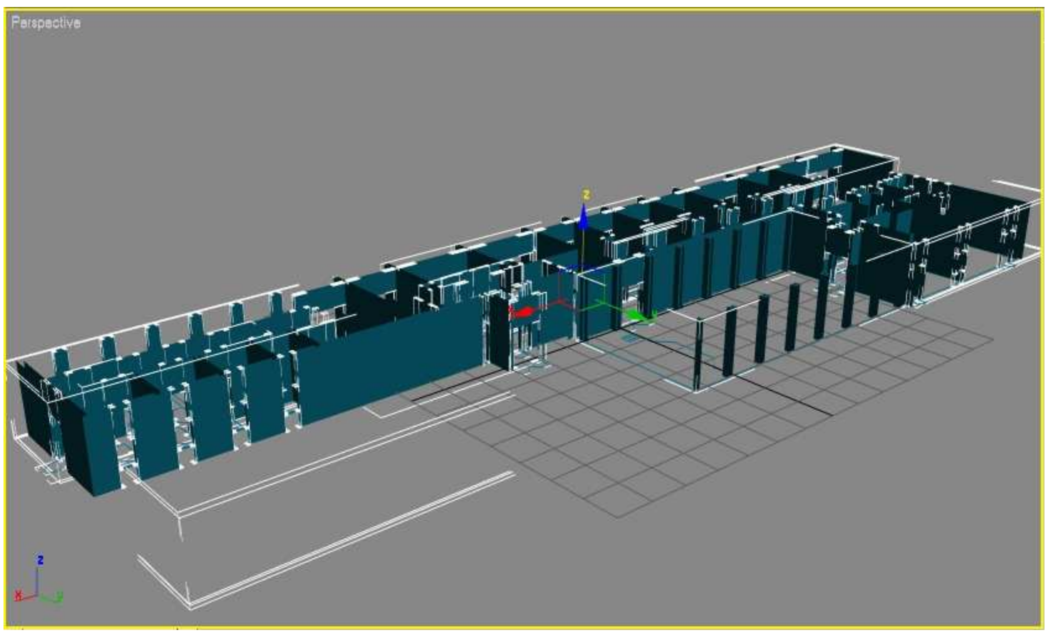

Fig 14: An example of a 3D CAD file provided by the UEA Estate & Building Department. This is the ground floor of the School of Music.

Although photographing campus is not directly related to literature research in urban modelling, it has played a very important role in gaining an appropriate understanding of how to model each building.

Over 1500 photographs have been taken of campus. These photographs include texture maps for each building as well as overview pictures of campus and general overview photographs of each building. All of these photographs are included in appendix A.

Photographs were taken at specific points of each building to get the most out of each photo session. The general approach was to take photographs of each building from eight different angles forming a shape that might resemble an eight-pointed star or more depending on the shape of the building. Figure 15 illustrates this approach for a generic cube building. As only a few of the buildings on campus have a cube structure this approach had to be adapted accordingly. The UEA Registry is one example of such a building. For the overview photographs, it was necessary to obtain a written permission for the rooftop access. The UEA Estates & Building Department provided this permission.

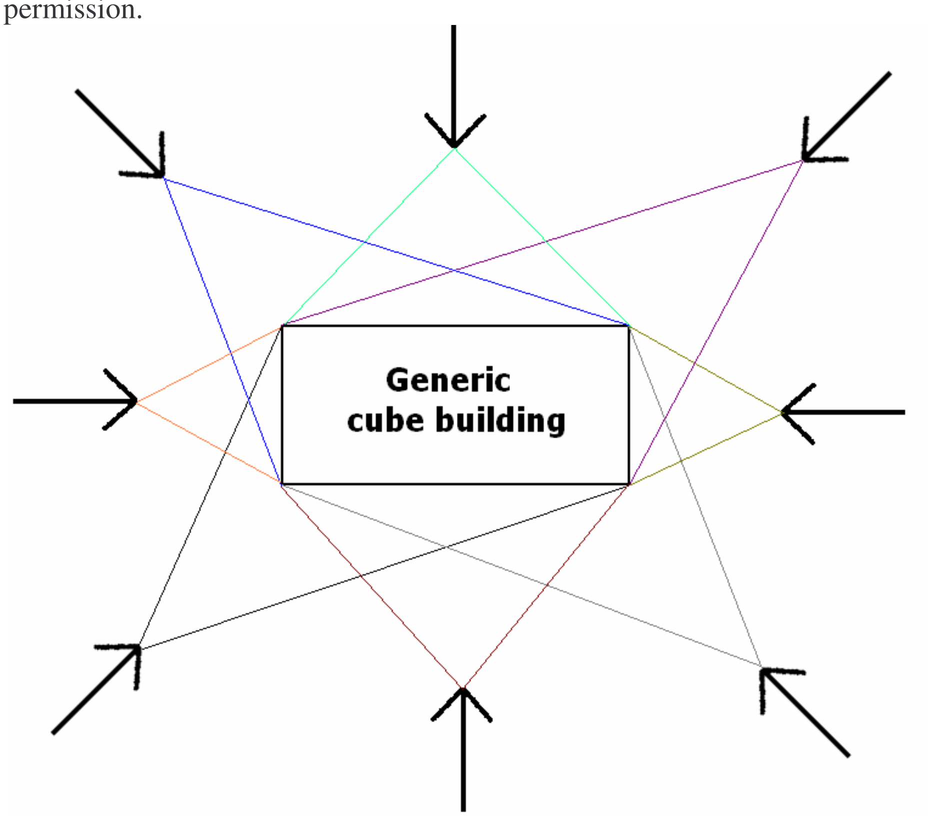

Fig 15: Shows the general approach of photographing each building. Each arrow represents a camera angle while each colour represents field of view.

Implementing a real-time interactive virtual environment requires finding a balance between what details are necessary and relevant according to what hardware specifications are available. The Level of Detail (LOD) is an important aspect of computer graphics [6], [7]. There are several ways of altering the LOD in a virtual environment. The rest of this section discusses some ways to work with LOD all of which have been used in this project.

Texture Mapping is a widely known topic in the field of computer graphics and is used to replace filled polygons with images to increase realism in a virtual scene. The use of texture mapping for this project revolved around learning how texture mapping can be applied to urban models.

The LOD on building surfaces depend on the resolution of the textures applied to it and various effects applied to the surface such as bump mapping, MIP mapping, reflection and transparency.

Textures in this project are photographs or images that have been created or edited in a separate 2D image editor program such as *Photoshop*, *GIMP* or *Paint .NET*. The textures have to be edited so they may be tiled several times or perhaps stretched without it affecting the outcome of the realism of the building. To ensure the modelling process was done in a correct fashion, photographs have been compared to the texture mapped virtual models.

Fig 16 and 17 show two examples of textures that have been made for this project. Both of these textures can be tiled on large surfaces without it seeming to create edges indicating the end of the texture. Section 4 explains in detail how each model was assembled with texture mapping applied to them.

Fig 16 & 17: Two examples of photograph textures applied to this projects' models. *Left*: The brick texture for the Chaplaincy, *Right*: A wall texture for the Drama studio

MIP mapping (MIP is an acronym of the Latin phrase: *multum in parvo*, meaning *much in a small space*) is a technique that allows the LOD to be preserved in a virtual environment [8]. This technique reduces jagged edges from distant repeated textures by only rendering necessary LOD. Figures 18 and 19 show the visible differences.

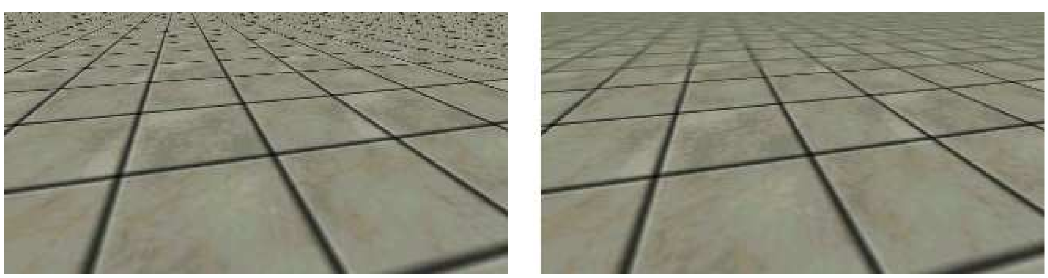

Fig 18 &19: Illustrates a floor without (left) and with (right) MIP mapping.

Figure 20 shows the same texture in different sizes, each different by a factor of two. The smallest texture is used for the farthest rendered surface distance, while the texture with the highest resolution is only necessary near the viewing perspective.

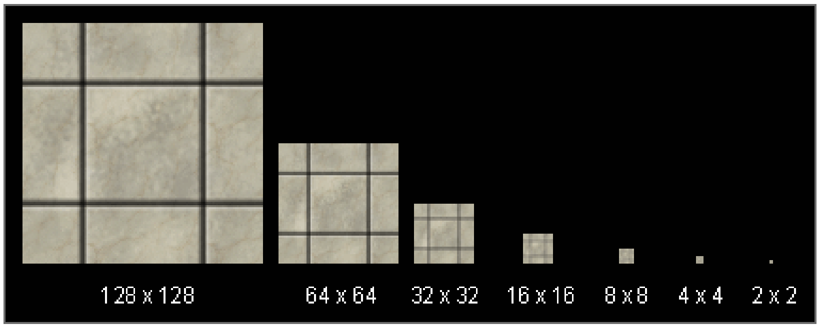

Fig 20: Shows the same texture, but in different resolutions

Occasionally polygonal objects in 3D environments are needlessly rendered in great detail even though they may be far away from the viewing perspective or at an angle which makes seeing that object in such detail needlessly. One way to considerably reduce the amount of computational cost of rendering a scene is to introduce impostors and billboards into the 3D environment [6], [7], [9]. Impostors are 2D images that may replace specific 3D objects or characters, while 2D billboards replace sceneries.

Rendering a flat plane is not as computationally expensive as rendering an entire 3D object in a virtual environment. This enables faster rendering, which is particularly important for real-time applications. 2D billboards and impostors are useful in urban modelling for creating the illusion of interiors existing in buildings.

It is important to note that impostors are not meant to replace 3D geometry entirely. They serve as a method to remove unnecessary computational costs of 3D models in a virtual environment when 2D planes can work just as well to give the illusion of 3D models existing in the scene. Unfortunately using billboards and impostors may result in clipping errors and figure 21 shows.

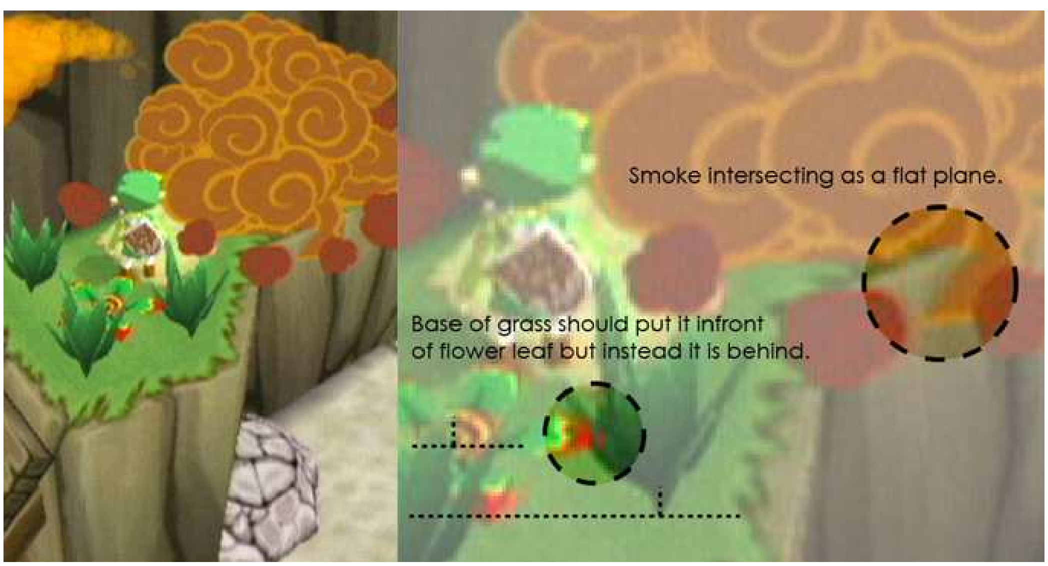

Fig 21: Shows the disadvantage of using 2D billboards and impostors in a 3D virtual environment. Here from video game *The Legend of Zelda: The Wind Waker*

Using an impostor such as the image in figure 22 may cut computational costs [6]. To maintain the illusion of a 3D character, the image always has to be at a perpendicular angle to the image plane. The greater the angle leans towards a parallel to the plane itself, the greater the chance of the illusion failing.

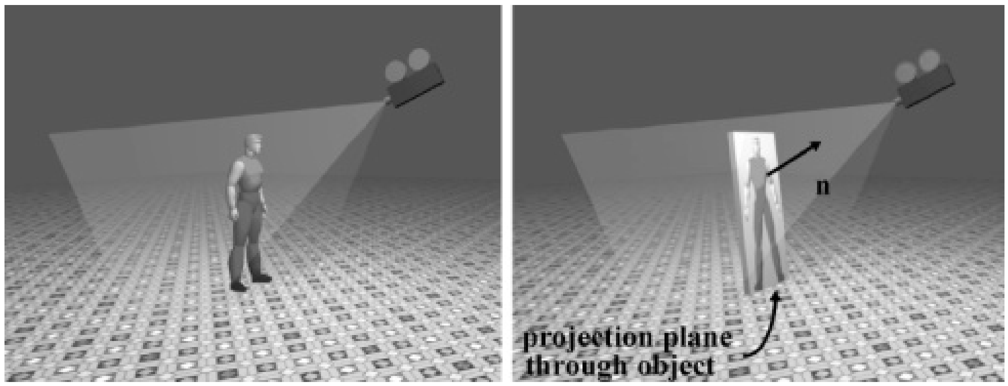

Fig 22: A good example use of an impostor in a virtual environment

Impostors and billboard inside buildings can give the illusion of interiorised urban buildings. Billboards can also be used at the edge of the virtual world to give the user the illusion of a larger scale world.

2.3.2 Other topics related to Urban Modelling research

This section aims to describe other topics related to that can be applied to this project, but is not used in this project. It aims to give a greater understanding of what can be applied to this virtual urban project in the future to increase the realism of the models.

One way of creating an urban environment is to automatically generate it by using the footprint data of real buildings [10]. This can be done in three main stages. The first stage involves gathering building features into a data structure such as the topology of the building footprints. The second stage deals with approximating an appropriate height for the buildings. The final stage deals with applying the most suitable roof model for the virtual buildings. Having a variety of roof models for any given polygonal structure is therefore required. Once the base geometry for the urban environment has been obtained the realism can be improved by using texture mapping.

Theory and Design in section three of this report discusses a real-time application that has made use of the results of this form of creating virtual urban models. Figure 30 shows as few of the buildings in this virtual environment.

Urban models cannot be portrayed as realistic without including interiors to give the impression that the buildings are inhabited by people. 3D interiors have already been discussed, and placing in 3D interior is a problem for real-time environments. Impostors and billboards are useful and less computational costly because of their simple 2D structure.

Creating interiors individually and placing them piece by piece is a very time consuming process. However, by creating a small library of generic objects such as tables, chairs, book shelves etc. and by randomly distributing them according to a set of rules defined in the program code of the real-time application, one may decorate the inside of a model while loading the program.

There are third year computer graphics students who are implementing such programs for real-time applications this year. If these rules defining how to place objects are implemented properly, their projects can be merged with this one and in the future, all interiors can be generated automatically.

Shading languages and programmable shaders play an important role in adding realism in graphics. In terms of realism, one may say texture mapping produces one form of realism, but programmable shaders is the next step forward in the evolution of implementing realism in computer graphics.

Shaders are the term given to computer graphics programs often described by high level languages that execute on the graphics processor. They control how the pixels and vertices are rendered in a virtual environment. Shaders can define many attributes of a polygon including its colour, position, texture, transparency and reflectivity among others. Examples of shading languages today are: *DirectX High Level Shading Language* and the *OpenGL Shading Language*.

Although shaders and shading languages are not used for this project, they can be an addition included in further work on this project to improve realism. (See section 5.1)

High Dynamic Range Lighting revolves around storing the intermediate results of lighting calculations in high precision, normally floating point, and then scaling the end results back to the normal range for display. This can add more visual realism to a virtual lit scene.

Fig 23: Illustrates use of High Dynamic Range Lighting in a virtual urban environment.

Using Layered Models is a way to ensure that there is no unnecessary computation of rendering level of detail of 3D objects in a virtual environment [6]. The idea is simple; if an object is close to the viewing perspective, then render the model of high detail. If it is far away, render a mesh of the object with a lower polygon count.

This means each mesh is associated with a range of distance and will be replaced by a mesh of the same object of greater or lesser LOD according to whether the camera from the object gets closer or farther away from the object. There is no point in rendering many polygons onto the screen if the resulting projection of the object only occupies a few pixels.

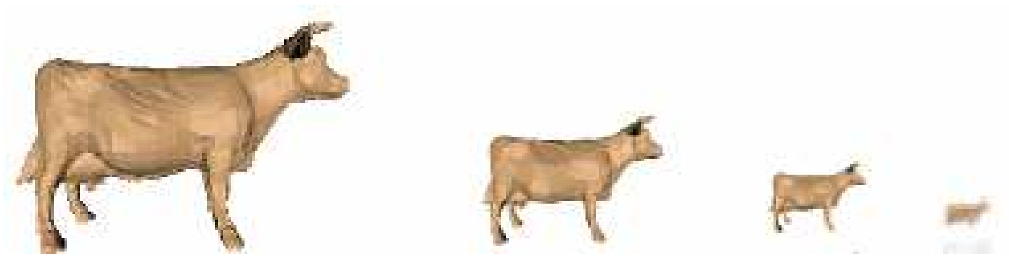

Fig 24: Shows several models of the same object, each with a different polygonal structure.

L-System is a formal grammar developed by Aristid Lindenmayer. It uses formal language theory to model the growth processes of plants [11], [12], [13]. The general concept is to successively replace the parts of an initial object by using a fixed set of re-writing rules. By applying this technique to a basic object, the object can grow over time.

This grammar is not limited to plants. It can also be applied to buildings Figure 25 shows how a skyscraper model can be created using the formal grammar. Nonetheless, *L-System* is not cost effective and therefore not very ideal for real-time environments [11].

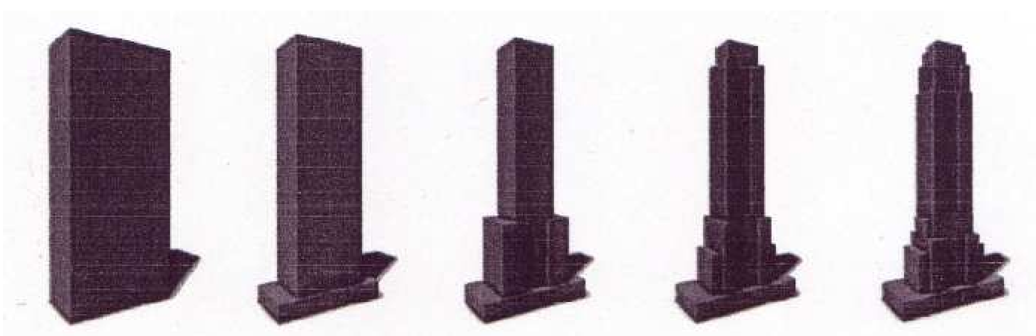

Fig 25: Skyscraper created using L-systems

Non-Uniform Rational B-Splines (NURBS) is a good modelling method for creating organic characters and for CAD files [11]. Smooth curved surfaces may be represented in an efficient and flexible way using NURBS and can be used in *3DS Max*. Using NURBS may be an advantage for certain smoothed surfaces; however the main disadvantage lies in the fact that they require additional storage space for traditional geometric shapes (e.g. a circle).

Section 3.0 - Theory & Design

3.1 Definition of problem & solution

The sub-sections of section 3.1 examine the definition of the problem that arouse in the creation of a virtual UEA before discussing the potential of the project. It moves on to discuss the realistic aims of the project and the plans on achieving this. Finally, it discusses what compromises had to be made during the project and why altering the project specifications were necessary.

3.1.1 Addressing the tasks

The project brief stated that this project had to "*Produce a realistic populated 3D model of the UEA so that 'visitors' can guide themselves around the place…"* This indicated that the project would strictly be modelled for a real-time environment. The UEA Admissions Team has specified they want to use the project as a product they can send out to prospective students. A project like this would also include creation of a fully functional user interface which also would have to include a small database of information on each building of the campus. (See section 3.1.2 for details)

However, after much consideration, the choice was made to focus on the graphical aspect of the virtual environment and to replace the interface with a short video sequence. This way, more energy could be focused on the realism of the university campus. Nonetheless, working on a real-time application would also be a large part of this project, primarily to ensure this project does not turn into an arts project, but also due to a personal preference: To complete a real-time application of campus would feel more personally satisfying.

The UEA Estates & Buildings department aim to use the virtual campus for building planning purposes and hope to expand the model by mapping the plumbing pipes of the university. This would allow them to keep an up-to-date virtual environment that would represent the university as a whole giving them a comprehensive perspective view of how pipes and buildings relate to one another.

Fortunately, this task would not be completed alone as *"...This project will be carried out in collaboration with the urban modelling group and the UEA admissions team…"* and much help has be provided by the members. Also, the opportunity to work with fellow students such as Paul Hatton and Marc Clare with the same level of experience in urban modelling gave the ability to compare this project with other modelling projects of the same calibre. It also allowed us to confer among each other if we were faced with the exact same problems in modelling. This was especially helpful during the rendering process. The project came across a problem which made *3DS Max* render the graphics 16 times slower than necessary (more on this in section 4.2.1).

The target of this project was to produce a realistic model of the UEA campus which ultimately the UEA could use how it pleases as the project brief specifies; *"…The complete model (if good enough) will be used by the university."* While the real-time application will have some compromises particularly in the field of level of detail, they are mostly alike.

3.1.2 Initial ideas and possibilities

The initial main focus for this project was to develop a real-time environment which would include an information system with text information on campus buildings and general information for prospective students. It would also have a graphical user interface. Ideally, the interface would allow a satellite view similar to that available in *Google Earth* (a virtual Earth-map application); however only go as far as until the entire campus is in the field of view. The interface would enable users to pick paths, and the camera would go to the destination following a set of fixed camera paths. The shortest distance from point A to point B would be calculated according to the camera paths available and a pathway algorithm would have been developed to calculate the shortest distance with the camera paths in mind.

These drawing are initial sketches for the originally planned information system interface. As the idea was dropped, the design has not been refined, hence why these sketches are rough drawings.

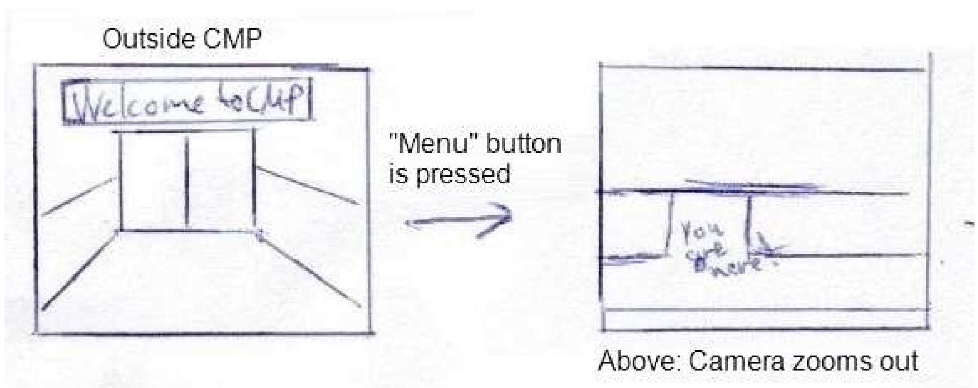

Fig 26: Shows how the camera zooms when the user wants to access the main menu

Figure 27 shows how the camera would zoom out even further to access the full view of campus. Once the perspective shows the entire campus, the program accesses the main menu. (See figure 28)

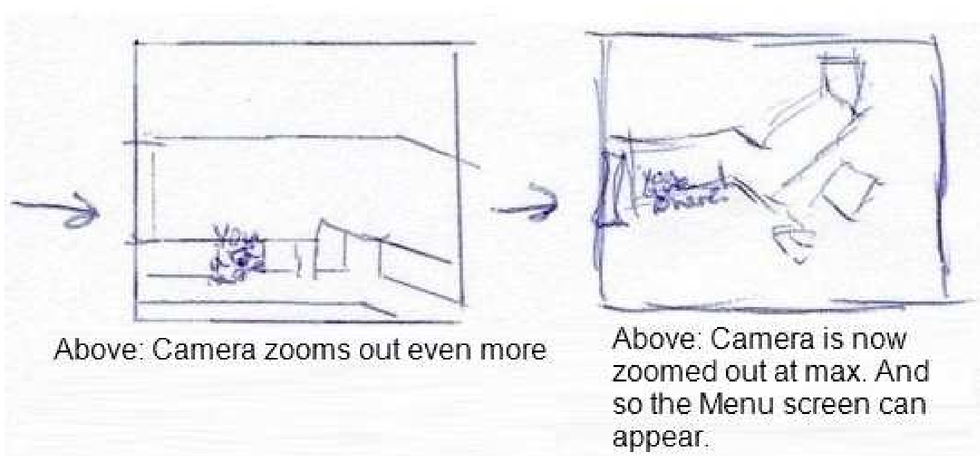

Fig 27: Shows how the camera zooms out even further than the previous figure

Figure 28 shows the basic menu of the planned interface. It was aimed to be a very intuitive mouse-point-and-click interface in which users select according to what they desire to see or read about.

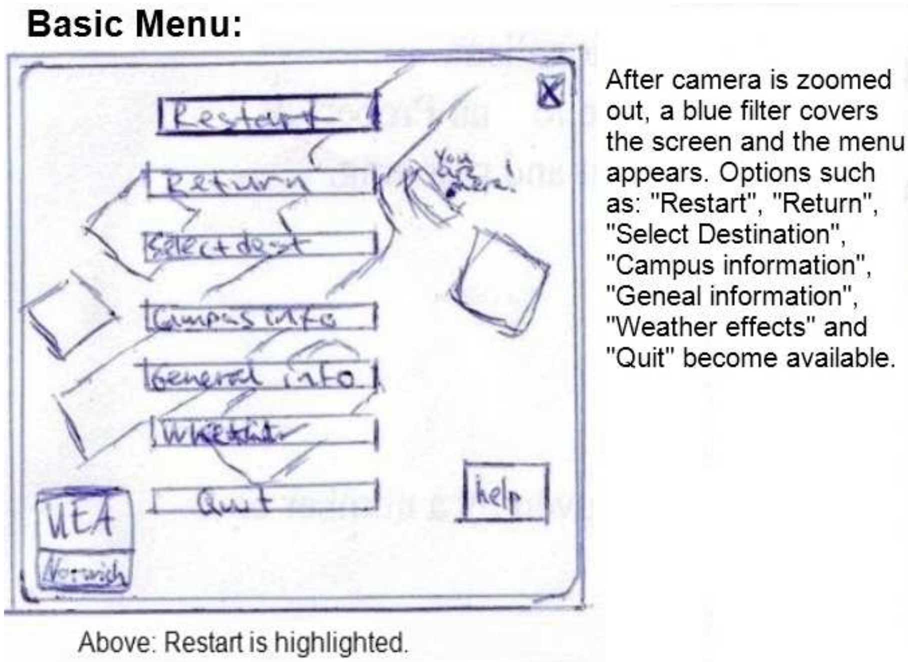

Fig 28: Shows the main Menu of the interface

Figure 29 shows how one of the options (Select Destination) in the main menu gets placed in the upper left corner new section of options appear, all of which the user may select from.

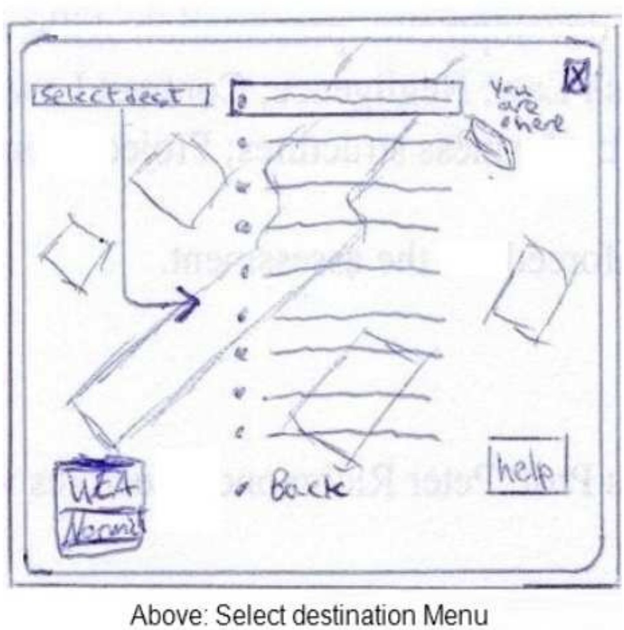

Fig 29: Shows the “Select Destination” options in the interface

Other initial thoughts for potential areas to work on in this project include adding real-time weather effects such as rain, sunlight and snow, and applying vegetation modelling to this project. However, it was quickly realised this was not doable in the span of time for the project.

3.1.3 Realistic aims and design for project

After completing a few models it was realised that the project was too ambitious. The aims were altered to focus more on the graphical aspect of the project and add realism to the urban models.

The altered aims of the project are as follows (also discussed in section 1.1.2) - Produce two realistic 3D virtual models of the eastern section of the UEA: The first, a real-time interactive application with realistic models and the second a short pre-rendered video fly-by of campus. Both will hopefully be used by the school of Computing Science at the UEA.

The original real-time interactive application has been modified to fit the specifications of this project and to load the model into the environment. Figure 30 shows the original application. Items such as the skybox and the ground remain from the original source code.

After completing this project, several new ideas on how to expand the project have come from the experience of this unit. These are discussed in section 5.1.

Fig 30: Shows Greg Ryder's original interactive crowd behaviour application with a few automatically generated urban models discussed in section 2.3.2

3.2 Resources

The sub-sections of 3.2 discuss what resources have been used during this project. It goes into details on what hardware and software tools, documentation and other resources have been used to recreate each building in the virtual environment.

3.2.1 Hardware

The computer workstation is the most essential item of this project. Without a proper work station, modelling the buildings could not be possible. The workstations used were machines available in the computer graphics laboratory 5 and the author's own personal computer.

Laboratory computer workstations basic specifications:

CPU: Pentium 4 - 3.20GHz
RAM: 1024 Mb
Video Memory: NVIDIA GeForce 6600 GT – 128 Mb

Home computer workstation basic specifications:

CPU: Pentium 4 - 3.20GHz
RAM: 1024 Mb
Video Memory: ATI X300 – 128 Mb

Fig 31: Shows the computer workstation in Computer Graphics Laboratory 5

While rendering the video sequence, several computer workstations have been used. Segments of the entire camera path are rendered at each workstation. Each segment were placed together to form the final video sequence.

A digital camera is a camera that stores photographs electronically rather than on film. Digital cameras were used to photograph textures. Photographs were edited using photo editing software. The photographs of campus were one of the most useful resources to recreate an environment in a virtual form.

A graphics tablet is an input device that uses a stylus (a device that looks like a pen) or a specialised tablet mouse to write or draw on the tablet surface to communicate with the computer. *Wacom Graphire 4* was the graphics tablet used for the project.

Using graphics tablets is an excellent way of editing 2D textures that can be used for 3D environments. Most 2D photo editing software supports these graphics tablets. *Adobe Photoshop* was the 2D photo editing program used to edit the textures in the virtual environment. The images used to edit textures were either photographs taken on campus or pure colours.

Textures became easier to modify using graphics tablet as they work similarly to that of a pen and piece of paper. Using a mouse to draw elements on screen (especially for 2D textures) was a very difficult task. Utilising a tool that is more intuitive to the human hand like a graphics tablet and a pen made the process of editing textured both easier and faster to accomplish.

Fig 32: Shows the graphics tablet used to edit textures in this project

3.2.2 Software

Microsoft Windows XP is an operating system. It was the operating system and working environment in which this project was implemented.

3D Studio Max is a modelling package that has been chosen to use for this project. It provides the opportunity to easily model realistic buildings and characters for virtual environments. More specifically, it is a 3-dimensional vector graphics and animation based program, written by Autodesk Media & Entertainment and is largely used by animators, game developers and virtual environment designers.

3DS Max has a user-friendly interface (see section 2.1.1 for screenshot); however with its vast selection of options within the virtual environment, it was a very difficult program to learn, even with its common and conventional interface design. Learning how to edit virtual models in an effective manner has been a very slow process.

Microsoft Visual Studio .NET (VS.NET) is an IDE for programming languages such as C, C++, C#, Visual Basic and Visual J#. It is an IDE for the Microsoft Windows operating system and is aimed mainly, (but not exclusively), at development for Win32 applications.

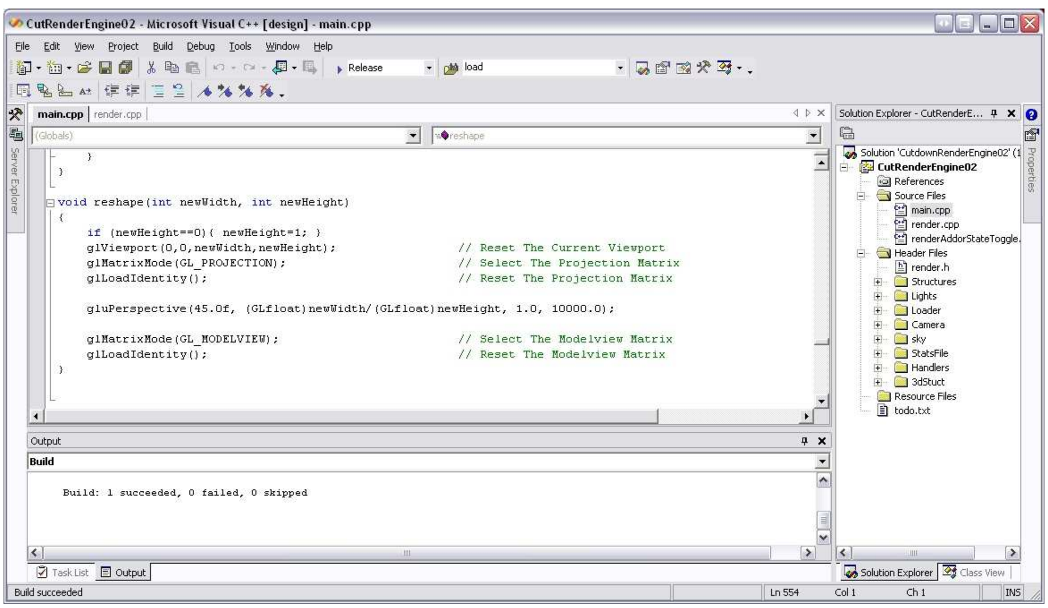

Fig 33: Shows a screenshot of the working environment *Visual Studio.NET*

OpenGL is a cross-platform API consisting of over 250 fixed function calls which can be used to draw and manipulate complex 3D computer graphics scenes. It is widely used in the computer games industry and for research in computer graphics. In this project it is used together with VS.NET to implement the virtual environment.

Adobe Photoshop is a 2D photo editing program that was mostly used during this project. Nonetheless, software such as *GIMP* and *Paint .NET* have been used as alternatives to *Photoshop*. There are also a few effects that are easier to achieve in these programs than in *Photoshop*. (E.g. Adjusting brightness and contrast in image.)

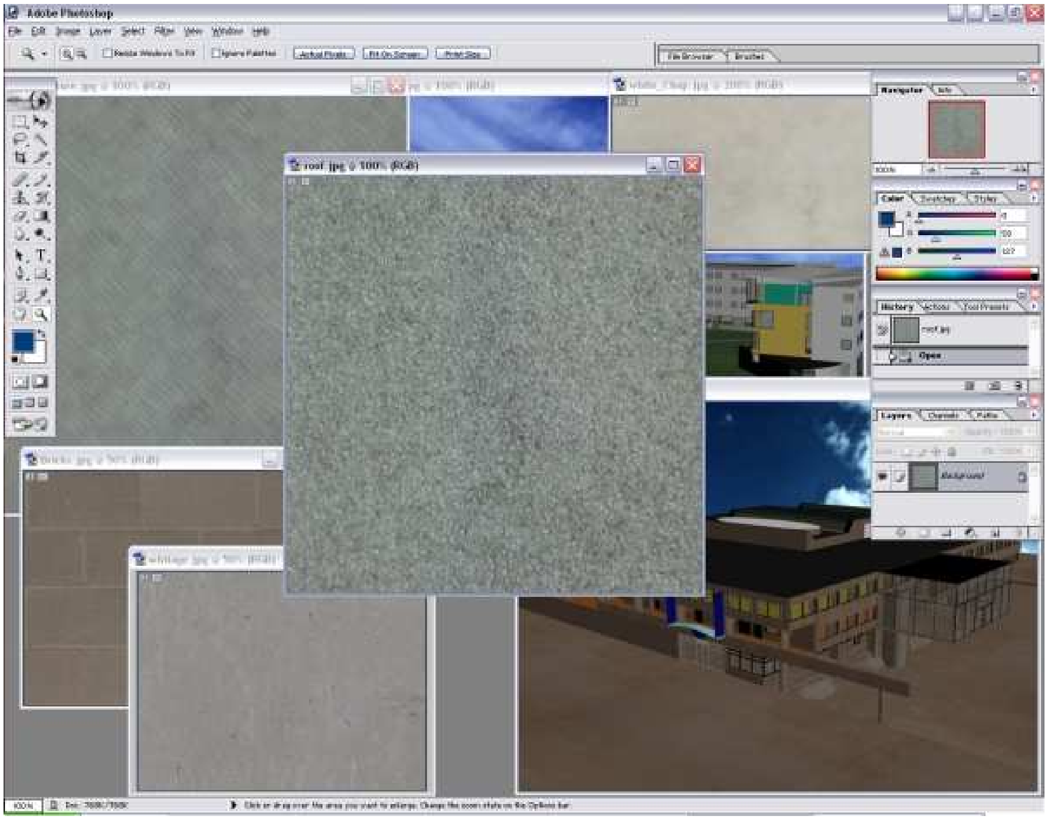

Fig 34: Shows a screenshot of the 2D Photo editing software *Adobe Photoshop*

Microsoft Office is a widely used suite of productivity programs that can be used to write reports, spreadsheets or create databases among other things. During this project it has been used to write reports as well as Gantt charts using *Microsoft Word* and *Microsoft Excel*.

Internet Explorer is a web browser developed by *Microsoft*. Today, it is the most commonly used internet web browser. For this project the browser has been used to research information regarding urban modelling and creation of virtual environments.

3.2.3 Documentation

CAD files are electronic Computer Aided Design blue prints of buildings. The Estates & Buildings Department provided CAD files of the .dwg format. This format works best in the *AutoCAD* modelling environment. Nonetheless, it was imported into *3DS Max* as it is easier to deal with modelling and texturing virtual environments with multiple 3D objects in the same environment than in *AutoCAD*. *AutoCAD* focuses more on modelling of each item or building separately.

Maps of the university campus have been very useful to use during the course of this project. *Google Earth* has also been of great help to compare maps like figure 1 to the real world (see figure 35) and place the models in accordance to both maps and the overview satellite photograph of the UEA. Although the overview photograph of campus in *Google Earth* is quite old, it still provided much more realistic view of campus than the maps.

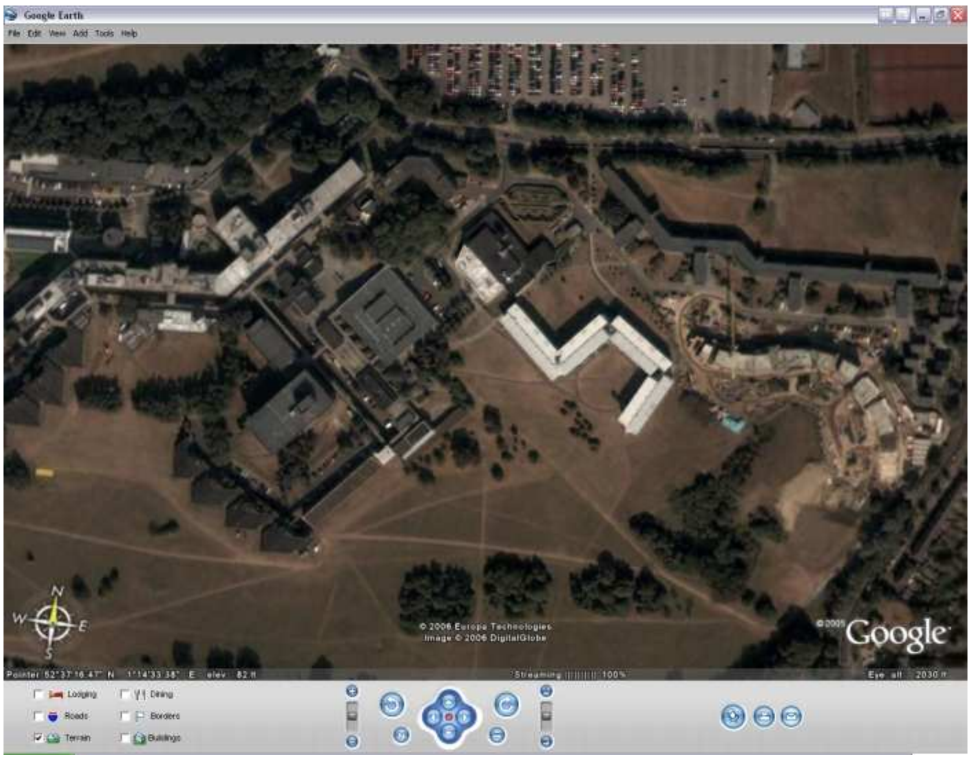

Fig 35: Shows the Eastern section of campus using *Google Earth*.

Photographs have been a very important aspect of the project. Appendix A contains all photographs in their digital form in the same folder as the original *3DS Max* files.

The internet has been a great resource to research urban modelling. *The Association for Computing Machinery* (ACM) digital library has been the primary source of academic papers related to urban modelling (See bibliography for other resources). Interestingly enough, most papers found on this site related to urban modelling research were written by researchers at the UEA.

A few books have been researched to gain an appropriate understanding of how to model virtual buildings. These can be found in the bibliography.

3.2.4 Assistance and help

Urban modelling is a difficult area to start on without any prior experience in the field. The practical help, guidance and opinions of modelling and general progress of this project from people already involved in Urban Modelling has given a greater understanding of what is appropriate and what does not work when working with virtual models (See Acknowledgements for details).

Section 4.0 - Implementation, testing & results

4.1 Implementation

The sub-sections below describe the implementation, testing and results of this project. It starts with discussing some basic techniques used in *3DS Max* in very general terms, and moves onto discussing how each building was modelled separately. It then describes how buildings were placed together in the virtual environment for both the pre-rendered sequence and the real-time application, also discussing the implementation of the camera path for the project.

Section 4.2 discusses the testing and the problems encountered in this project. Section 4.3 talks about the results of this project. These results can be found in appendix A. Improved versions will be demonstrated at the bench inspection. It also covers what will be improved from the version submitted in this report.

4.1.1. Using 3DS Max

3DS Max is the primary working tool and modelling package for this project. This section goes into detail on what main techniques have been applied to the models from what has been learned from the *3DS Max Bible* [14] as well as the tutorials available in the modelling package itself. It does not go into detail of how to create objects and general manipulation of vertices and polygons, but focuses more on general techniques in which there are more ways to solve the problem.

Constructive Solid Geometry (CSG) is a technique in solid modelling that deals with representations of complex solid objects that can be defined as a combination of simpler solid objects. CSG is closely related to Set Theory in mathematics [15], [16].

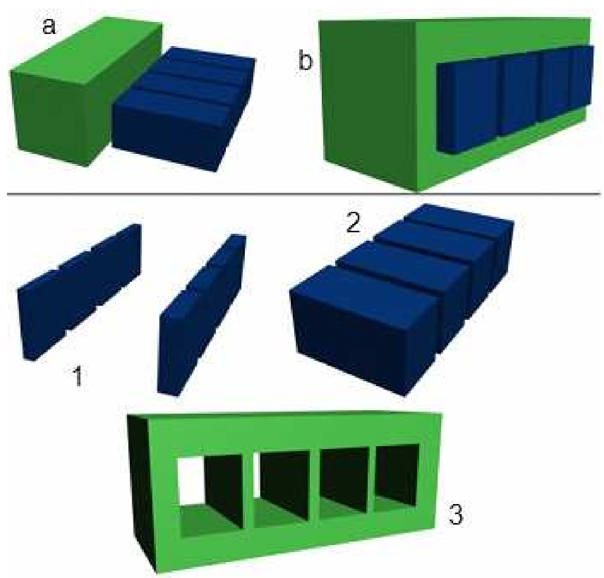

Fig 36: Illustrates the effective use of CSG.

Above the grey line of figure 36 indicates what the green and blue objects look like separately (a) and placed together (b). Below the line the results are shown.

G = Green block, B = Collection of blue blocks.

1. “B and not G” → B - G
2. “Intersection of B and G” → B ∩ G = G ∩ B
3. “G and not B” → G - B

b: Note how like in plain set theory → (G U B) = b.

Using CSG is a good starting point to create windows and doors for urban models. Figure 37 & 38 shows how CSG has been applied to the careers centre.

Fig 37 & 38: Illustrates how CSG has been applied to the careers centre.

Another method of creating the basic building structure similar to using CSG is to create boxes with more polygons and vertices than necessary. This means that each wall surface must consist of multiple polygons. One may then manipulate the vertices and delete the unnecessary polygons that make the doors and windows as figure 39 and 40 show. Although this is a valid approach, it leaves unnecessary amount of polygons. The CSG approach was preferred because it did not leave unnecessary and unused amounts of polygons in the scene.

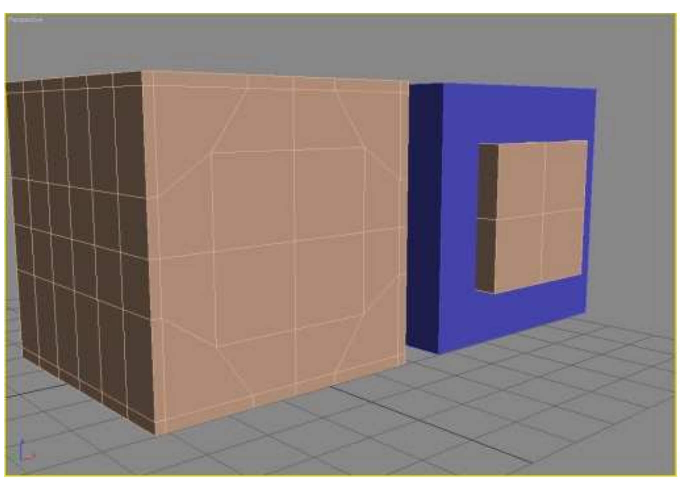

Fig 39: Shows the amount of polygons required to create a window without using CSG (left box) and compares it to a box defined by CSG (right).

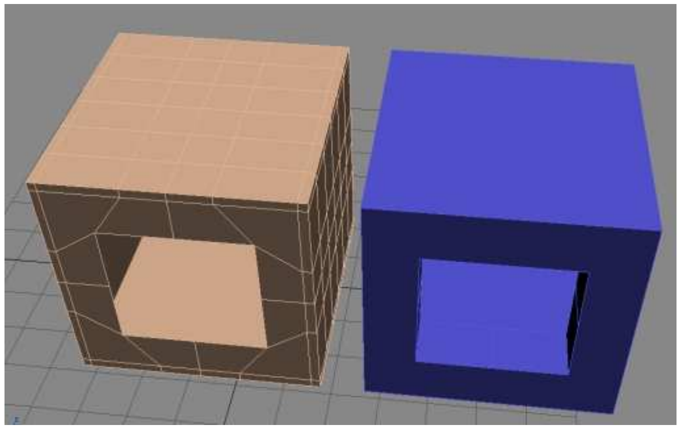

Fig 40: Shows the result of window creation when not using CSG (left) and compares the result to a model defined by CSG (right).

Several of the models were created using 2D CAD file. By creating splines that follow the exterior outline of each building and then turning these splines into 2D polygons, these polygons could be extruded to give a height to the 2D buildings and give them a third dimension. This 3D representation of a building could then be modified according to specifications of the building, adding windows, frames and other details of that specific building. Extruding polygons was useful to add other features to buildings such as extensions or roof top elements among other things.

3DS Max 5.1 (the version used during the course of this project) does not support easy creation of simple window and door. Each window and door had to be hand made and copied where appropriate. Glass was made by decreasing the opacity of pure grey polygons. A level of 30% (instead of 100%) creates the effect like figure 41 depicts. The sphere goes through the glass to show the difference in colour, similar to how real life glass would change the colour of the sphere. This technique was applied to all windows in the *3DS Max* environment. In the real-time application, the windows got a grey colour and had to be altered by declaring all polygons without textures to be transparent in the code.

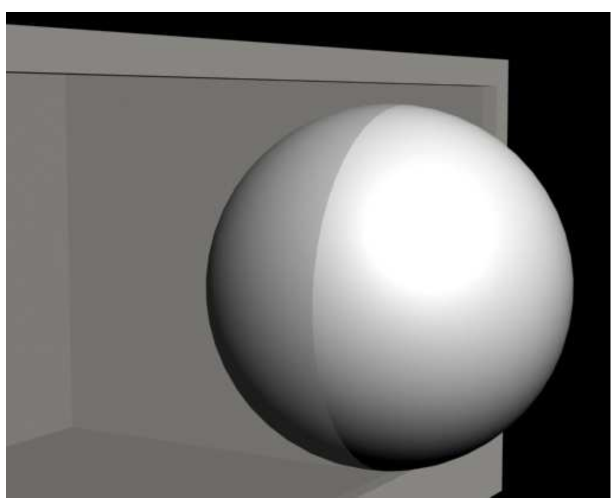

Fig 41: Shows how opacity was applied to a plane surface to create virtual glass.

Optimising the polygon count for virtual objects is a feature in most modelling packages. It removes unnecessary surfaces to 3D objects by approximating closely related polygons to as few polygons as possible without changing the appearance of the virtual object itself.

In essence, this means a flat surface consisting of for instance 50 x 50 polygons can be optimised to a flat plane consisting of only 2 polygons as figure 42 depicts.

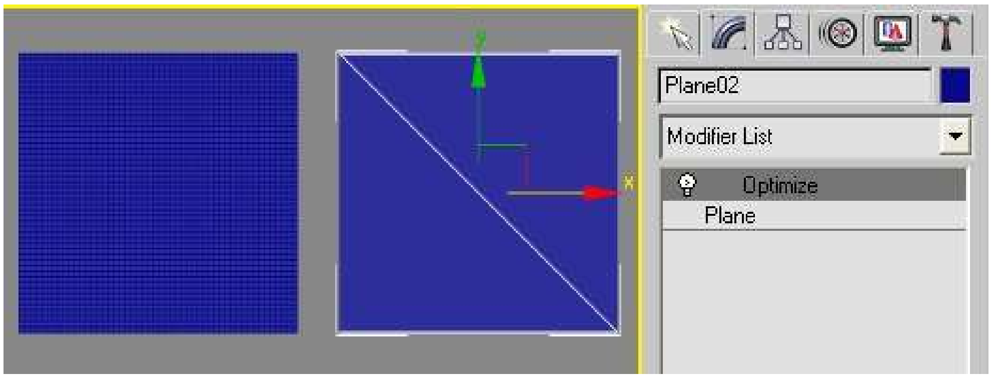

Fig 42: Shows how optimise can be used in *3DS Max* to reduce the polygon count.

Although optimising is very useful in many respects, this approach has a tendency of triangulating the polygons which may make manipulation of the polygons more difficult.

Bump mapping is a technique to make a surface appear rough or wrinkled 3D appearance. It is achieved by changing the normal of the surface/polygon used in the lighting computation in the virtual environment [17], [18].

Fig 43: Shows the difference between the brick texture that does not have bump mapping (left) and one that does (right).

Reflection can be added to polygons that represent glass (and has a low opacity) to increase realism to the scene. Figure 44 shows an example of how reflection adds realism to the scenery when a red sphere is in front of a polygon that represents a glass window.

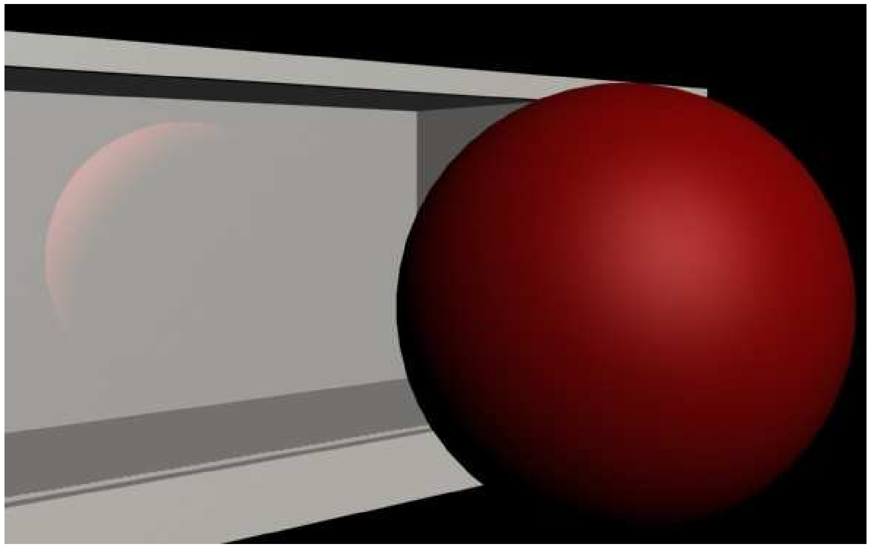

Fig 44: Showing reflection on a polygon with 30% opacity

The sub-sections of 4.1 from 4.1.2 to 4.1.23 discuss the individual implementation of various aspects and buildings of campus and problems that occurred for each individual section. All of which show work in progress photographs that have been refined for the final submission.

4.1.2 Music Centre

The music centre is a building made up of mostly primitive objects. As it is not a very complex building it was decided to model that building first. As it was the first building attempted and several mistakes were made throughout the modelling process, the school of music ended up to be modelled three times to get the appropriate accuracy. The process of modelling each building has been of a trial and error nature.

During the first two attempts of modelling the building, a few issues with texture mapping and vertex manipulation occurred, so the texture mapping would not be applied properly. The textures appeared distorted and looked unnatural for a building. It was discovered at a later stage of the project that the building was modelled properly and only a few minor adjustments would have solved the problem.

The problems occurred due to lack of experience in using and understanding *3DS Max*. There was nothing wrong with the texture mapping as per se, however they were placed on the objects in an inappropriate manner. Once the model looked correct according to the photographs, the next building was modelled.

There were some minor problems with this building. Similar problems reoccur throughout the process of modelling the project models.

Figure 45 shows how the CAD file differed itself from the real life model. The section above the main entrance should have been much lower than in reality, and the music centre is much taller than what the figure depicts. It suggests there are only two floors to the school, while in reality there are three floors. In the CAD file two floors has been blended into one floor. Windows on the east side of floor 1 should have been placed on a (non-existent) second floor and not on the same floor as the western windows of floor 1. This lead to a misleading perception of what the music centre actually looks like in real life.

It was due to such inaccuracy, the CAD files were not considered to be as trustworthy of a source for 3D buildings as they should have been.

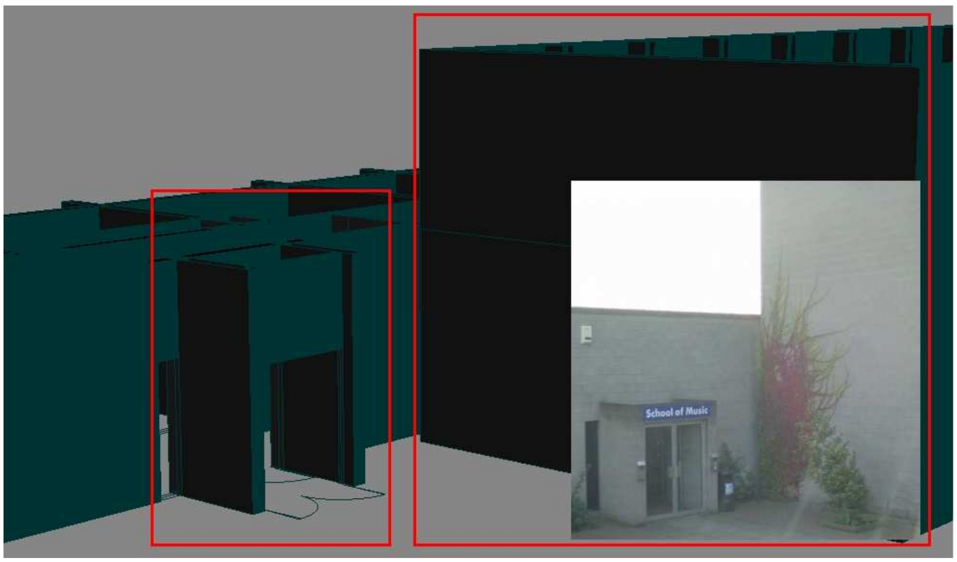

Fig. 45: Shows a few problems with the school of music CAD file, and compares it to the real world.

There were two problems with the eastern section of the ground floor of the same building. Figure 46 shows how entire window segments were missing and how the studio room windows were not of the same size as their real-life counterparts.

Fig. 46: Shows more problems with the school of music CAD file, and compares it to the real world.

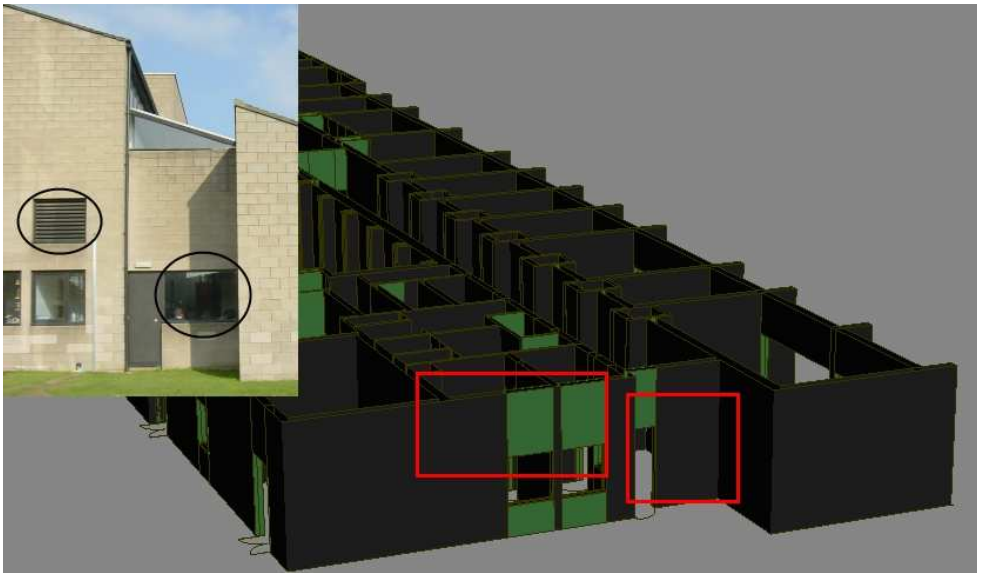

Fig. 47: Shows the problems with the southern section of the school of music CAD file, and compares it to the real world. A window and ventilation filter was missing.

Figure 47 shows that important features of the school of music were missing. In the southern section of the building, a ventilation shafts filter and a window was missing compared to the real-life building.

4.1.3 Chaplaincy

The Chaplaincy was the second building that was modelled. In this model the building consist of 3 floors; one entrance floor, one lower floor and one roof. The 3D CAD files for this building blended into each other in such a fashion that it was easier to build this model from a set of 2D plans. It was then decided to model the building from photographs and the 2D files.

Fig. 48: Shows the Chaplaincy as a whole 3D model object.

4.1.4 Career Centre

Section 4.1.1 has already shown how the use of CSG has helped in the process of modelling this building. No 3D CAD files were provided for this building, which means it was modelled from 2D CAD files and photographs. The letters were created using *3DS Max*, and all individual 3D objects.

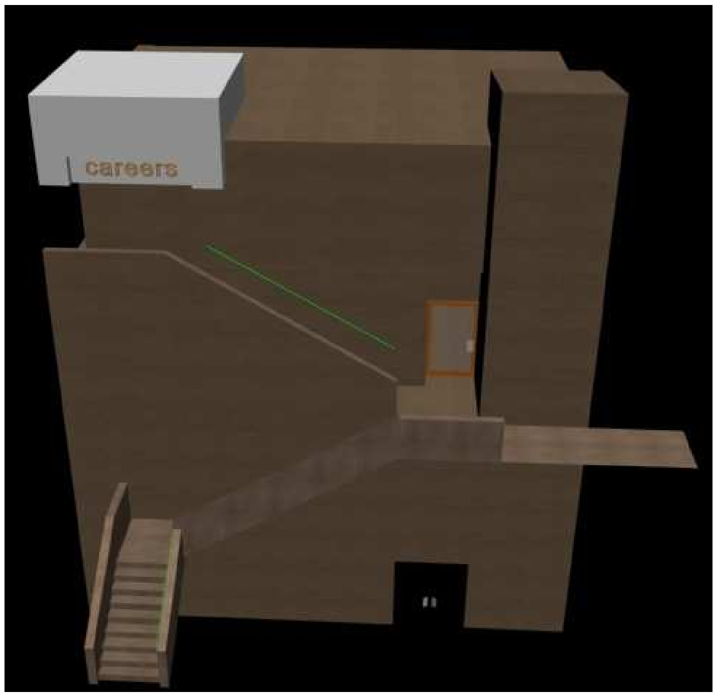

Fig. 49: Shows an early version of the Career's Centre as a whole 3D model object.

4.1.5 Dean Of Students' Office

Two main boxes make up the Dean of Student's office. They have been placed on top of each other. The upper box has also been formed into the symmetrical shape shown in figure 50, while the lower box was created similarly to the Career's centre by using CSG and shaping each window individually.

Fig. 50: Shows the Dean of Student's Office as a whole 3D model object.

4.1.6 Student Counselling Office

The Student Counselling Office was created in the same fashion as the Dean of Student's office. However, the upper section was created by extruding polygons rather than creating a new box entirely. Figure 51 shows the result.

Fig. 51: Shows the Student Counselling Office as a whole 3D model object.

4.1.7 Waterstone's

Of all models in the entire project the Waterstone's building was the simplest building to model. The building consists mostly of a few cube-shaped primitive geometric objects with glass on some edges of the building. There has been one problem with this model. Figure 52 shows the ceiling of the upper entrance. As of the middle of this academic year the ceiling has been covered by flat tiles to cover these bowl-shaped holes. They have not been removed from the final model as these tiles may be removed in the future.

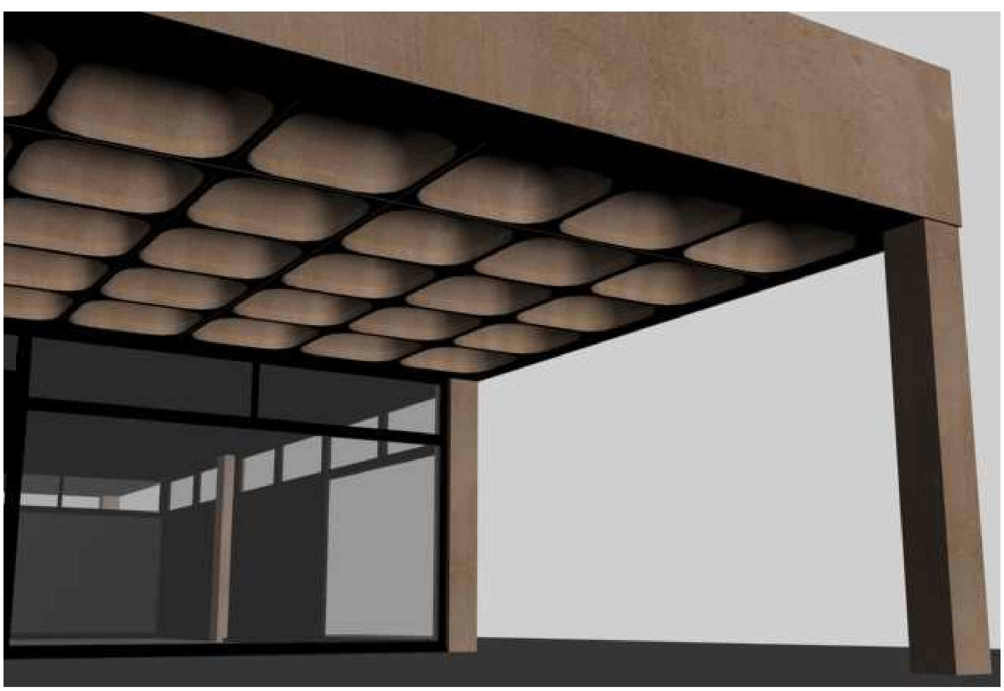

Fig. 52: Shows the Waterstone's ceiling.

Figure 53 shows what the Waterstone's upper section looks like. The lower half of Waterstone's is part of the street. See section 4.1.10 to see how that section was modelled.

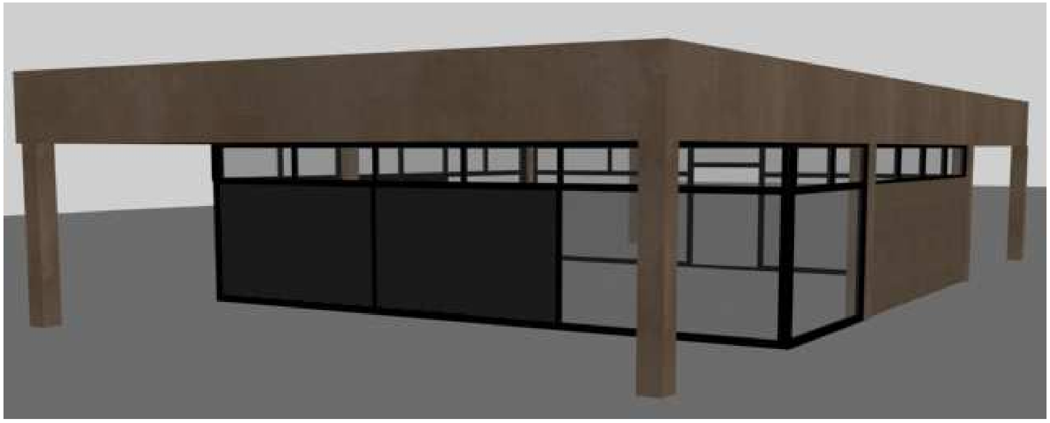

Fig. 53: Shows Waterstone's as a whole 3D model object.

4.1.8 Old Sports park/Congregation Hall

The Congregation Hall was not very difficult to model, but it was a very time consuming process. This building consisted of polygons grouped in a seemingly very illogical manner. After all groups were exploded from each other, they were still attached to each other in an odd way. Section 4.2.2 elaborates on this problem.

Fig. 54: Shows the old sports park/congregation hall as a whole 3D model object.

4.1.9 Drama Studio

The Drama studio was implemented without any major problems. Fortunately, the CAD files for the building were of good quality and were visually very accurate to the real-life counterpart. The only item missing from this model was the large green ceiling/roof above the entrance.

Every floor was predominantly made in advance in a very good manner, and the only time consuming and slightly difficult section of this model was to apply the textures correctly and to model the main brick texture surrounding the building as shown in figure 55.

Fig. 55: Shows the Drama studio as a whole 3D model object.

4.1.10 The Street/Shopping Centre

Modelling the Street was not particularly difficult, however it was a very time consuming process. The main floor is a large box with many windows and doors within the environment. It covers the bottom half of the Waterstone's building and goes all the way to the laundrette next to the Union Food Outlet. The lower floor has a parallel wall that faces the library.

Fig. 56: Shows the back end of the Street as a whole 3D model object.

4.1.11 Union House

The Union House is a more complicated building due to its partial symmetry. The entire first floor is a symmetric and simple floor to model, the roof, half of the ground floor and the pub section however were more difficult sections to model. Pillars outside the pub were of uneven heights. Even if there was a local symmetry for neighbouring windows, globally they would not repeat more than three in a row.

Fig. 57: Shows the Union House as a whole 3D model object.

4.1.12 Lecture Theatre

The lecture theatre consists mainly of three floors. There is the ground floor which is the same level as the concrete walkway. This level consists of a small hall and the actual lecture theatre room 1. The physical ground level acts as floor 02.

The main issue with modelling this building was that each floor plan in the 3D CAD files had key sections of buildings modelled twice. While this is a good way to model each floor separately to visualise how rooms relate to the building, it got up to the point where separating between rooms got very difficult once each floor were placed together as figure 58 shows.

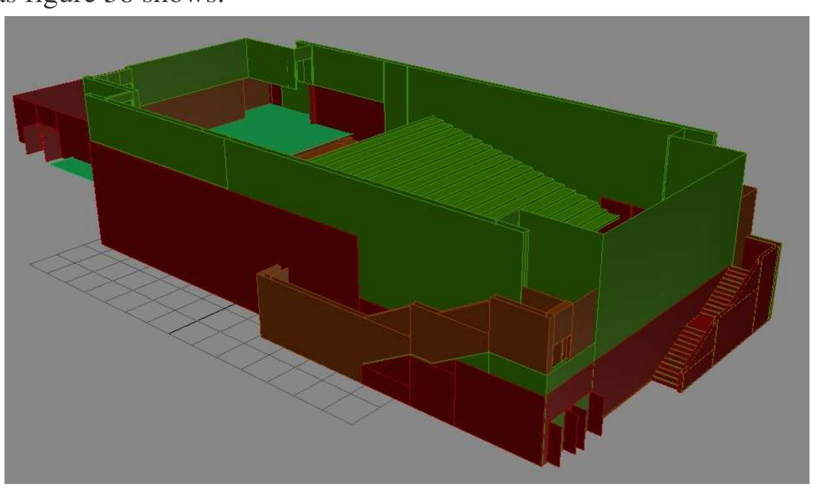

Fig. 58: Shows how the original CAD files overlapped each other in a confusing way

4.1.13 Old Library

The old library is a building with much repetition. It also, mostly consists of the same texture. Fortunately this was another time in which the CAD files were quite accurate even in their 3D shape. Although, all of the organising and restructuring of each polygon for this model also had to be done individually, the main changes made to this model were related to the new library as depicted in figure 59. Figure 60 shows the old library in its entirety.

Fig. 59: Shows the connection between the old and new library.

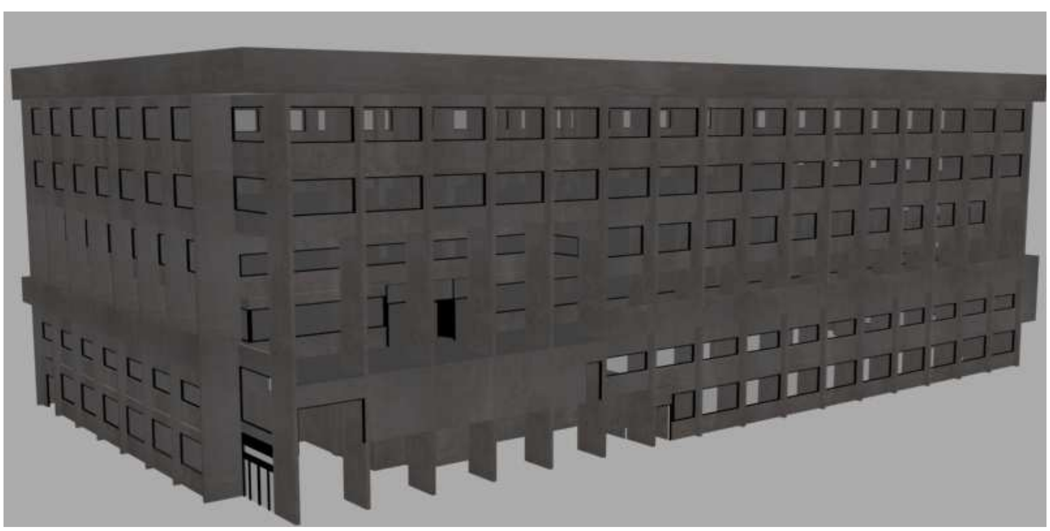

Fig. 60: Shows the old library as a whole 3D model object.

4.1.14 New Library

No CAD files were available of the new library from the UEA Estate & Building department during this project. This building was the most time consuming and the most difficult building to model due to its relatively unsymmetrical structure. Although there are certain features that repeat throughout the entire building, most of them vary to across the building. The only exception for this is the wooden pillars that stick out of the building. Window frames and the decorative frames were the most difficult areas to model as those sections were the ones with least symmetry.

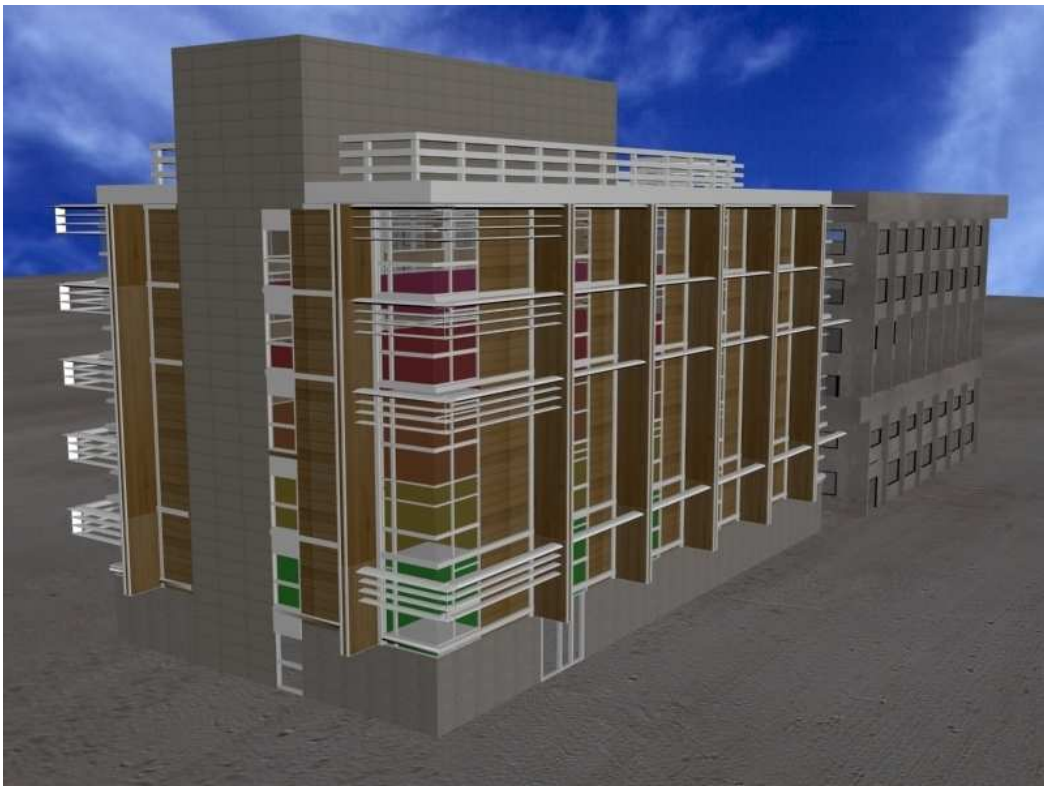

Fig. 61: Shows the new library as a whole 3D model object.

4.1.15 Restaurant Building

The restaurant building consists of basic primitive objects such as boxes and walls. It was time consuming to model due to its large amounts of dissimilar windows and its lack of symmetry. The UEA Estates & Building department could only provide parts of the exterior CAD plans. Certain walls had to be modelled by hand as seen on figure 62. This made the modelling process go somewhat slower. A few outlines of interior models came with the CAD files, and remain in the final model for visual appearance purposes. During the modelling process they were used to keep track of separating each floor. Figure 62 show the restaurant building early on during the modelling process.

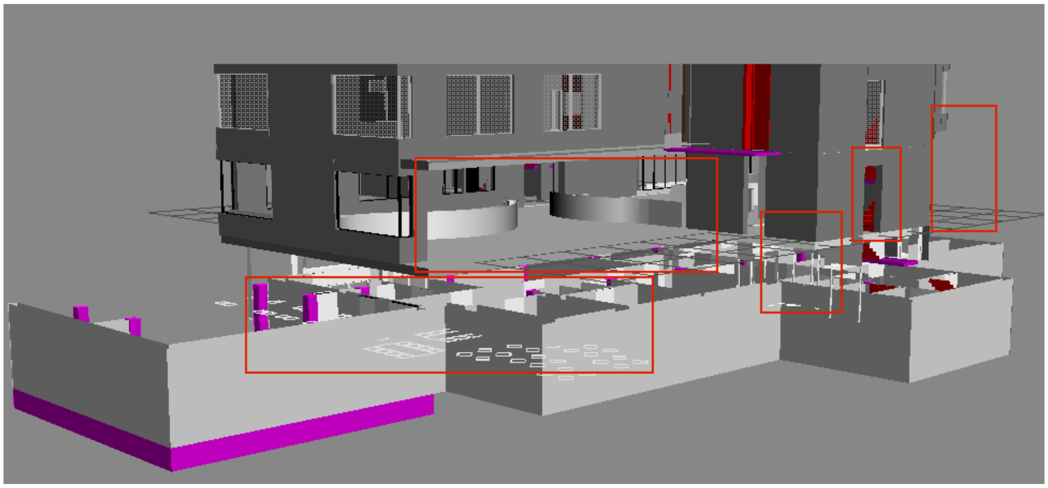

Fig. 62: Shows the restaurant building as a whole 3D model object.

Each red frame indicates where the CAD files failed to produce accurate exterior parts.

4.1.16 Suffolk Walk

Suffolk Walk is the accommodation next to Suffolk Terrace. The eastern section of the building is mostly made up of windows and walls. This was a simple section to model as it dealt with repeating the same window frames several times.

The difficult part to model was the entrance section of the building due to the descending ground. This became particularly a problem as the CAD files provided were only of 2D nature, also the amount of stairs did not increase by a fixed size either.

Figure 63 shows the western side of the building while figure 64 shows the eastern half.

Fig. 63: Shows the most difficult front section to model of Suffolk Walk.

Fig. 64: Shows the window section of Suffolk Walk.

4.1.17 Suffolk Terrace

Suffolk Terrace as one of the first buildings that was attempted to be modelled. However, due to the building structure that seemed simple at first, the initial version was abandoned until more experience had been acquired from working on this project.

This was a good decision as once working on the model started the second time, the process of modelling went much quicker and it was easier to work on due to the experience from the simpler models.

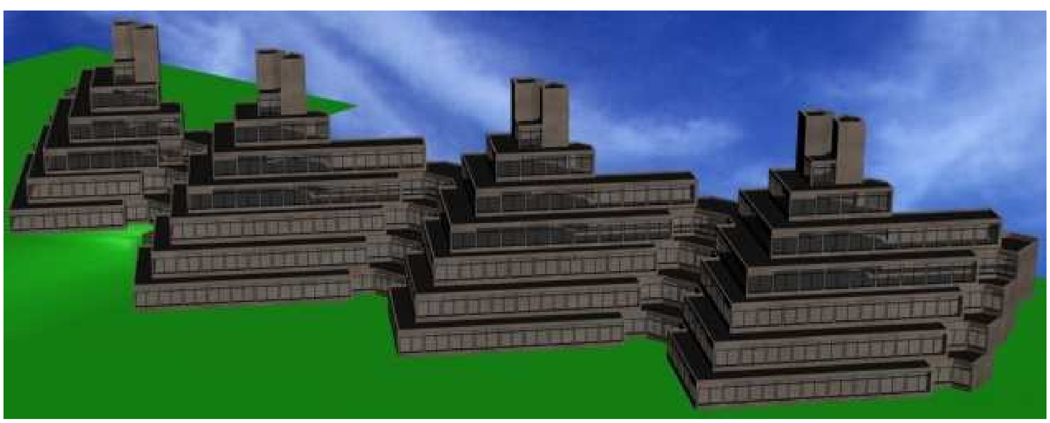

Fig. 65: Shows an overview picture of Suffolk Terrace as a whole 3D model object.

4.1.18 Nelson Court

Most of the CAD files of Nelson Court were corrupt from the start, and only a 2D base of the building was available while modelling the building. Fortunately, as the floors one to three are almost identical (floor one is similar to the ground floor), floors two and three are simply repeats of the first floor. The most difficult sections to model of this building were the corners of each of the three building segments and the south-west wall because of its stair structure leading to the top floor.

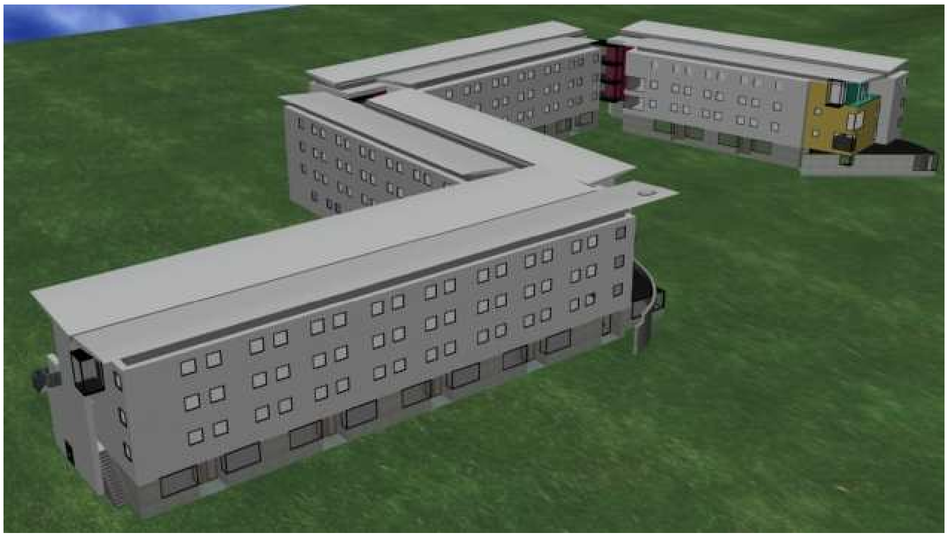

Fig. 66: Shows the Nelson Court as a whole 3D model object.

4.1.19 UEA Registry

The UEA Registry is a complex building as it consists of a vast amount of simple and small models. Each small section is very dissimilar to the other as one can see in figure 67. Nonetheless, by modelling each segment one section at a time, this turned out to act more as a time consuming effort than being difficult.

Fig. 67: Shows the UEA Registry as a whole 3D model object.

4.1.20 Wolfson & Orwell Close

Most of the effort has been focused on implementing a realistic campus with the main section being the most vital part. This means that at the time of this reports deadline, these two buildings are still work under progress as they are far away from the main campus, however, both will be ready for the bench inspection.

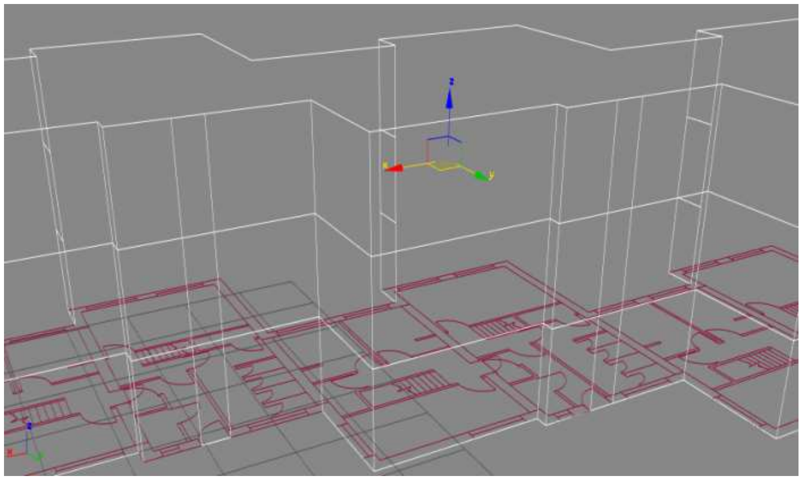

Fig. 68: Wolfson Close as an object model in wireframe mode (work in progress).

4.1.21 Colman House & other new accommodation

The new accommodation consists of Colman house, Kett House, Browne House, Victory House. At the time of the deadline for this report, these buildings are also still being modelled. They will be available to see during the bench inspection and a full list of details to them will be added. Figure 69 shows Colman house as it stands at the time of the deadline.

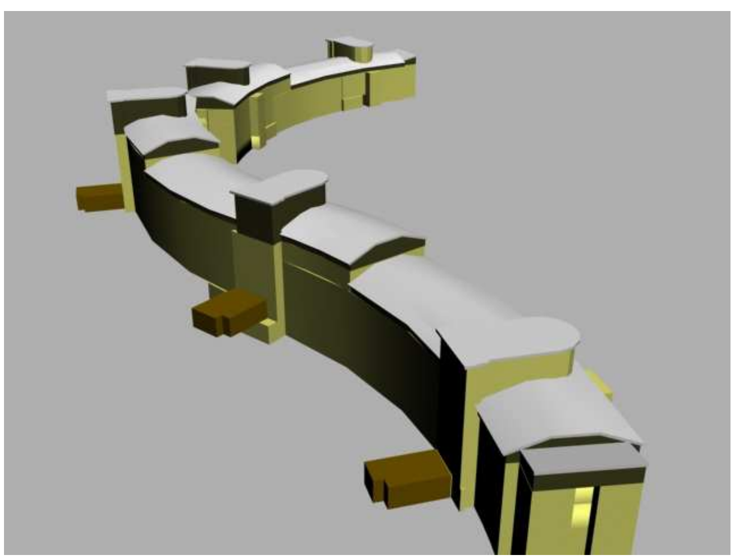

Fig. 69: Shows Colman house as a whole 3D model object as it stands at the time of the report deadline.

Waveney Terrace was not modelled as it will be torn down within two years.

4.1.22 Height Map/Trees/Campus as a whole

Trees and plant vegetation models have been used in this project. None of the vegetation models have been made specifically for this project. All of them have been borrowed from separate sources. All sources are acknowledged in Section 6 of this report. Figure 70 shows an example of a few trees, each of which holds around 20,000 polygons. They use many polygons and this makes them not ideal for a real-time environment. However, they are used in the pre-rendered video due to their realistic features. These trees were downloaded from: http://www.max-realms.com/

Fig. 70: Shows one type of tree that has been used in the pre-rendered sequence

Mesh smoothing is a useful feature in modelling packages that increase the amount of polygons to a model in order to smooth out corners and objects that have changes to its polygonal angles. Mesh smoothing is mostly used to character modelling due to this feature. Buildings tend to be of more roughed-edge nature.

Furthermore, as most of the UEA buildings consist largely of flat surfaces, mesh smoothing is not a useful feature for the actual models. Mesh smoothing is however an excellent method of creating uneven terrains in 3D maps as depicted in figure 71.

Fig. 71: Illustrates how the congregation hall slope has mesh smoothing applied to it.

Photographs have been useful during the modelling of items such as trash bins, benches, stairs and the walkway among other things that exist on the university campus. Figure 72 shows an example.

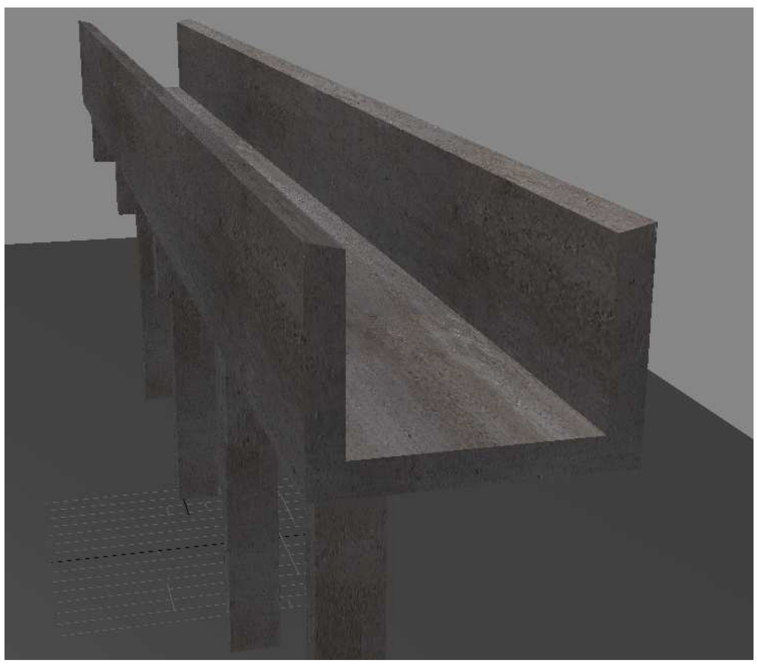

Fig. 72: Shows a section of the walkway path modelled

4.1.23 Pre-rendered video

A pre-rendered video was created using a frame rate of 60 frames per second to ensure the video runs at a fluid speed. The length of the video is three minutes, which means a total of approximately 10,800 frames have been placed together to form the video. CMPS3E29 taught how creating a storyboard is an excellent way of planning the look of a video. This has been done for this project as well. Appendix D consists of the storyboard and other ideas how to create the video. The entire video will be demonstrated on the bench inspection.

The video was rendered using a camera path designed in the storyboard. The camera followed this during rendering. Figure 73 shows the outline for the camera path.

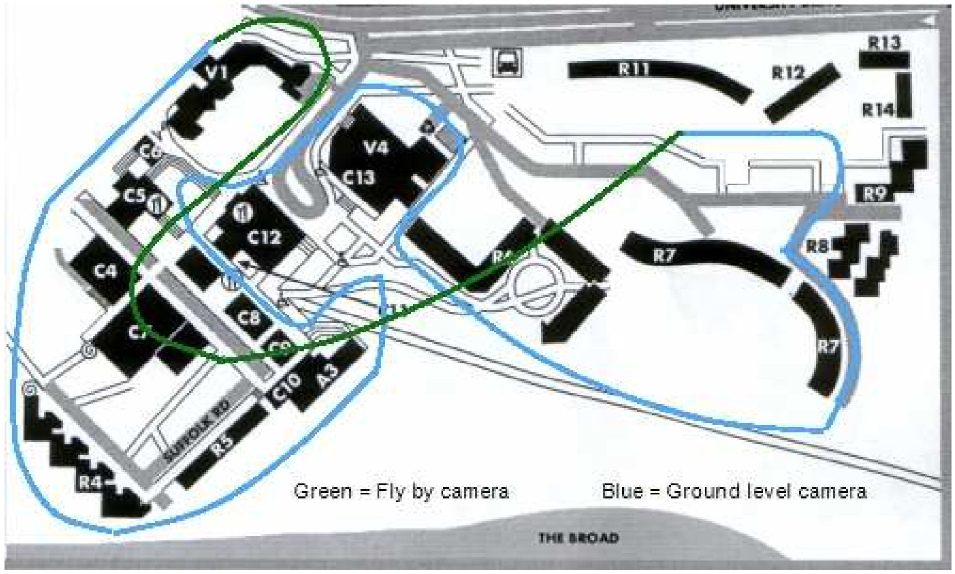

Fig. 73: Shows the camera path for the video

4.1.24 Real-Time Interactive application

Section 3.1.3 has already discussed the real-time interactive. It has been modified to fit the specifications of this project and loads models into the environment. Certain aspects of his code such as crowd simulation have been removed, but the code for debugging/testing remains. (See Appendix B)

This is the area in the project in which experimentation has taken place from a programmer's point of view. Objects were exported in *3DS Max*. Their appearance in the real-time application is defined according to how they have been exported from *3DS Max*. *3DS Max* objects were exported as .obj files as this was the format supported by the real-time application code.

Figure 74 shows an early example of the program is run. It shows what the appearance of the real-time world right before the spring presentation. The latest version of this world is in appendix A.

Fig. 74: Shows the world in a real-time environment. This is taken from the presentation version during the middle of the spring semester.

4.2 Testing & Problems Encountered

Section 4.2 discusses the problems encountered during modelling process and the importing and testing of the urban models in the real-time application.

4.2.1 Learning 3DS Max

Learning *3DS Max* was a slow process. Although the user-interface is user friendly in version 5.1, there were numerous bugs within the modelling package that made the learning process slower and more difficult than it had to be. *3DS Max* would at times crash for unknown reasons.

Grouping objects seemed like an appropriate method for structuring the models. It was assumed that grouping objects together to form floor groups that were part of a building would be a sensible approach to organise polygonal structures.

While working with the models, it was detected that grouping slowed down the rendering process of the entire campus by more than 16 times. This was the case for the virtual model of campus before the presentation in the middle of the previous semester. The rendering process would have been even slower if this problem had not been discovered. This meant that every single building on campus had to be modified separately to ensure polygons were attached to each other in the best possible way, instead of being grouped together.

Window frames and glass of each floor were grouped together with walls and exterior objects belonging to that floor (See figure 75). Eventually, this created a hierarchy of groupings, some of which would reach down to six levels. It had no noticeable effect for amount of time spent on rendering each individual building stored in separate files. After all buildings were placed in the same environment, the rending time was of very noticeable effect.

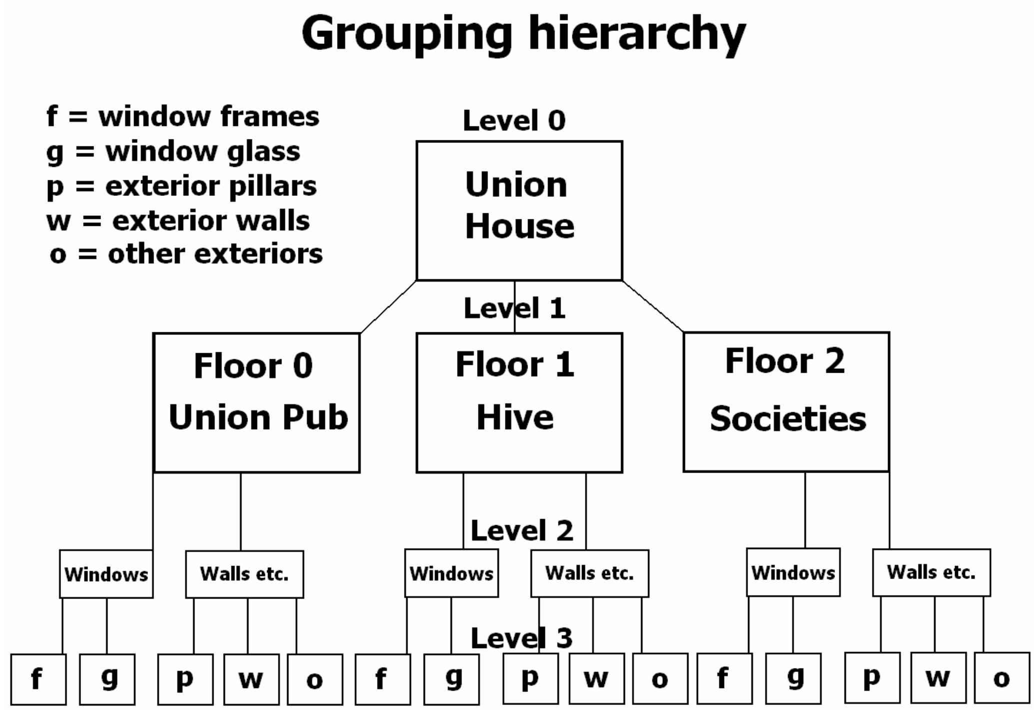

Fig 75: Shows the general grouping hierarchy structure approach of the project buildings. Here exemplified with the Union House.

4.2.2 Importing .dwg files & problems with CAD files

Working with CAD files showed itself to be both invaluable and frustrating at the same time. CAD files of the .dwg format are designed to work in the AutoCAD modelling package and not primarily designed for use in *3DS Max*. This may have caused some of the problems mentioned below. The choice was made to hold onto the CAD files because even if they caused many problems, they were still very accurate to their real-life counter parts in respects to each other.

The CAD files provided were extremely large in size in comparison to the home grid in the *3DS Max* environment that each building had to be scaled down to 0.5% accordingly. This was done so they would be easier to change, because the home grid was in sight.

CAD files of the newer buildings were not provided by the Estate & Building department as they were not accessible for that department. This includes buildings such as the library extension, Victory, Kett and Browne House. This disrupted the consistency of accuracy of the models; however every effort was made to ensure the models are as accurate to the real life counterpart as possible.

There were also several problems with the actual CAD files provided. Around 15% of the CAD files provided would not load up in a *3DS Max* environment, so these models had to be approximated according to photographs and neighbouring models. This also created a form of inaccuracy in the virtual environment similar to that of the models not provided as CAD files. Similarly however, every effort was made to ensure the models are as accurate to the real life counterpart as possible.

The CAD files were grouped in an irregular manner. Window edges would be in the same group as the ceiling, or stairs would somehow be grouped with window glass. This meant that every 3D CAD file provided by the Estate's department had to be broken down and restructured from the ground up because they were organised in such an illogical fashion.

Figure 76 shows an example of such an odd grouping. This was done to make control of the modelling easier, although it also meant slowing down the process of modelling even more. The image is a screenshot of the Union House. Here one can see how interior wall-polygons and window frames have been grouped together with exterior frames. This might be the fault of the person who assembled these CAD files, nonetheless it might also be a conversion issue of *3DS Max*. During the conversion process, *3DS Max* might have organised each groupings differently to the original CAD files if opened up in AutoCAD.

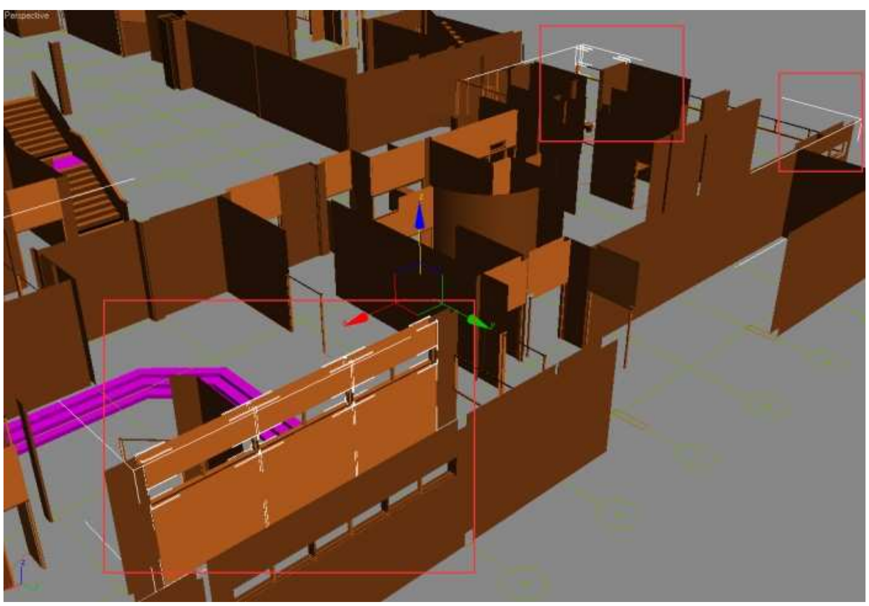

Fig. 76: Shows how oddly original 3D CAD files were grouped

Many of the CAD files were provided with one sided polygons. This meant that some of the buildings had invisible sections unless they were forcefully displayed. These walls were therefore forcefully rendered as two-sided polygons in *3DS Max*.
Figure 77 shows how the original CAD file displays the old sports park once the two-sided polygons were forcefully rendered, and how they were displayed in their original form.

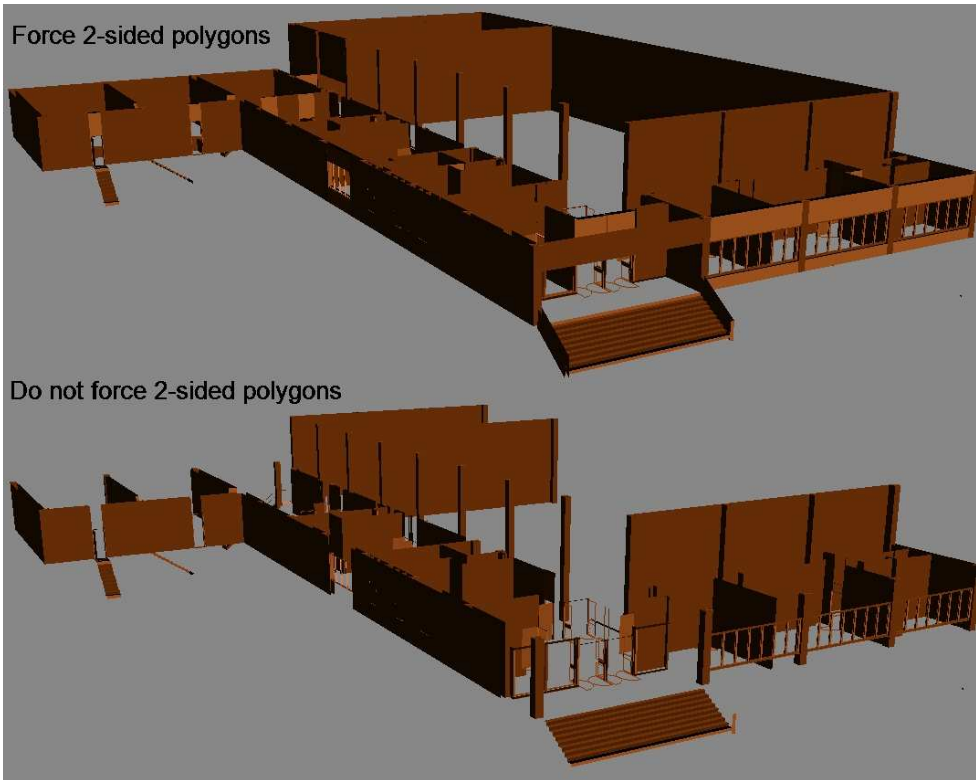

Fig. 77: shows an example of forced two-sided rendering.

4.2.3 Texturing – adding realism

Most texture maps in this project are photographs of real life buildings on campus and have been specially made for this project. They have been modified in *Photoshop* to ensure they look appropriate for the virtual environment. This was necessary to do as some of the textures were taken on rainy or days with little sunlight. Two textures however have been borrowed from Paul Hatton's urban modelling project and others were used from the standard library available in the *3DS Max*.

4.2.4 Problems exporting/importing models to C++/OpenGL

The real time application was very adaptable and easy to use and to change for the purpose of this project. The entire UEA campus environment was exported as one large mesh to avoid unnecessary work of hard coding the project.

The main problem with the real-time environment became obvious as some of the polygons were not part of the same mesh object (and were only grouped together with the object), but still part of the object would reflect light differently. This was solved by forcing each of these polygons to become one mesh, then reloading the virtual model. Figure 78 gives a visual example of this problem.

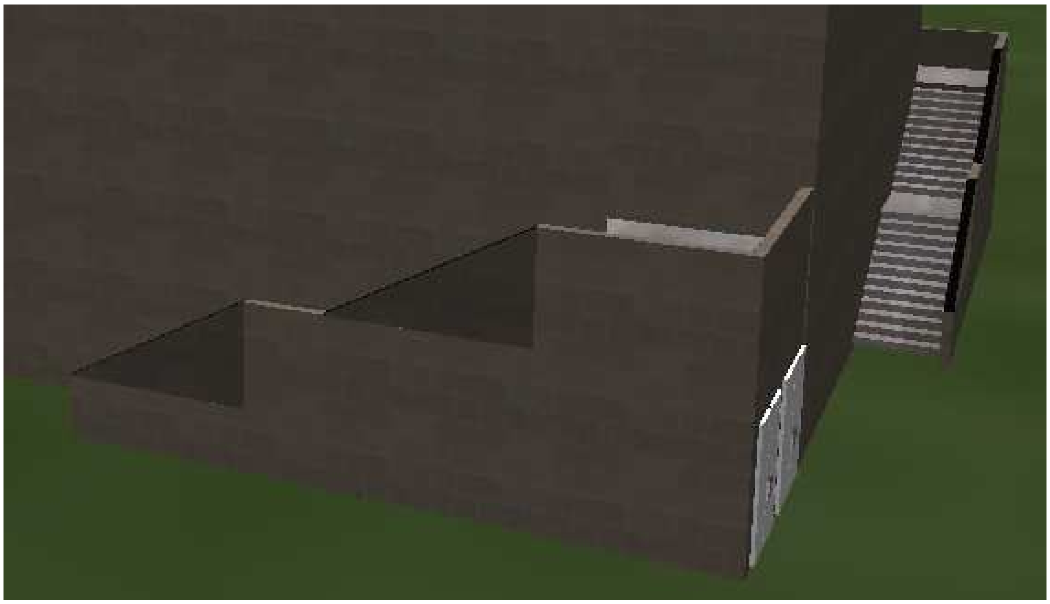

Fig. 78: Shows how the stair object of the lecture theatre consisting of several polygon meshes reflect lighting differently if it is grouped.

Fig. 79: Shows the problem with grey windows in the real-time environment

4.3 Results

Appendix A contains both the pre-rendered sequence and the real-time application. Both of which will be polished and adjusted for improvement for the bench inspection and serve to show what the final result of this project.

The DVD will contain the following:

1. A video file named "*ReportRender.avi"*

2. A folder named "RenderingEngineUEA".

3. A folder named "3rd year project"

1) This is a pure video file one can play using a common video playback program like for instance *Windows Media Player*.

2) "ModelLoader.exe" in the RenderingEngine folder starts the real-time application.

The most necessary controlling scheme is:
Right-click and hold mouse button – Changes viewing direction
Arrow keys – Moves the camera in corresponding direction
"+" & "-" – Increases/decreases the speed of movement
F5 – Shows important statistics such as Frames per second etc.
"W" – Goes into wireframe mode
"N" – Toggles between night and day mode

More details on the controlling scheme can be found in Appendix B.

3) This folder contains all models for this project as .max files and in their original .dwg form, each in their separate folders. Each of the models have photographs and textures associated with them in their respected folders.

Previously submitted coursework related to this project such as the provisional proposal, interim report, the presentation slides and other resources is also in this folder.

Section 5.0 - Conclusion and evaluation

5.1 Further work

With the near completion of this project there are several possibilities to expand it. Below follows a brief description of areas which can be expanded upon to make the virtual UEA even more realistic and extend the potential of the models.

5.1.1 Modelling the north side of campus

This project has modelled the eastern part of the university campus while Marc Clare has worked on the western part. North of both sections there are some buildings left to be modelled.

5.1.2 Improvements of LOD, Textures and Environment detail

Even if the virtual model is of very good quality as it stands, there are several improvements that can be made to the level of detail in this model. There is not much separating the LOD or textures for the pre-rendered sequence and the real-time application models. One may increase details on buildings such as adding more detailed stairs, doors, signs, exterior items and so forth.

For the real-time application there is also the possibility of applying shading languages to the project for increased realism. Applying weather effects such as wind, rain, snow, direct sun light and sound effects is another thing that could be added to add realism. The sounds would naturally correspond to the weather effects.

5.1.3 Interior modelling

Another way of increasing overall realism of the buildings would be to include the interior of the buildings as full scale 3D models.

There are a number of students this academic year whose third year project revolved around automatically generating interiors of a house. If anyone of them made a *3DS Max* file loader that analyses a loaded model and generate interior for that building, it would make the buildings more realistic for people on the outside looking in through the window. Most of the interiors at the moment are only 2D billboards.

If this is not possible, adding the models by hand is also a way to increase realism.

5.1.4 Vegetation modelling on urban models

Vegetation modelling on urban models such as vines and other plants are particularly visible during the summer and was not added due to the aim of keeping the buildings as clean and neat as possible. Vines could have been embedded into the texture maps of each building; however modelling full vine structures would increase the realism even further.

For the real-time application it could also be possible to design an algorithm that generates vines onto walls with a random distribution as the vines will look slightly different from the previous year.

5.1.5 Vegetation modelling on campus

The university campus is surrounded by plants in many shapes and forms. Increasing overall realism of bushes and trees is another way to increase realism of the virtual environment. The main aim of this project was to make the overall graphical realism of the building models as realistic as possible, and place them in a virtual environment that looks like the UEA campus.

5.1.6 Information system & Guided Tour

The UEA Admissions Team were eager to have a fully functional information system they could show to prospective students. Even if this project is not a database project, an attempt for a graphical user interface was sketched and thought of in the initial plan of this project and discussed in the provisional proposal, however the idea was dropped due to time constraints.

Another way to extend the project and fully immerse prospective students into the UEA would be to implement a fully functional user interface with a connection to a small database that has all the information about this university that any prospective student would want. This would include a description of each building as well as a choreographed guide tour of the campus.

This information system may also give new UEA security staff the possibility to familiarise themselves with the campus faster.

Further details of the information system have already been discussed in section 3.1.2.

5.1.7 Maintaining the virtual campus

This urban model project will be outdated within a few years. Keeping the campus up to date is also one way to work further on this project. It has been difficult to keep up with the maintenance work at the real-life UEA as small exterior parts have sometimes been altered without prior notice to the students.

5.1.8 UEA Estate & Building – New Buildings & Plumbing modelling

The UEA Estates & Building department have talked about using this model for future planning of buildings, and more specifically about how this model can enable them to create a full 3D plumbing chart/map of campus. Modelling this plumbing system according to their plans is another way of extending the project.

5.2 Evaluation & Conclusion

5.2.1 Report Summary

Section 2 of this report gave a summary of what literature survey has been done while undertaking this project. The third section discusses the initial plans and potential of the project, and how some of it was changed to focus on realistic aims for a project of this nature. Implementation, testing and results of the project were discussed in section 4. The section explains exactly how the aims have been accomplished and what compromises have been made along the way.

Section 5.1 discusses what aspects can be improved in this project and its models, but also suggests possible expansion of the project into other topics such as vegetation modelling and graphical user interface design among other things.

5.2.2 Project Summary

This project has finished the tasks it set to accomplish. All buildings of the Eastern section of the UEA campus stand of very good visual quality. The appendix A that follows this report does not contain the final version of this projects result, but should give an idea of the effort involved to create the virtual UEA.

As there will be a few weeks between the deadline of this report and the bench inspection there will be certain aspects that will be improved upon. These include increased level of detail, re-rendering of the video (with a better and improved camera path), and hopefully a fully functional collision detection in the real-time application. A full list/executive summary will be provided at the bench inspection.

5.2.3 Evaluation of performance

This project has been similar learning experience to that of first learning programming languages. At first, modelling in *3DS Max* went at an incredibly slow rate, however by the end of project, modelling urban buildings went at a much faster rate.

The amount of time required to learn all necessary techniques applied to the models was underestimated. If all tutorials in *3DS Max* had been done before the summer of 2005 was over (and not during autumn 2005), this project would have gone at a more steadily rate, like the first Gantt chart (provisional proposal) suggested.

5.2.4 Final Thoughts

To conclude- this project will fulfil the tasks it aimed to accomplish by the bench inspection. Almost every aspect is done. All that is left is to bring everything together. Each urban model is of high graphical quality and is placed in a virtual scene that looks like the UEA campus. The result is of very good quality for a student who has no prior experience in urban modelling before this project.

Section 6.0 - Glossary, List of Figures and References

6.1 Abbreviation list (in alphabetical order)

3DS Max	-	3D Studio Max
ACM	-	Association for Computing Machinery
API	-	Application Program Interface
CAD	-	Computer-Aided Design
CSG	-	Constructive Solid Geometry
GTA	-	Grand Theft Auto (a computer game)
IDE	-	Integrated development environment
LOD	-	Level of Detail
L-System	-	Lindenmayer-system
NURBS	-	Non-Uniform Rational B-Splines
MIP (Mapping)	-	M*ultum In Parvo*, meaning "much in a small space"
MS VS.NET	-	Microsoft Visual Studio .NET
PGR	-	Project Gotham Racing (a computer game)
UCLA	-	University of Los Angeles
UEA	-	University of East Anglia
UMG	-	Urban Modelling Group
UST	-	Urban Simulation Team

6.2 References

Websites last accessed in April 2006.

[1] – “projects_2005-06_Mk1” – 3rd year projects list provided by the University of East-Anglia, http://www.cmp.uea.ac.uk/courseware/2005-2006/cmps3p4y/

[2] – *Urban Modelling Group* website:
http://www.sys.uea.ac.uk/Research/cgp/umg/about.shtml

[3] – *Urban Simulation Team* website:
http://www.ust.ucla.edu/ustweb/projects.html

[4] – Wikipedia article on *AutoCAD*:
http://en.wikipedia.org/wiki/AutoCAD

[5] – Wikipedia article on Computer-aided Design files:
http://en.wikipedia.org/wiki/CAD

[6] – *Animation, Virtual Environments & Games Development Virtual Environments* lecture by Dr. Stephen Laycock, 2005, http://www.cmp.uea.ac.uk/courseware/2005-2006/cmps3e29/Lectures/Virtual%20Environments/LOD_IBR.pdf

[7] – Wikipedia article on Level of Detail:
http://en.wikipedia.org/wiki/Level_of_detail

[8] – Wikipedia article on MIP mapping
http://en.wikipedia.org/wiki/Mip_map

[9] – Wikipedia article on impostors, billboards and sprites:
http://en.wikipedia.org/wiki/Impostor_%28computer_graphics%29

[10] – R. G. Laycock, A.M. Day. “Automatically Generating Large Urban Environments based on the Footprint Data of Buildings”; 2003; ISBN: 1-58113-706-0

[11] – Peter Birch. “Procedural Modelling & Rendering of Architectural Structures for Large Urban Environments.” Thesis. School of Computing Science, University of East Anglia, 2003.

[12] – *Advanced Computer Graphics* lecture by Prof. R. Forrest, 2005, original lecture notes author Prof. J. Andrew Bangham, extracted from *The Algorithmic beauty of plants* by Przemyslaw Prusinkiewicz and Aristid Lindenmayer; Springer-Verlag; 1990; ISBN: 0387972978

[13] – Wikipedia article on L-systems:
http://en.wikipedia.org/wiki/L-systems

[14] – Kelly L. Murdock. “3DS Max Bible”; Hungry Minds Inc, U.S.; 2003; ISBN: 0764537032 – A tutorial driven 3DS Max teaching book, also used to learn 3DS Max.

[15] – John Vince. “Virtual Reality Systems” pages 118-132; Addison-Wesley; 1995; ISBN: 0-201-87687-6

[16] – Wikipedia article on Constructive Solid Geometry:
http://en.wikipedia.org/wiki/Constructive_solid_geometry

[17] - Siggraph explanation of Bump Mapping:
http://www.siggraph.org/education/materials/HyperGraph/mapping/bumpmap.htm

[18] – Wikipedia article on Bump mapping
http://en.wikipedia.org/wiki/Bump_mapping

Other background research bibliography/resources:

Association for Computing Machinery, Computing Literature database:
http://portal.acm.org/

MIP Mapping example websites:
http://www.gamedev.net/reference/articles/article1233.asp
http://www.flipcode.com/articles/article_advgltextures.shtml

More background research on urban modelling:
P.A. Flack, J. Wilmott, S.P. Browne, D.B. Arnold, A.M. Day “Scene assembly for large scale urban reconstructions” ISBN: 1-58113-447-9

6.3 List of Figures

Images with no specified origin, were created specifically for this report using *3DS Max* and edited in a 2D image editor program such as *Adobe Photoshop* or *Paint .NET*.

Website links were accessed April 2006.

Fig 1: UEA Campus map, acquired from the UEA Registry office.

Fig 2: A screenshot from the *UMG* project:
http://www.cmp.uea.ac.uk/Research/cgp/umg/index.shtml

Fig 3: Screenshot of the *UST* project at *UCLA*:
http://www.ust.ucla.edu/ustweb/ust.html

Fig 4: Wikipedia article on PC game *Grand Theft Auto*:
http://en.wikipedia.org/wiki/Grand_Theft_Auto_%28video_game%29

Fig 5: Wikipedia article on PC game *Syndicate Wars*:
http://en.wikipedia.org/wiki/Syndicate_Wars

Fig 6: A screenshot of the *PlayStation 2* game *Grand Theft Auto: San Andreas*, from official website: http://www.rockstargames.com/sanandreas/

Fig 7: A screenshot of the *PlayStation 2* game *The Getaway*
http://www.blackmonday.co.uk/

Fig 8: A screenshot from the Xbox 360 Project Gotham Racing 3, taken from a gamesarefun.com article:
http://www.gamesarefun.com/news.php?newsid=4920

Fig 9: A Screenshot of the *AutoCAD* interface by *Autodesk Inc*
http://en.wikipedia.org/wiki/AutoCAD

Fig 10: A screenshot of the *3DS Max* interface. The Nelson Court model from the project is in this image.

Fig 11: A screenshot of the *Softimage XSI* interface
http://www.softimage.com/

Fig 12: A screenshot of the *Maya* interface
http://en.wikipedia.org/wiki/Maya_%28software%29

Fig 13: Image of 2D-CAD file provided by the UEA Estate & Building Department. The image is the Dean of Students' office. Screenshot from *3DS Max*.

Fig 14: An example of a 3D CAD file provided by the UEA Estate & Building Department. The image is the ground floor of the School of Music.

Fig 15: Shows the general approach of photographing each building. Image created using *Paint .NET*

Fig 16: An example of a brick texture created specifically for this project. It was edited in *Photoshop*.

Fig 17: An example of a wall texture created specifically for this project. It was edited in *Photoshop*.

Fig 18: Illustrates a floor with a high-resolution floor texture, but without MIP mapping. http://www.gamedev.net/reference/articles/article1233.asp

Fig 19: Illustrates the same floor as figure 18, but uses MIP mapping. http://www.gamedev.net/reference/articles/article1233.asp

Fig 20: Shows the various floor textures, when using MIP mapping. http://www.gamedev.net/reference/articles/article1233.asp

Fig 21: Shows the disadvantage of using 2D billboards and impostors in a 3D virtual environment. This was taken from a Wikipedia article that uses the GameCube game *The Legend of Zelda: The Wind Waker* as an example: http://en.wikipedia.org/wiki/Sprite_%28computer_graphics%29

Fig 22: An example of use of an impostor in a virtual environment, taken from *Animation, Virtual Environments & Games Development Virtual Environments* lecture by Stephen Laycock, 2005, http://www.cmp.uea.ac.uk/courseware/2005-2006/cmps3e29/Lectures/Virtual%20Environments/LOD_IBR.pdf

Fig 23: Shows a screenshot from a virtual London demonstration by Sony from the Electronic Entertainment Expo (E3) convention in Los Angeles, 2005
Video can be downloaded from:
http://uk.gamespot.com/news/2005/05/16/news_6124681.html?sid=6124681

Fig 24: Shows several meshes of the same object, each with a different polygonal structure, taken from *Animation, Virtual Environments & Games Development Virtual Environments* lecture by Stephen Laycock; 2005; http://www.cmp.uea.ac.uk/courseware/2005-2006/cmps3e29/Lectures/Virtual%20Environments/LOD_IBR.pdf

Fig 25: Shows an image of a skyscraper created by using L-systems, taken from Peter Birch. *Procedural Modelling & Rendering of Architectural Structures for Large Urban Environments*; Thesis; School of Computing Science; 2003; University of East Anglia.

Fig 26: A sketch drawing from a potential information system for this project.

Fig 27: Another sketch drawing from a potential information system for this project

Fig 28: A sketch drawing showing the Main Menu of the information system.

Fig 29: Another sketch drawing showing the Main Menu of the information system.

Fig 30: Interactive crowd behaviour application with a few automatically generated urban models. Image provided by the author/programmer Greg Ryder.

Fig 31: A photograph of the computer graphics labs 5.

Fig 32: Shows a picture of the Wacom Graphire 4, the graphics tablet used for this project. http://www.wacom.com/graphire/index.cfm

Fig 33: A screenshot of the real-time application code in the working environment *Microsoft Visual Studio.NET*

Fig 34: Shows a screenshot of the 2D Photo editing software *Adobe Photoshop.* All textures and in the picture was used for this project.

Fig 35: Shows the Eastern section of campus using *Google Earth.*

Fig 36: Illustrates the effective use of CSG, image was created using *Paint .NET*. Image was created specifically for this report.

Fig 37: A rendered image of the career's centre. The image was rendered using *3DS Max*. Image was created specifically for this report.

Fig 38: Photograph of the career's centre to compare to the rendered image that is figure 37.

Fig 39: An example of creating windows without using CSG. The image is a screenshot of *3DS Max*.

Fig 40: Same example of creating windows without using CSG as figure 39. The image is a screenshot of *3DS Max* and shows the actual window cut out.

Fig 41: Shows how opacity was applied to a plane surface to create virtual glass using *3DS Max*.

Fig 42: Shows the effect of optimising polygon meshes.

Fig 43: Brick texture for the project with bump mapping applied to it.

Fig 44: Showing reflection on a polygon.

Fig 45: Shows a few problems with the school of music CAD file, and compares it to the real world.

Fig 46: Shows more problems with the school of music CAD file, and compares it to the real world.

Fig 47: Shows the problems with the southern section of the school of music CAD file, and compares it to the real world. A window and ventilation filter was missing.

Fig 48: Shows the Chaplaincy as a whole 3D model object.

Fig 49: Shows an early version of the Career's Centre as a whole 3D model object.

Fig 50: Shows the Dean of Student's Office as a whole 3D model object.

Fig 51: Shows the Student Counselling Office as a whole 3D model object.

Fig 52: Shows the Waterstone's ceiling.

Fig 53: Shows Waterstone's as a whole 3D model object.

Fig 54: Shows the old sports park/congregation hall as a whole 3D model object.

Fig 55: Shows the Drama studio as a whole 3D model object.

Fig 56: Shows the Street as a whole 3D model object.

Fig 57: Shows the Union House as a whole 3D model object.

Fig 58: Shows how the original CAD files overlapped each other in a confusing manner of the Lecture Theatre.

Fig 59: Shows the connection between the old and new library

Fig 60: Shows the old library as a whole 3D model object.

Fig 61: Shows the new library as a whole 3D model object.

Fig 62: Shows the restaurant building as a whole 3D model object.

Fig 63: Shows the most difficult front section to model of Suffolk Walk.

Fig 64: Shows the window section of Suffolk Walk.

Fig 65: Shows Suffolk Terrace as a whole 3D model object.

Fig 66: Shows the Nelson Court as a whole 3D model object.

Fig 67: Shows the UEA Registry as a whole 3D model object.

Fig 68: Shows Wolfson & Orwell Close as object models that are work in progress.

Fig 69: Shows Colman house as a whole 3D model object.

Fig 70: Shows trees that have been used in the pre-rendered sequence. Rendered using 3DS Max. However, the tree models are taken from http://www.max-realms.com/

Fig 71: Illustrates how the congregation hall slope has mesh smoothing applied to it.

Fig 72: Shows the walkway path modelled

Fig 73: Shows the camera path for the video sequence. Original map was acquired from the UEA Registry.

Fig 74: Shows the virtual environment in a real-time application as it stood in the middle of the spring semester.

Fig 75: Shows the initial general grouping hierarchy approach of the project. This grouping technique was dropped after it was learned it created rendering problems.

Fig 76: Shows an example of how oddly original 3D CAD files were grouped. This example shows the Union House.

Fig 77: Shows an example of forced two-sided rendering. This example was taken of the Congregation Hall.

Fig 78: Shows how the polygons of the stair object reflected lighting in different manners.

Fig. 79: Shows the problem of grey windows in the real-time environment.

Appendix B

Control Manual for real-time application

Main controlling scheme consists of:

Basic controls

- Click and hold left-mouse button – Changes viewing direction
- Arrow keys – Moves the camera in corresponding direction
- "+" & "-" – Increases/decreases the speed of movement
- F5 – Shows most important statistics such as Frames per second etc.
- "W" – Wireframe mode
- "N" – Toggles between night and day mode

Advanced Controls

- Middle-mouse click - Insert camera path point
- Right-mouse click - Run created camera path
- F1 - F4 control Camera Paths
- F5 - F7 control stats display
- F8 - Records images to a file stats
- F9 - Save out a movie as TGA frames
- "S" - Display white background

Although there are more controls available for even further debugging purposes, these are the main ones that have been used for this project while testing the program and importing the models into the scene to make sure the models look appropriate in the scene.