



High Polygonal Game
Modelling Techniques Applied to Low
Polygonal Models

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Abstract

This project investigates appropriate high end game modelling techniques, with the aim of determining their effect upon low polygonal models. An exploration into the limitations involved in modelling for video games is presented, exploring the necessity for such limitations and how they constrain the development of a model. An identification of the current techniques used in developing high end game models is presented, discussing each technique, function and application. An overview of current game engines is also given determining what functions they comprise of, and exploring both Valves Source Engine and EPIC Games Unreal Engine 3 in greater detail.

A design created from analysing the relevant research gives information on specific limitations, and how they were to be accounted for in the implementation. A discussion on the implemented artefact is given showing the processes and issues involved in creating a low polygonal character. The project also presents an overview into the application and development of the researched techniques.

The projects evaluation presents information pertaining to the effectiveness of the applied techniques. It discusses relevant factors affecting the quality of the final artefact, and the construction of the model and relevant assets. Findings show the employed techniques to be beneficial to the final artefact.

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Glossary

2.5D – This technologies presents 2D images, which can be navigated in an almost 3D manner.

3D – 3D describes an image with data in the X, Y and Z Coordinates of space.

Bump Map – Bump map is a 3D modelling technology which adds fake bumps to a model.

Detail pass – A detail pass comprises of adding further detail to an object.

Digital Sculpting – Much like clash sculpting digital sculpting is the created of artefacts within a digital environment.

Filters – Filters are used within specific applications to add effects such as lens flare and noise.

Film Grain – This is a filter which adds a film style quality to an image.

Game Modification – A game modification involves the modification of maps and assets to create a custom experience within a pre-existing game.

Mesh – A mesh is comprised of polygons shaped to form an asset for example a character model.

Next Generation – This term is commonly used to describe cutting edge graphics.

Normal Map – A normal map adds detail to a model.

Polycount – A Polycount represents the number of polygons an item is made up of.

Ported – This relates to software and games, porting is the process of making something designed for one system work on another.

Polygonal - 3D models are comprised of polygons, they generally consist of 3 or 4 points to form triangles or squares.

Plug-ins – A plug-in is a tool which enables software to perform functions they are not natively designed for.

Rendering – This is the process of generating a 3D image.

UVW Unwrap – This is the process of flattening a 3D model to prepare it for texturing.

UI – A user interface is used to help users interact with a system.

Vertex – A vertex is a point in 3D space

1.Project Introduction

This chapter presents a high level outline of the project detailing its aims and objectives , as well as discussing the motivation behind its undertaking. It also talks about why the project is valid to be conducted. Finally a brief description of the produced artefact will be presented. The finished artefact and project files are available on the accompanying DVD (see Appendix 1).

1.1 Project Introduction

The importance of high quality graphics has an ever growing presence within the gaming community, and while many of the more enthusiastic “gamers” are willing to invest their money into the latest hardware there are still a large number of people who are not, due to factors such as cost. Because of this many people who play games are still using lower end gaming platforms such as the Sony Playstation 2 and low end computers. Even the Nintendo Wii, which is heralded as a “Next Generation” console has lower graphical capabilities than that of other higher specification systems. This in turn suggests that a large portion of gamers will not be able to experience the same graphically rich experience as other users

As an example of this issue a comparison of quality between the latest “Call of Duty” game on the Nintendo Wii (Top), and Microsoft XBOX 360 (Bottom) can be seen in **Figure 1.1**. It can clearly be observed that the Wii version offers a poorer graphical experience, the graphics appear less smooth, and less detailed.



Figure 1.1 - Call of Duty World At War Comparison, Wii (Top), 360 (Bottom). (IGN, 2008)

It can also be noted that there are limitations in the number of objects, characters etc that can be displayed to the user at the same time. For example Dead Rising on the Nintendo Wii could handle a far smaller number of enemies on screen, than the Microsoft XBOX 360 version. However with further optimization of Polycount it could be possible to increase the number of objects on screen, for both old and new hardware platforms.

The latest generation of hardware brought with it more advanced techniques which are used to develop game models, enabling their appearance to be of a much higher quality.

The overall aim of this project was to conduct research into, and learn to use these techniques, in order to test their effectiveness upon the artefact. The artefact was created based upon the limitations of game models designed for lower end hardware. The project ultimately aims to determine if, and how it is possible to improve the quality of lower polygonal models, and to distinguish if current generation games could be optimized in terms of Polycount without a loss of quality for the user.

1.2 Aims

- ❖ To conduct research into the limitations of high and low end hardware with regards to the polygonal constraints of character models.
- ❖ To determine the techniques developed to produce current high end video game models.
- ❖ To develop a well designed character model based upon the polygonal limitations found for lower end hardware.
- ❖ To apply, and evaluate researched techniques, ultimately to determine if it is possible for lower polygonal models to appear of a similar visual quality to current high end game models.

1.3 Objectives

1.3.1 Basic Objectives

- ❖ To conduct appropriate research, and a literature review.
- ❖ To design and create an appropriate artefact.
- ❖ To determine the potential improvement specific techniques bestow upon low polygonal models.

1.3.2 Intermediate Objectives

- ❖ To conduct research into appropriate technologies, and software.
- ❖ To conduct a literature review into background research.
- ❖ To translate research into design limitations.
- ❖ To create an artefact based upon design limitations.
- ❖ To apply research to model.
- ❖ To test effectiveness of the applied techniques via the use of evaluation tools.

1.3.3 Advanced Objectives

- ❖ To conduct research into polygonal limitations imposed upon 3D character models with regard to older hardware platforms.
- ❖ To conduct research into advanced techniques used upon high end 3D game models.
- ❖ To conduct a literature review into the subject area.
- ❖ To further research appropriate techniques, and allow appropriate time to assimilate their function.
- ❖ To translate research into design constraints.
- ❖ To concept, and design a character model based upon said constraints.
- ❖ To create a 3D character model, taking into account appropriate limitations.
- ❖ To apply researched techniques to the model.
- ❖ To deploy the model in a appropriate 3D game engine.
- ❖ To evaluate effectiveness of applied techniques via the use of visual aids and a questionnaire.

1.4 Project Rationale

The intention of this project was to help in developing a wider range of knowledge about the 3D Modelling subject. Enabling the expansions of skills already developed during the previous academic year, and allowing a much more in-depth understanding of industry standard limitations and techniques. It also allowed for the exploration of new software platforms and tools such as Z-Brush, used to create Normal Maps and 3D Sculptures. The project also enabled the production of an artefact which could contribute towards a 3D asset portfolio.

A wide range of people purchase the latest video gaming platforms, however many people still purchase and use older technologies to play games. As can be seen in the statistics in **Figure 1.2**, which show console sale figures for September 2008, older platforms such as the Sony Playstation 2 are still in popular demand.

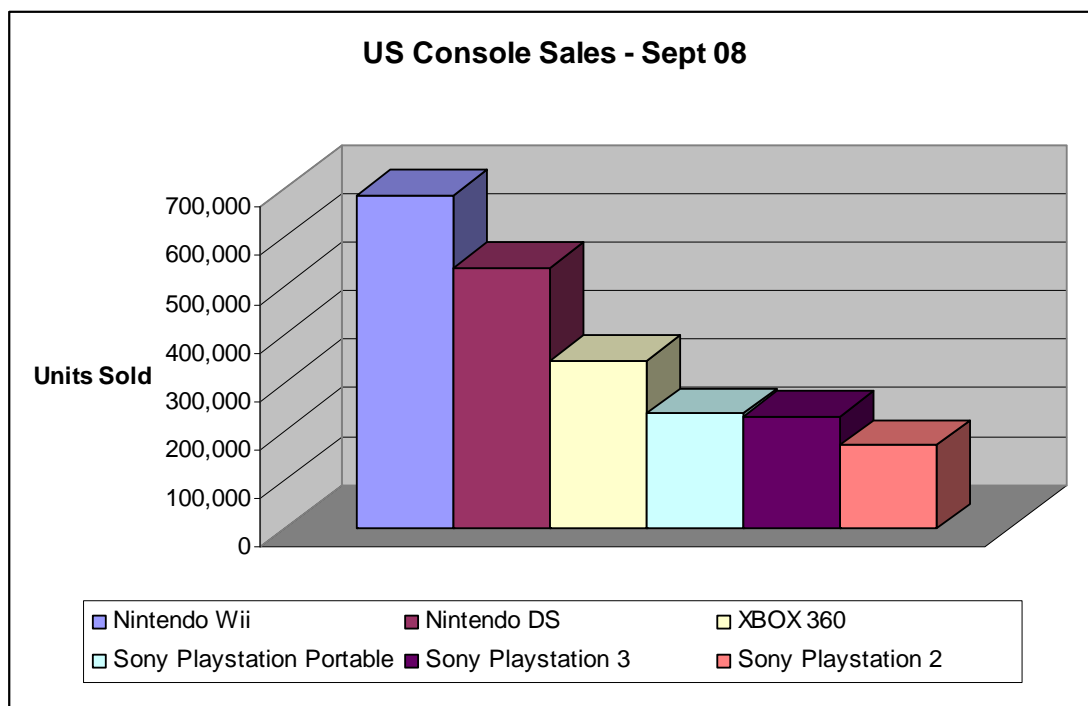


Figure 1.2 - Statistics taken from the following an article (Carless, 2008)

As a result of using older hardware, users will experience a lower quality graphical experience to those with the latest hardware, due to lower quality models and environments.

3D Modelling techniques are constantly being developed, ergo the overall graphical look of video game models is always improving, especially with the latest generation of hardware and software. Games are constantly pushing the boundaries of available hardware, and in some cases this renders users incapable of running the games at full potential until more advanced technologies are developed.

An example of this is “Crysis”, which at the time of launch required users to own a top of the range computer in order to run it well, and is still unable to be ported to consoles due to its demand on hardware. The sequel however “Crysis Warhead” was developed with this issue in mind, and this resulted in it being able to run on older machines than its predecessor. This is discussed further in the article by (Remo, 2008) *“Crytek hopes to combat the belief that highend PC gaming demands thousands of dollars”*

With these issues in mind, a low polygonal model was developed, based upon the polygonal constraints of lower end hardware. The researched techniques used in current video games were then applied to the model, to determine if it could be improved to be of a similar quality to high end game models. The evaluation was used to measure what impact the techniques did have upon the lower polygonal model, determining if there was an improvement in graphical quality which could be beneficial. The project should help determine which technique(s) have an impact upon the model, in terms of graphical improvement.

It is suggested that if it is found possible to offer a similar quality experience to the user, while optimizing the polygonal usage within a model, then games across multiple platforms could potentially deliver a very similar graphical experience in relation to 3D models. This would also potentially determine if high end game models could be optimized to be less demanding upon hardware. Overall the research aimed to establish if it is possible for lower polygonal models to look as good as higher polygonal models while still being able to run within the constraints of current high and low end hardware.

1.5 Deliverables

Main Artefact – The project required that background research into the limitations of older games platforms be conducted. From these limitations the polygonal limitations of the main artefact were defined, allowing a valid design to be created for its production. The production of the artefact consisted of several stages, talked about in more depth in later chapters.

- ❖ Production of design – Based upon limitations.
- ❖ Translation of design into a 3D Character model.
- ❖ Application of researched techniques.
- ❖ Importing of model into a valid game engine.
- ❖ Outputting appropriate material showing the model both with, and without the applied techniques in a range of still and animated renders.

Evaluation Artefact - In order to evaluate the model, the produced renders were demonstrated to a group of people with technical knowledge of the field. The developed questionnaire was then completed in order to determine the effectiveness of the applied techniques.

1.6 Chapter Overview

Chapter 1 – Project Introduction – This chapter consists of a high level overview which discusses the overall project., detailing its aims and objectives, and the validity of its undertaking. It also gives an overview of how the project was conducted, and discusses briefly the overall production of project artefacts, but avoids disclosing any information relating to the outcome of the project.

Chapter 2 – Methodologies and Tools – This chapter discusses the development methodologies employed for use in conducting the overall project. It evaluates the relevant available tools relating to the development of the artefact, determining their use. It also discusses briefly possible alternatives to the software tools chosen for the development of the artefact. Although a logical format would suggest that the Methodologies and Tools section come after the Background Research chapter, it was deemed as necessary to maintain this structure due to the software tools being discussed within the projects background research.

Chapter 3 – Background Research – This chapter contains a large amount of background research relating to the project. It discusses in depth game engines, their use, and their limitations in relation to the development of the project artefact. An overview of techniques used within current high end game model development is also present as well as a brief overview of the necessity of low polygon modelling within the games industry, and finally the development process for creating a games character model.

Chapter 4 – Design and Concept – This chapter relates to the design of the produced artefact. It defines the overall limitations used within the implementation of the artefact, as well as discussing the techniques employed in its development. It also covers the overall design of the character model, discussing concept, both visually and technically.

Chapter 5 – Implementation – This chapter details the implementation of the artefact, covering its development, and the use of several software tools. It also discusses how the artefact relates to the initial designs, as well as defining any problems, or changes encountered along the development stages of the final artefact. Finally an overview of all produced assets is present.

Chapter 6 – Evaluation – This section discusses the evaluation of the produced artefact, evaluating the success of the employed techniques. It consists of two main sections, one relating to the production ,undertaking and evaluation of the questionnaire and the second consisting of an evaluation of the artefact overall.

Chapter 7 – Conclusions – The final chapter concludes the project, and reflects upon its overall success, discussing the processes involved in its production. It also redefines major findings from within the project, and discusses the potential improvement and continuation of the project.

1.7 Chapter Summary

This chapter has presented a high level overview of the project as a whole. Discussing the validity and purpose of its undertaking. It details the overall aims and objectives of the project, and discusses briefly the produced artefact. It also consists of a brief overview of each chapter, showing what will be discussed throughout the paper.

2. Methodologies and Tools

This chapter covers appropriate methodologies used within the development of the project. It also gives an overview of the available tools for use in modelling, and texturing a 3D character model., discussing tools used within the industry, and comparing them to alternatives.

2.1 Methodologies

2.1.1 Research

Research was key in completing the project, and defining the design of the artefact, information was gathered from a large range of sources.

Books – Books were one of the most important sources of information, used to provide data on techniques, software etc. Books however generally convey information which is less recent than other sources..

Journals – These are generally more up-to-date than books, providing information on recent studies, future areas of interest etc. They were pertinent to gathering information on recent developments, for example the use of Ambient Occlusion.

Websites – While generally seen as unsuitable for academic work, websites were essential in the completion of this project. They provide recent information, which very often is unavailable elsewhere until published.

Personal Correspondence – Due to the helpful nature of development companies it was possible to obtain information, relating to the development of character models within games.

2.1.2 Development

Research has shown that most development methodologies tend to be aimed at software development projects, involving the production and testing of code. However while the produced artefact has both technical and creative aspects, it is developed as an asset, not as a program. Due to this many of the methodologies were not suited for use with the project without modifications to their function being made.

One identified methodology was the **Kroll et al (2003)** “Rational Unified Process”, which offers flexibility in design, and presents many functions such as milestones, indicating when certain aspects of a project should be completed. However it was necessary to adapt a more linear methodology in the production of the project artefact, primarily due to the set goals, and timeframe.

Ergo the waterfall methodology as discussed (**Lewis, E. W, 2000, p. 41**) was identified as an appropriate solution, and thus employed for use within the project. It employs a linear design, allowing each aspect of development to be completed individually, before moving onto the next stage. However this methodology was also designed more for use with software development, thus modifications were made to ensure that it would suite the production of the project artefact.

The main differences being that the maintenance stage was removed. This was necessary as the model does not contain code that will be altered, or patches that will need to be implemented. The modified version of this methodology can be seen in **Figure 2.1**.

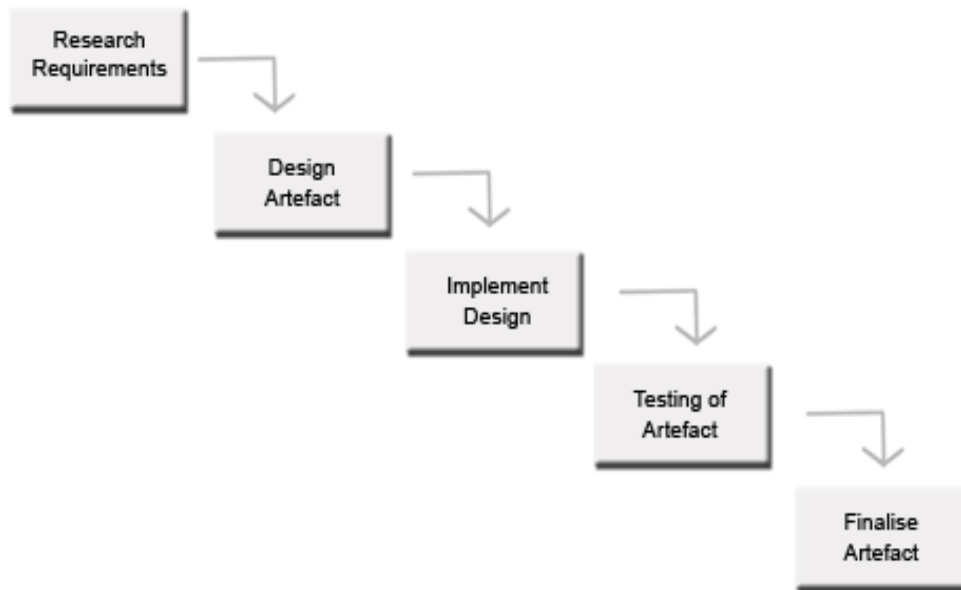


Figure 2.1 - Waterfall Methodology - Relating to artefact production

The stages of development were broken down into 5 main sections, “Research Requirements”, “Design Artefact”, “Implement Artefact”, “Testing of Artefact” and “Finalise Artefact”.

Research Requirements – This stage required research to be conducted into the limitations, and techniques to be applied to the final artefact, determining any potential problems and development platforms.

Design Artefact – The requirements were then translated into a design, detailing exactly what would be produced and what limitations were imposed.

Implement Design – The design was then used to produce the artefact, and all relating assets.

Testing of Artefact – The artefact was then tested to identify any potential problems.

Finalise Artefact – Any issues were then corrected, and the artefact was finalised. Renders were then produced of the artefact for use within the evaluation stage.

2.1.3 Evaluation

In order to determine the effect the applied techniques had upon the produced artefact, it was necessary to employ some form of evaluation methodology. This methodology would take into account the critical opinions of individuals with an understanding of the subject field.

For this purpose both qualitative and quantitative methodologies were investigated, these are talked about in more detail here (**Corbin, M. J, 1998, p. 11**), the final employed approach contained aspects of both. The research was qualitative in that a specific user group with prior knowledge of the field was targeted, knowing that the feedback would be of a more critical nature. However analysis comprised more of a quantitative format, quantifying results in a statistical manner.

The questionnaire was developed based around the Likert scale system, in order to enable the capture of quantifiable data. The scale talked about more by (**Bryman, A, 2001, p. 68**), is comprised of a series of statements rather than questions, each with a scale of truth ranging from 1 to 5. The questions were designed with the artefact in mind, attempting to validate how well constructed it was, and how much the techniques effected its appearance.

2.2 Tools

The creation of a 3D character generally requires the use of a much broader range of tools, including programs such as Autodesk Combustion, used for creating character animations. These additional applications will not be discussed here as they are not deemed as relevant to the project.

2.2.1 Chosen Software

The software chosen for use in the creation of the artefact is discussed below.

3D Studio Max - 3D Studio Max is a product which was first developed for the DOS operating system, to allow the more technically minded to develop 3D assets. Later released for Windows by a company know as Discreet, 3Ds Max became more popular within the industry. Eventually Discreet was purchased by Autodesk, and 3Ds Max's latest release is known as "Autodesk 3ds Max 2009" (**Autodesk, 2008a**).

3Ds Max allows for easy exporting of created assets for use in other 3D related software tools, for example animation suites, sculpting programs etc. Due to this functionality it is one of the preferred tools for use in creating game assets.

3Ds Max allows for the creation of 3D assets, these ranging from simple box models, to complex character models comprised of millions of Polygons. 3Ds Max of course is not without its limitations, and these come in the form of how many Polygons can be displayed in the viewport at any one time. However these limitations are generally derived from the hardware platform that 3Ds Max is used with.

Professional games modellers, such as those who worked on Gears Of War **Lanning et al (2007 p.31)** optimize models to ensure that the mesh will work within 3Ds Max, by reducing the number of Polygons to a manageable number.

Models are created via the manipulation of Polygons, or vertex points, along the X, Y and Z Axis, when modelling a certain level of experience is necessary, dependant upon the complexity of the model. For example a character artist with experience of life drawing will have a better understanding of anatomy, than one without said experience. The only true limitations of 3D modelling are within the creativity of the human mind.

3Ds Max also allows for the creation of Normal Maps, by taking a created high polygonal model, and overlaying the detail onto a lower polygon model. Once completed, rendering of the low polygonal model will show most of the detail of the high polygonal model.

Once finished, game characters generally need to have the ability to be animated, this is done via the rigging process. 3Ds Max allows for the use of inbuilt features such as the biped as well as custom bone creation the latter generally being preferred for use in video game engines. A rig is basically the process of building a virtual skeleton from bone objects, which are then set up to move and function much like a real skeleton would.

Once the rig has been completed it is necessary to skin the character, in other words the process of linking the 3D model to the created rig. This is a time consuming process requiring the weighting of individual vertex points to be carried out in order to ensure that the character moves realistically. It is for example necessary to create realistic deformation in some characters, such as making sure the jaw moves with the mouth.

While the animation of characters is supported by 3Ds Max, in many cases the completed model is exported into alternative programs which allow more realistic animations to be created, as discussed within the article (**Autodesk, 2006 p.6**).

Due to its ever increasing popularity, 3Ds Max has now become known as the industry standard, this is discussed in **Autodesk (2006)** "*Today the most popular game production and development tool is 3ds Max.*" (p. 6) This is however a somewhat biased opinion as 3Ds Max is produced by the author of the article. It can however be seen that 3Ds Max is used in the production of an extensive amount of games.

Due to the integration of support for models from other software tools, the chosen software used for 3D modelling is now based more upon artist preferences **Autodesk (2006)** “...a lot of the artists here use both 3ds Max and Maya on a regular basis” (p. 11) than on other factors.

3Ds Max is used to create many assets, such as architectural models, and most relevant to this project 3D game models. It has been used to create assets for many games including Gears of War (**Lanning, 2007 p.50**).

This tool has been selected as relevant to this project for several reasons. Firstly the author’s prior knowledge of its functionality and lack of experience in other leading 3D tools. Secondly the availability of the software, the University of Lincoln holds several licenses allowing the use of 3Ds Max 2008. Finally research has proven that this tool is used within the industry, and that it is relevant to the creation of the artefact for this project.

ZBrush - Zbrush is a program created by Pixologic (**Pixologic, 2008**), it is used as a tool for artists and modellers alike, within many industries such as film and video games.

It is developed as a digital artists toolbox (**Keller, 2008 p.2**), allowing for the creation of 2D and 3D art. It can be used to create exceptionally detailed 3D sculptures, and is useful for creating organic looking models.

The program is not 3D, but instead 2.5D, while you can view the entire model, it is not as fully interactive as it would be in other 3D programs. Due the large array of tools within ZBrush it is possible to add many details to a model, from creases in clothing, to individually made hairs and pores.

ZBrush also supports the importing and exporting of models, to and from other 3D software tools. This feature is used when creating modern video game characters, allowing for the creation of a low polygonal model in another program, which can then be detailed within ZBrush. Once this detailing is completed the model can be exported in the form of a Normal Map.

ZBrush also supports much higher polygonal counts than other programs due to its design, which again helps when adding in very fine details to models. These models however generally need optimizing upon exportation to function correctly in other software **(Lanning, 2007 p.31)**.

ZBrush has been chosen for use primarily due to the resources available for it, also because it has been shown to be used within the creation of video game Normal Maps, which were necessary in the completion of this project.

Adobe Photoshop CS3 - Photoshop is an image manipulation software package, created by Adobe and now part of the CS4 Adobe Suite. It allows for the editing and creation of image files, altering photographic material and painting works of art.

It has a wide array of tools, and filters as well as support for various plug-ins all of which help when creating image files. It also has a layer system, which allows for the creation of very detailed effects within images.

Photoshop is also recognised as an industry standard tool for creating video game textures, as discussed in the below quote.

(Ahearn, 2006) *“Photoshop is the right hand of the game artist. While there are many 3D applications, Photoshop pretty much stands alone as the 2D application of choice for game developers.”* (P. 79)

Because of this Photoshop has been chosen for creation of the artefacts texture elements. It is also available for use at the University of Lincoln in the form of Adobe Photoshop CS3.

2.2.2 Alternative Software

The below software tools were not to be used within the project, however research has shown that there are many alternatives to the chosen software for this project. While it is not possible to discuss all of these, some alternatives are presented below.

Maya - Maya is the main alternative to 3Ds Max, and up until recently was its main competitor. Maya is again made by Autodesk, and the current release is known as Autodesk Maya 2009 (**Autodesk, 2008b**).

Maya offers much of the same functionality as 3ds Max, and because of this will not be discussed in depth. It allows for the modelling, texturing and rigging of 3D assets.

Maya is also used more for animation, allowing the importing of motion capture data, which can then be perfected manually (**Autodesk, 2006 p.6**).

The main difference between Maya and 3Ds Max is their background, Maya tends to be seen as less technical than 3Ds Max, however the main difference in the modern industry is simply the preference of the modeller.

While this is a similar program to the chosen 3Ds Max, it was not deemed as appropriate for this project. This is firstly because the author has no experience with its functionality, and secondly because research suggested that 3Ds Max was a more suitable software tool for creation of the artefact.

Mudbox - Mudbox is an alternative to ZBrush, this is a program made by Autodesk, and allows for the creation of digital sculptures and high polygonal models (**Autodesk, 2008c**).

The key difference between Mudbox and ZBrush is that it is a true 3D platform, unlike the 2.5D environment used within ZBrush, it still offers much of the same functionality of its rival.

This theoretically offers better functionality between exporting, and importing of 3D assets, however research has suggested that ZBrush is an industry standard software tool (Lanning, 2007).

Due to this point Mudbox was not chosen for use within the project, as this project aimed to create an artefact which utilised the tools and techniques, used to create real high polygonal game models.

Nvidia DDS plug – in - This is one of many plug-ins (NVIDIA, 2008) available for use with the Adobe Photoshop package, it enables the user to create simple Normal Maps for use with a 3D Model. While this cannot emulate the detail provided by more advanced tools, it is able to simulate some additional detail such as folds in cloth, or bumps in brick.

This can be used for the creation of simpler objects, for example detailing a keyboard, however can't convey the fine details needed for characters models. Thus while this is an interesting tool it was not be used for the creation of the artefact.

2.3 Chapter Summary

This chapter has given a brief overview of the techniques employed in conducting research for the project as a whole. It has also presented the chosen methodologies used within the development of specific aspects of the project. Finally it has given an overview of the chosen software tools, and their function and suggested logical alternatives.

3.Literature Review

This chapter demonstrates the range of research conducted for the project, discussing the necessity of low polygonal modelling, and techniques used within current high end games. It also details background information on specific game engines and their limitations.

3.1 Game Engines

A game engine is usually created by games development companies and offers functionality to both developers and end users.

In conjunction with produced development toolsets they offer a powerful development platform. This allows for the production team to compile a large array of assets in a uniform program, with a user friendly UI. The software is capable of creating complex levels, and scripted sequences, and can be used in the production of both full scale titles and game modifications alike.

Companies handle the distribution of their engines and software tools in different ways, some charge large amounts for them to be used, for example a commercial license for the Unreal Engine costs \$350,000 as stated (**EPIC Games, 2008c**). While others release them for public use simply with the purchase of a related game, for example the Source Engine tool “Hammer” comes free with the Half Life 2 game.

(Al-Najdawi, 2007) “Game engines provide a suite of visual development tools in addition to reusable software components. In order to provide an integrated development environment to enable simplified, rapid development of games” (p. 3)

As seen summarised in the article above, game engines provide a tool which makes the development of games much faster, and easier. Although the initial stages of developing a game engine can be time consuming and costly (**Al-Najdawi, 2007**).

Development time, and costs can be reduced with the use of these tools, ergo companies are likely to adapt these engines for use in developing their own games, generally by compiling their own assets as opposed to reusing the supplied ones.

Access to game engines and related tools also facilitates the development of game modifications, due to the ease of access to the required tools, and the wealth of knowledge available on their use.

As the below stated (**Al-Najdawi, 2007**) “*A game engine is the central part component of a video game or other interactive application with real-time graphics*” (p. 2), game engines are now an integral cog in the development and presentation of completed games.

Once development is completed, the engine is used to present the finished product to the end user. This in relation to the project provides real time rendering of 3D assets, and environments. In other words this removes the need for a third party program such as 3Ds Max for use in pre-rendering the games visuals. While older titles such as Resident Evil did use pre-rendered backgrounds, real time rendering is now the industry standard, due to the added interactivity and immersion within the game world. Via the use of complex calculations (**Eberly, 1999**) game engines set up the games Shaders, lighting, scripting, rendering, physics, A.I, etc.

There is of course competition in regards to game engine development, while many companies purchase licenses to use specific engines, many also create their own. Because of this there are many different available engines, two of which are developed by Valve, and EPIC Games.

These engines, while in essence designed for the same task offer different features to each other. Support for different modelling techniques, or optimization of specific Shaders etc. They also offer alternative development tools, some of which are easier to use than others.

Engines also have different limitations imposed upon them depending on when they are originally developed. In general the newer the engine, the higher the supported polygonal counts, texture resolutions and number of modelling techniques it supports.

Engine limitations are generally derived based upon the hardware platforms currently available. The issue however is that rather than optimizing models using new techniques, developers tend to increase the Polycount of models, thus stressing hardware more than may be necessary. These limitations generally come in several forms.

- ❖ Texture resolution limitations.
- ❖ Polygonal Limitations.
- ❖ Number of supported techniques.

The demand for advancements in games technologies is ever increasing, hence the need to constantly develop support for new modelling techniques in relation to game engines.

(Eberly, 1999) “The increased demand for games and the potential size of the market has created an impetus for increased improvement in the computer technology...” (p. 2).

To accommodate this, new engines are designed to take full advantages of the latest, and fastest hardware, while older engines are constantly being updated to handle new features, and increase the life of the engine itself.

Game engines also generally support a function known as Character LOD (Level of Detail) **(Eberly, 2005 p.299)**. This entails the use of adaptive models where several versions of a model with varying polygonal counts are created. The engine will alternate between models dependant on where the camera is at any one time. If the camera is close to the face for example then a very high polygonal model may be used, this of course would be a waste of resources if the character were far away, ergo a lower polygonal model is used. While this is a very in depth subject of it’s own it is not relevant to this project, and thus only covered in brief.

So far the chapter has given a generic overview of engines as a whole, the engines chosen for references in this project will be discussed in more detail in the next two sections.

3.1.1 Source Engine

Valve is an experienced games development company, having produced many well known games such as the Half Life series. For the creation of their hit title Half Life 2 they created the Source Engine, offering new features and better looking environments to the user.

The source engine is over 5 years old, having been released for use in 2004. (**Valve Corporation, 2008**) The engine was initially intended for use with Microsoft Windows based computer systems, however it has recently been upgraded to support cross platform development for the PC, XBOX 360 and PS3.

The development kit for the engine supplies the user with a host of programs, most notably the Hammer Editor, which allows for the creation of custom modifications to existing games, and levels. It has the ability to import and use custom assets and it supports file types from many leading applications, including, most relevant to this project 3Ds Max.

The engine is not only used for producing Valve products, but has been licensed for other titles such as ZENO Clash and Vampire: The Masquerade.

The engine currently supports many features, such as advanced Dynamic Lighting, Shader support and several other graphical related technologies (**Valve Corporation, 2008**).

Due to the engines age, the models are less advanced in terms of Polycount, supported texture resolutions and techniques. For example in many games it uses bump mapping instead of Normal Mapping, which while adding detail, is less effective. This suggests that the games will look less visually appealing than those created for newer engines.

This however is not such an ailment for the engine, it is still widely used for development, mainly due to its ability to be constantly upgraded, as described below.

Valve Corporation. (2008) *“At its core, Source is designed with a modular component-based architecture that enables the seamless integration of new features and technologies”* (p. 3). (**Valve Corporation, 2008**)

The features added do allow for more advanced techniques to be used, however at a cost. This cost is creating more demand on hardware, as can be seen in **Table 3.1** which is a comparison between the system specifications for Half Life 2, and one of the latest Source games Left 4 Dead.

Table 3.1 - Hardware Specifications from (STEAM, 2009a) , (Left 4 Dead, 2009)

Game	Half Life 2 (STEAM, 2009a)	Left 4 Dead (STEAM. 2009b)
CPU	2.4GHz	2.4GHz Duel Core
Memory	512MB	1024MB
Graphics	DX9 Card	Nvidia 7600+

This shows that the system specifications have almost doubled within the 5 years the engine has been available, simply due to upgrades to the engine. These do however add in new feature support such as advanced lighting and the ability to display more Polygons on screen.

Valve perform a hardware survey on a monthly basis, showing what technology people are using to play their games, the results shown for February 2008 (**STEAM, 2009c**), show that many people still use older technologies, which run original Source Engine games perfectly well. **Figure 3.1** shows that while the adoption of newer technologies is on the rise, the number of people using older hardware is still considerable at over 35%, and this suggests that these users would benefit from less demanding 3D models.

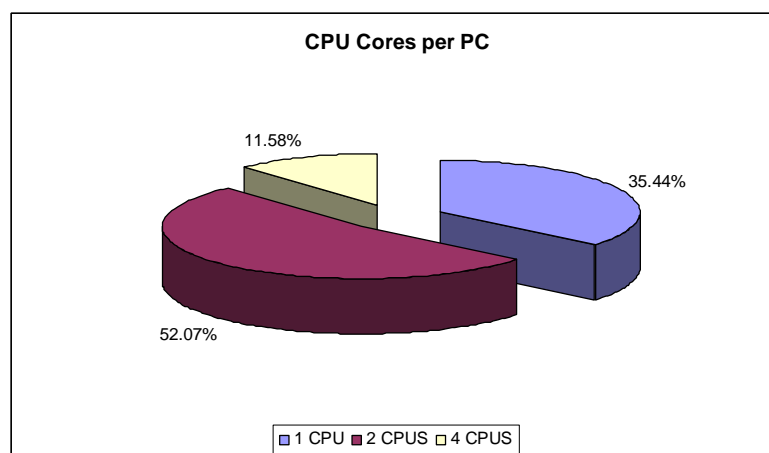


Figure 3.1 - Statistics showing number of cores in use per PC, statistics taken from (STEAM, 2009c)

Left 4 Dead uses a modified version of the Source Engine, allowing for new effects such as in game film grain, and more detailed Polycount for character models. An example of the difference between character model detail levels and Polycount from Half Life 2, to Left 4 Dead can be seen in **Figure 3.2, 3.3.**



Figure 3.2 - Half Life 2, Average Polycount 7,000 (Wood, 2009)

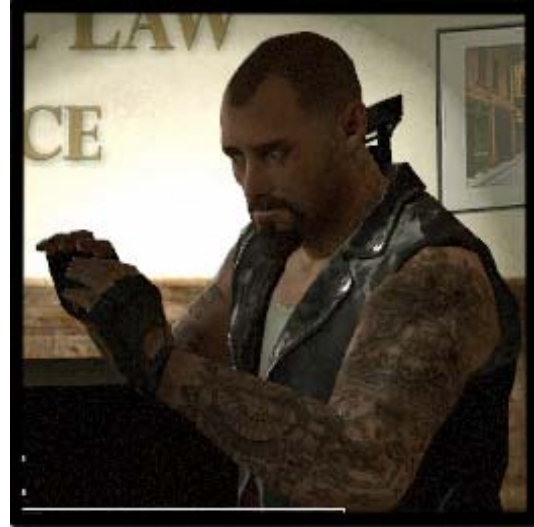


Figure 3.3 - Left 4 Dead, Average Polycount 12,000 (Durrand, 2009)

While these extra Polygons do add detail to the models, it is possible that alternative techniques could produce the same visual quality, without using the additional resources required to render them.

The Source Engine has been chosen to define the limitations for the project artefact, it is deemed as appropriate due to the age of the engine, and the specifications required to run the base games. It defines sensible limitations, while still offering support for detailed models, and thus should allow for the creation of a more complex artefact.

3.1.2 Unreal Engine 3

EPIC Games are the creators of the Unreal series of games amongst others, and are known for creating their own engines. The latest iteration of this engine is in the form of the Unreal Engine 3 (**EPIC Games, 2008b**).

Again this engine is licensed out to other developers, and used to create other titles such as Mass Effect. The engine is cross platform, making it possible to develop for PC, XBOX 360 and PS3.

It is a modern engine, and is used to create high end games such as Gear of War (**Lanning, 2007**). As a result of this it supports many of the latest techniques (**EPIC, 2008a**), such as Normal Mapping and advanced lighting.

However as a consequence, the engine is much more demanding upon a system than the Source Engine. This in turn does however result in the engine being able to handle even an higher Polycount, the average character model being approximately 12,000 Polygons (**EPIC, 2008b**), when run on the base engine.

The Unreal Engine 3 was chosen for this project so that the generated artefact could be rendered within a 3D game engine, demonstrating the current high end game modelling techniques, using a low polygonal mesh. This engine automatically sets up lighting and Shaders, and has native support for many techniques used in creating game models which enabled for testing of the applied techniques.

3.2 Modelling Limitations

There is one key difference between modelling for games and modelling for films and that is the imposed limitations (**Capizzi, 2002 p.37**). While there are still constraints such as deadlines within the film industry, models can be made up of millions of Polygons with high resolution photorealistic textures. This is because the models and animations are not rendered in real time.

However modelling for the video games industry is very different, due to graphics generally being rendered in real time. Due to this hardware specifications must be taken into consideration, and reasonable constraints relating to Polygonal Limitations, texture resolutions, etc must be presented to the modellers. Game engines are limited to the number of Polygons they can render per frame, this in turn limits the number of models that can be displayed.

Thus the need for polygonal considerations is introduced, the latest video game releases, as seen below can be made up of 12,000 Polygons, and this is a step towards film quality game models.

(Gahan, 2009) *“...12,000 triangles. This is a reasonable amount for a prominent game character for a first-person shooter on the XBOX 360...”* (p. 246)

However this increased Polycount generates more demand upon hardware. So while they may be more visually appealing, not everyone has access to the latest hardware (**STEAM, 2009c**). As discussed below, older systems may not be able to handle the latest graphics, regardless of if the game engine supports them.

(Wetterschneider, et al, 2005) *“...if the character being designed is going to be in a game like Quake III: Arena or Unreal Tournament, it can be up to 2,000 triangles and still work. But unless you have the latest machine with the latest pimped-out 3D accelerator card, you’ll experience a serious performance hit if the character is much bigger than the normal 800-polygon range.”* (p. 5)

This suggests that model optimization is an important process in generating game assets. Optimizing models is basically the process of creating models with lower Polycounts while still attempting to portray the models in a realistic manner. Coupled with the latest techniques (detailed later in the chapter), it could theoretically be possible to create a well optimized character model with similar graphical quality to a higher polygonal model.

It is still important to take into consideration the layout of Polygons within these models so that realistic animations may still be achieved. Low polygonal models are generally produced to run on older hardware, and handheld consoles, but with a reduction in visual quality. Lower quality models may also be produced if a large amount of models are required to be on screen at the same time.

Limits on texture resolutions are also applied to these models, which can result in less detail, or unpolished looking models, however it is possible to reduce this via the use of technologies such as Anti-Aliasing which smoothes edges, reducing pixilation of models.

It is of course not only modelling which causes performance problems with the latest games, for example Grand Theft Auto IV first released as a console game, later performed sluggishly for PC users. This was due to issues such as lack of optimizing code to run on multicore CPU's, and is addressed in an article (**Onyett, 2008**).

These issues suggest that games may need optimizing in other areas such as programming, however this is not relevant to the project, as these areas are not directly related to 3D modelling. As the below article suggests, the quality of the players experience is reduced should the game be to demanding upon a system.

(Shelly, 2001) *“If a player finds himself waiting all the time while the computer grinds through some brilliant calculations, maybe the computer is having more fun than the player is.”* (p. 4)

To summarise, it is important to generate well optimized games, and in relation to this project well optimized models. This is beneficial for the hardware, and the experience of the user. While these limitations may not be around indefinitely they are still an issue, at least until technology reaches the point where it can go no further, namely the theoretical graphics plateau (**Sheffield, 2008**). However due to the complexity of models, and the realism they would need to convey in order gain this level of graphical quality, it is possible that game engines may never be capable of achieving this.

3.3 High End Modelling Techniques

In order to create a 3D model a variety of processes must be undertaken. While the manipulation of Polygons is important, texturing and other techniques are also key to the models development. This project investigates recent techniques used within high end games, the main focus game being Gears of War (**Lanning, 2007**).

Gears of War was originally developed for the XBOX 360, and later ported to the PC. It uses a range of techniques for creating models, and employs the use of the Unreal Engine 3. It is a recent title, and due to this it is relevant to the project, when determining techniques to apply to the main artefact.

Many different techniques exist for use in developing 3D models, some of which are not appropriate for game engines, and some which are outdated, or unsupported by a particular game engine. While it is not possible to explore every technique relating to the modelling field, research into the Unreal Engine 3 has identified the most appropriate techniques, for use within this project as, Diffuse Mapping, Specularity Mapping, Ambient Occlusion Mapping and Normal Mapping (**Lanning, 2007**)(**Unreal Engine, 2008**).

Diffuse Mapping - The Diffuse Map contains the main texture for the model, painted on to the UVW Unwrap render. It basically contains all the main information, such as colour, highlights, basic shadows etc and is much like a flat painting. This, as shown by (**Ahearn, 2006**) *“The Diffuse Map is what most people are talking about when they use the word “texture”.”* (p. 284)

Visible seams on the model can be generated during this stage, if the Diffuse Map is not generated correctly. It is therefore necessary to ensure that the textures blend well, in order to reduce this issue. This can also be reduced during the UV Unwrap stage, by creating natural seams which flow with the model (**Lanning, 2007**). **Figure 3.4** is an example of a created Diffuse Map for use with a character model.

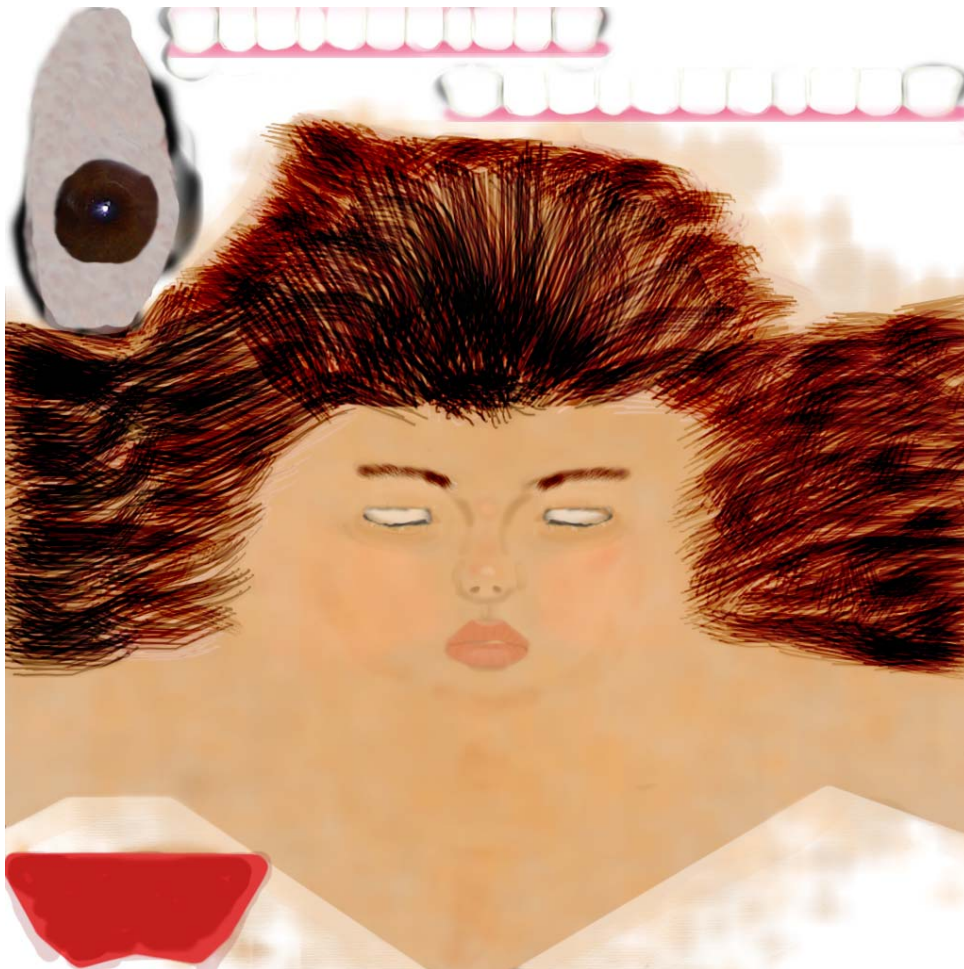


Figure 3.4 - Example Diffuse Map

Specularity Mapping - A Specularity Map contains data which determines which areas of a model should reflect light, and which should not, as shown (Ahearn, 2008, p. 80), this is basically the task of generating fake realism

The map is comprised of black and white image data, white representing reflective areas, and black representing none reflective areas. As stated Lanning *et al* (2007) this process is important to the model, if it is done incorrectly then the model will seem fake, however when done correctly will appear much more realistic.

Ambient Occlusion Mapping - Ambient Occlusion works in a similar manner to Specularity Maps. It enables the artist to define concave areas which should receive less light, and more shadow, as well as being able to define areas that should receive more light.

As described (Bunnell, 2005) Ambient Occlusion *is a useful technique for adding shadowing to diffuse objects lit with environment lighting.*” (p. 225), the technique is used in conjunction with Diffuse Maps in order to add additional detail. This is done via the process of baking textures, which allows for the data from several renders to be condensed down into one texture map, allowing for additional detail without requiring additional resources to render them.

Normal Mapping – The Normal Map contains directional information defining the direction a polygon faces, and stores this information in the Red, Blue, and Green channels of the texture file (Keller, 2008, p. 3). Simple Normal Maps can be generated within Photoshop, however these are less accurate than if created in a program such as ZBrush.

A Normal Map contains additional information, which generates a fake sense of detail within the model. When applied, the map makes a model appear of a much higher quality than it actually is. This is especially useful for game models, as it allows additional detail while generating less demand on hardware.

Alpha Mapping - Alpha Mapping is the technique of defining areas of transparency, this is used commonly for defining features such as hair (**Lanning, 2007**). This for example allows the hair to be constructed of simple plane objects, and then the detail added via textures. This is especially useful within a game engine where realistic hair takes up vital system resources.

An example of these techniques being used within a game model can be seen in **Figure 3.5**.

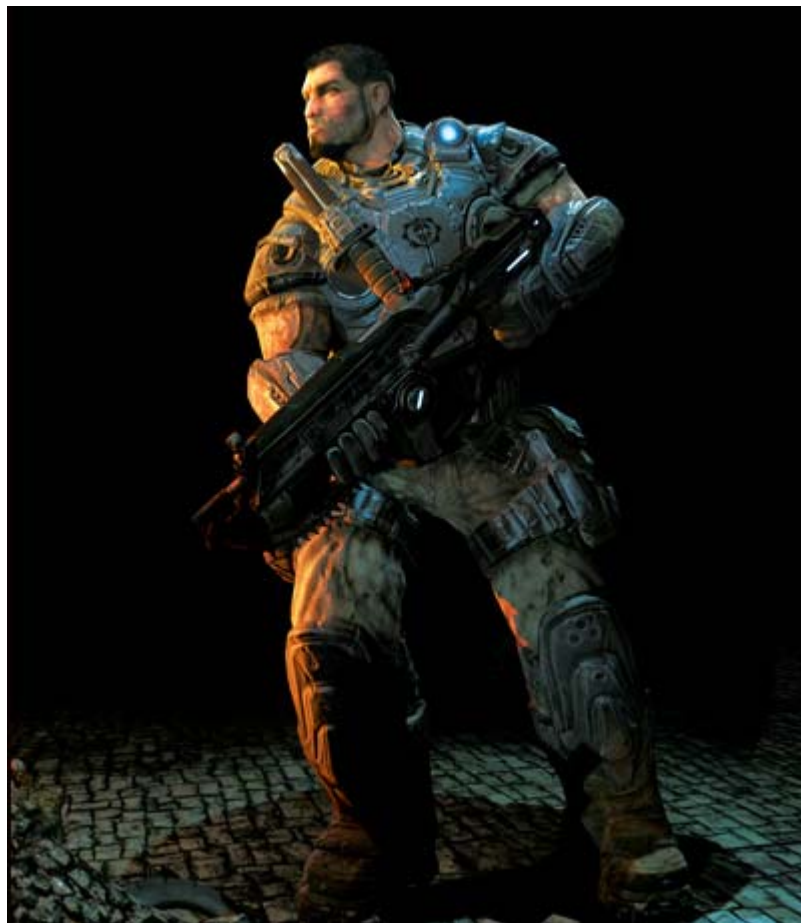


Figure 3.5 - Dominic Santiago - Gears Of War character by character artist Kevin Lanning (Lanning, 2007)

These techniques are not natively supported within all games, however it is possible to add support for them. For example the Source Engine is constantly being updated with support for new techniques (**Valve Corporation, 2008**).

While not always implemented, it is also possible for older hardware to support these techniques. For example, a paper (**Mikkelsen, 2004**) discusses how it is possible to generate Normal Maps using hardware available within the Sony Playstation 2 as demonstrated (**Mikkelsen, 2004**) “*We have shown that it is possible to do DOT3 Normal Mapping very similar in quality to PC-style Normal Mapping*”. (p. 19). This shows that it should be possible to use current high end techniques both with lower quality models, and older hardware.

Due to the discussed limitations of modelling for games, new techniques are constantly being developed to improve the visual quality of game models. As stated by (**Lanning, 2007**) “*As with past years we’ll continue to see breakthroughs in the graphics of games.*” (p. 11) an artist who worked on Gears of War, graphics have been, and will continue to evolve.

An example of past evolution is the step from bump mapping to Normal Mapping. Normal Mapping allows for much more realistic detail to be added to a model while bump mapping only allows for very basic details which do not look as realistic (**Keller, 2008**).

This suggests that more advanced, and optimised techniques will be developed in time which may contribute further to better quality models, with less demand on hardware.

3.4 Character Creation

The creation of a character for use within a game involves many processes. However many of these do not directly effect modelling techniques, thus are not relevant to the project. The main steps will however be discussed in brief to give an understanding of the stages involved. The stages that are relevant to this project are Concept, Modelling, Texturing and Game Engine.

Concept - A character is usually proposed in the form of concept art long before it is created, this conveys the image of whom the character will be, and shows if the idea will suite the specific art style of a project.

Background - Characters backgrounds are developed, showing who they are, where they come from etc. This gives more life to the character, and makes interacting with it more immersive.

Modelling - The model will be developed based upon the initial concept art, while changes may need to be made along the way the initial idea will generally be followed.

Texturing - This is the process of adding colour to the model, skin, clothes etc in order to make it appear more realistic.

Rigging - This stage involves the creation of a bone structure in order to enable the character to move. It involves the process of weighting individual vertex points to specific bones to ensure that they move correctly.

Animating - A character will generally have a set of animations linked to it to give it life. These will involve walk cycles, lip syncing etc.

Game Engine - The character will then be set up to work within the game, texture and animation data will be included.

3.5 Chapter Summary

This chapter has given information on game engines, and discussed both Valves Source, and EPIC Games Unreal engines in greater detail. Research into modelling constrains has shown that models need to be optimized for use within game engines. Finally the main high end modelling techniques have been discussed, and it has been identified that it would theoretically be possible to implement them within the constraints of older hardware.

4.Designing the Artefact

This chapter will introduce the design of the project artefact, detailing its main design specifications. It will also demonstrate an in depth overview of each stage of design, discussing relevant research and stating what assets were required.

4.1 Requirements Analysis

The overall purpose of this project is to establish the effect that applied techniques have upon low polygonal models. Additionally aiming to resolve if such low polygonal models could be made to appear of comparable graphical quality, to their higher polygonal counterparts.

In order to determine the answer to this it would be essential to develop a low polygonal artefact, employing the use of high end game modelling techniques. All applicable limitations, and techniques were investigated during the research stage of the project, this enabled the construction of an overall design. The artefact would be created based upon real development limitations, and processes.

It was determined that the production of a 3D character model would be appropriate for this task. This would allow for a large range of techniques to be applied, while still remaining within the realistic limitations of 3D asset creation.

This artefact would necessitate the need for the development of a basic concept design, which would consist of two main stages. Character concept art, and technical plans demonstrating the proposed polygonal layout of the 3D model. Conducted research stated that the imposed limitations of both older hardware, and game engines would require specific polygonal constraints to be adhered to. It was also determined that specific texture assets would need to be developed and applied to the final character model, in order to demonstrate and evaluate the required high end game model development techniques.

4.2 Imposed Limitations

The limitations affecting the design of the artefact are primarily in the form of technical constraints. The two main limitations accounted for during the design stage were Polygonal, and texture limitations.

Polygonal limitations impose a restriction on the number of polygons that can be used to create a 3D model. These restrictions are dependant on several factors, for example a model of a crate will require the use of a much smaller number of polygons than that of a character, and because of this it was necessary to determine an appropriate limitation for the creation of the project artefact. It was determined that the Source Engine would be a logical platform to ascertain required limitations. This was due to research showing that a large number of users have systems capable of running games such as Half Life 2 (**STEAM, 2009a**).

Due to this the facilitation of personal correspondence with the producers of Half Life 2 were commenced, allowing a contact with game animator Dough Wood to be formed. Via the use of these correspondences the polygonal limitations of Half Life 2 models were established. It was shown that the average Polycount of such a character would range from 7,000 to 10,000 Polygons (**Wood, D, 2009**).

Taking these limitations into account, the design limitations stated that created artefact should consist of no more than 8,000 Triangular Polygons. This would allow the character to function upon older technologies, while still allowing a sufficient level of detail to be implemented within its construction.

It was also determined that newer technologies such as the Unreal Engine 3 are able to support much larger Polycount for example characters in Gears of War consisted of up to 15,000 Polygons **Lanning et al (2007)**. This showed that that limitations imposed upon the design of the artefact were substantial, and this would factor in to the complexity of the final model. The less restrictive constraints of modern games allow for additional detail to be constructed, for example dents in armour, or advanced muscle detail. This in turn suggested that the final artefact would not be able to benefit from such advanced details, instead requiring that specific areas of importance for example the face be concentrated on.

Texture maps are image files which contain data pertaining to the overall appearance of the model, for example colour of the skin and shadowing of creases. The limitations imposed upon these maps relate to the resolution of the image, this are defined again dependant on what the model is.

These limitations were again obtained from the Source Engine, this time via the use of correspondence from a member of the team which worked on ZENO Clash Andres Bordeu. It was determined that the average character model was comprised of two texture maps, one with a resolution of 512x512 for the head, and the other a 1024x1024 map for the body (**Bordeu, A, 2009**).

The design stage took these limitations into account, reducing them slightly due to ZENO Clash being a more recent title than Half Life 2. It was therefore stated that the texture maps for the final artefact would each consist of a single 1024x1024 which would include data relating to the entire character model.

The more recent titles using the Unreal Engine 3 consist of two texture maps each with a resolution of 2048x2048 **Lanning et al (2007)**. One texture map contains information for the characters head, while the other contains information for its body. A higher resolution for a texture file allows for a much more detailed image to be created, it also reduced any potential artefacts or texture stretching. These higher resolution textures for example would be able to contain pores in skin and more detailed shading of clothes. Due to the notable limitations within the defined design it was determined necessary to give priority to key areas of the model such as the face and hair. While less visible areas such as the feet would suffer from a reduced amount of texture space, this would give the overall model a higher standard in relation to overall detail.

4.3 Concept Development

A concept is the initial idea of something, be that a story or a painting. In relevance to the project artefact this will be conveyed in two forms, concept art and technical overviews.

Concept art is the process of translating the original concept idea into a physical visual form, this is done via the creation of images. These can be created using contemporary tools such as pencils and brushes, or digital tools such as Photoshop. Concept art is used to communicate an artist's idea to others, showing what an object or character should look like. It will be able to demonstrate the overall feel of a character, for example showing what kind of clothes they wear, if they are timid or brave, etc.

As stated (**Gahan, 2009, p. 162**), character models take weeks to produce and concept art can help identify any problems which will potentially arise during the modelling stage before it begins. This could save both time and money for the project overall, rather than causing a model to be changed or restarted due to the problem being found at a later stage of production.

The use of concept art is especially vital in larger companies where teams comprise of separate concept artists and modellers, the concept art helps to communicate a strong image of what should be modelled, and to ensure that a constant art style is followed throughout a project. Keeping the art style is key to large titles such as Star Wars: The Old Republic (**Bioware, 2009**), as the production team is large, and many assets such as characters, creatures and worlds are being created simultaneously by different teams.

While the production of the project artefact was performed by an individual as opposed to an entire team of artists and modellers it was still vital to produce basic concept art. This would permit a basic overview of the design to be shown, allowing an understanding to be formed in relation to what would be created. As with larger projects this was intended to allow the model to be formed while taking technical considerations into account.

The produced concept was simplistic in nature, due to both the constraints of the model and the author's technical skills in relation to drawing. A simplistic character design would allow for more important aspects of the model to be concentrated on during the modelling stage. But still allowing for additional details such as stomach muscles to be added via the use of Diffuse and Normal Maps.

A technical overview consists of a concept design showing the proposed mesh layout of a model, again in the form of images. This is used to generate an understanding of the flow of a model, and to identify potential issues before they arise. Key areas such as the face will consist of higher polygonal distribution and this will be reflected in the layout of the proposed mesh.

As discussed (**Capizzi, 2002, p. 116**), this stage allows for the flow of difficult areas to be explored before the modelling process begins. This simplifies the overall task ensuring that the model works realistically, for example muscles moving in the correct direction and legs joining the torso neatly and efficiently.

The technical overview was produced for the project artefact to show how it should look once created. This was to ensure that an understanding of the characters mesh layout was formed prior to initialisation of the modelling process. This in turn was designed to benefit the overall creation of the final model by giving a strong starting point to work from and reducing any potential issues.

4.4 Required Techniques

The design stated that an overall 3D character model would be developed employing the use of several techniques. Polygonal modelling, Normal Mapping, Diffuse Mapping, Specularity Mapping and Ambient Occlusion Mapping.

The character model was to be produced using Autodesk 3Ds Max 2008 software, with the primary technique to be polygonal modelling. This is simply the manipulation of polygons or vertex points to ensure a logical look and flow is achieved overall. This was to be based heavily upon the technical overview, which demonstrates how the mesh should be set out.

As research has shown (**Ahearn, 2006**), the Diffuse Map contains information relating to the overall colour of the model. It details information on elements such as skin tone and basic shading which helps to give the model a more realistic appearance if done correctly.

A model can seem very lifeless without a well developed Diffuse Map, thus the design gave considerable time to its development. The file would be produced using Adobe Photoshop CS3, this tool supports layer functions and multiple filters which aid in the production of a realistic image file. It was also stated that specific areas of the model would require more image space than others due to their importance to the final artefact, for example the face, hair and hands.

As stated the Diffuse Map would be limited to an image resolution of 1024x1024, as the it could make or break the final artefact in terms of graphical quality, the allocated time and resources to its development were intended to enable the production of an artefact which could still deliver a decent level of quality.

A Normal Map is used to add additional details to a 3D model as previously identified **Lanning *et al* (2007)**. It basically takes the data from a high detail mesh and bakes them into a texture file known as a Normal Map for use on a lower detail version of the model.

The Normal Map for this project was to be created with the use of Pixologic's ZBrush, which would allow for a high detail version of the low polygonal model to be developed. Due to this the technical overview would be able to ignore specific areas of detail such as muscles and wrinkles in cloth, in order to concentrate on the overall appearance of the character. The high detail mesh would then perform the function of generating these details in order to be used as a Normal Map and aiming to increase the overall quality of the final artefact.

As discussed in more detail (**Ahearn, 2008, p. 80**), the Specularity Map is used to display areas of highlight and shadow upon a model. The lighter an area on the Map the more shiny it will appear, the darker the less shiny. It is used to add a sense of realism and depth to a model, taking into account that light hits all surfaces with altering intensity, and allowing this to be conveyed in the finished model.

Adobe Photoshop CS3 would be used to create the Specularity Map, with the aim of complementing the final artefact by attempting to make it appear of a higher quality. The overall Map would take into account the way that light reflects off of surfaces taking consideration to specific areas such as, the eyes and nose in order to add a sense of depth.

As defined (**Bunnell, 2005**) Ambient Occlusion consists of a process which calculates realistic lighting and shadows for a model. In the context of game models, the Map is rendered to a texture Map due to game engines not offering support for real time rendering of Ambient Occlusion.

If used correctly this technique would enhance the final model by adding a sense of realism and depth. It would take into account again realistic shadowing of models, and enable the creation of a more refined artefact.

Finally in order to test that the model would operate within a game engine and to render the effects in real time, the model was planned to be put into the Unreal Engine 3. This would allow for all techniques to be tested as the engine natively supports their use. Therefore it was stated that the model should be implemented within the Unreal Engine 3.

4.5 Design Summary

The overall design required the creation of a simple character based upon concept art, and technical overviews. The character should be created within 3Ds Max 2008 via the use of polygonal modelling, and consist of no more than 8,000 triangular polygons. Upon completion a high detail version of the model should be produced in Pixologic ZBrush, which should be free of limitations.

Taking into account texture resolutions, a set of Maps should be produced consisting of image files of a resolution of 1024x1024. Specific elements should be awarded priority as stated such as the face and hair. These texture sets should consist of four elements discovered as techniques used within high end game model production. A Normal Map which should be created from the high polygonal version of the model, a Diffuse Map and Specularity Map which should be produced in Adobe Photoshop CS3, and finally an Ambient Occlusion Map.

In order to form an evaluation of the effect of the researched techniques, they should be applied to the final model. The completed artefact should then be implemented within the Unreal Engine 3. The proposed assets are shown in **Table 4.1**.

Table 4.1 - Proposed Assets to Produce

Asset Name	Associated Program	Imposed Limitations
3D Character Model	Autodesk 3Ds Max 2008	Constructed of A Maximum of 8,000 Triangular Polygons
High Detail Model	Pixologic ZBrush	None
Diffuse Map	Adobe Photoshop CS3	1024x1024 Resolution
Normal Map	Pixologic ZBrush	1024x1024 Resolution
Specularity Map	Adobe Photoshop CS3	1024x1024 Resolution
Ambient Occlusion Map	Autodesk 3Ds Max 2008	1024x1024 Resolution
Model Implementation	EPIC Unreal Engine 3	None

4.6 Analysis Of Design

The polygonal and texture based limitations imposed upon the project do restrict the level of detail that can be conveyed by the produced model as standard. However these are researched limitations applied to older games, and thus are appropriate to apply during the creation of the project artefact.

While these limitations could affect the final artefact negatively they do still allow for some scope of realism to be created. The proposed techniques used within modern games such as Gears of War would in theory allow for much more detail to be added to the model, regardless of its limitations. This would allow for a valid evaluation to be constructed determining the effect such techniques have upon models, ultimately discovering if lower polygonal models could appear of similar graphical quality to their, higher detail counterparts.

While this is a realistic design, it must be noted that all designs have scope to change while limitations will remain constant the overall design of the final artefact could be changed during its implementation. This could be due to many factors including technical problems which could not be overcome, or discovery of more efficient methods of construction.

4.7 Chapter Summary

This chapter has discussed the research findings and how they effected the production of the artefact design. Taking into account techniques and limitations found it presents an overview of each stage of production. It concludes by summarising the overall design, and explaining its advantages and disadvantage.

5.Artefact Implementation

This chapter presents an in-depth overview discussing the development of the project artefact, examining all produced assets and how they were created. It also discusses any problems resulting from the creation of the artefact, stating how they were overcome, finally giving an overview of the implementation of the artefact, determining what was produced and comparing this to the original design.

5.1 Character Modelling

In order to evaluate the effect that modern modelling techniques have upon more constrained lower polygonal models, it was necessary to design and create a 3D character model. It was determined that this process would consist of two stages involving the creation of both low and high polygonal versions of the character model. The low polygonal model was created to test the effect of particular techniques. While the high polygonal version, was created specifically to test the Normal Mapping technique.

During the design phase of the artefact specific concept images were generated suggesting what the character model should look like. These images were used as reference during the implementation of the final model, which helped make sure that realistic proportions etc were kept. Ensuring that the model had realistic proportions was key to its development, as taking out this aspect of reality without creating a specific art style would have impacted the quality of the artefact in a negative manner. The concept designs were also used to ensure that the model matched the design as closely as possible both in terms of look, and mesh layout.

As the design specified the character model was implemented via the use of Autodesk 3Ds Max 2008. The produced concept images were used in conjunction with a range of reference images in order to ensure that the model appeared as realistically proportioned as possible. The base character mesh was created via the use of a range of techniques most notably polygonal modelling, which required the manipulation of polygons or vertex points to shape the model. As a form of testing it was necessary to constantly view the model from different angles, and to produce regular renders to ensure that it looked correct from every direction.

Polygons were distributed evenly throughout the mesh, with the exception of key areas such as the face. This was done to ensure that important elements of the character appeared more detailed and thus improving the quality of the final artefact. While the model would not be animated, principles of modelling were still taken into account so that it could be. This was done by adding in appropriate edge loops, which are key according to **(Gahan, 2009)**, to areas such as the mouth and eyes. To help with the overall look of the character when rendered, different shading groups were applied to specific elements to distinguish between material types. The final stage of creating the low polygonal mesh consisted of a detail pass, this was used to improve the visual quality of the character, enabling the addition of more precise details such as creases in clothes, and for the refinement of the mesh to ensure that it appeared smoother, and improve its overall flow.

The completed mesh had a UVW Unwrap modifier applied to it, this enabled the 3D mesh to be flattened into a 2D image, and was done so taking into account the researched design limitations. Areas of importance such as the face were given more room on the map, while less important areas such as the necklace were given less. The stage also required considerable time and thought to be put into the layout of the map in order to ensure minimal texture stretching would occur once the diffuse map was applied. The overall process of un-wrapping the mesh would enable the model to have further techniques applied to it, and make it ready for exporting into Pixologic ZBrush. In order to ensure that the model would be compatible with other programs it was exported to the OBJ file format. OBJ is supported by both ZBrush and 3Ds Max 2008, thus enabling work to be easily shared between them.

Once imported into ZBrush the low polygonal model was used as a base mesh for creating a high polygonal version. The geometry tool was used to increase the number of polygons within the model, this allowed for the creation of a smoother and more detailed character. ZBrush includes a large array of different brush tools for use in 3D sculpting. These tools were used in order to add additional features to the model. As the design hoped to achieve the most realistic character possible, reference images were studied to ensure that areas of detail would look more life like. Details such as knuckles, finger nails and stomach muscles were sculpted as it was not viable to model such details onto the low polygonal mesh. The implementation of this stage in production was unfortunately delayed due to compatibility issues with ZBrush. However the problem was eventually overcome when an appropriate solution was determined, requiring the installation of updated AMD dual core management software.

5.2 Technique Application

Once the creation of both the high and low polygonal model were completed it was necessary to implement the techniques outlined in the design. The creation of a Normal Map, Diffuse Map, Ambient Occlusion Map and Specularity Map was commenced. The aim of this implementation was to enable the demonstration and evaluation of the effectiveness of said techniques.

The design stated that the Normal Map should be created within ZBrush, however this proved problematic. While the high detail model was created correctly within ZBrush, the software would not output a valid Normal Map. While the detail was sculpted into the model, the produced output was simply of a flat image containing no additional information. Due to this potential solutions had to be investigated, however during this process a more beneficial method for creating the Normal Map was discovered.

This process required the high polygonal model to be exported from ZBrush as an OBJ file, and then imported back into 3Ds Max 2008. The projection modifier was then applied to the low polygonal model, this allowed for the details of the high polygonal mesh to be projected onto its low polygonal counterpart.

The projection modifier projected a blue highlighted cage onto the target model, initially with no resemblance to how it should look. The cage was then manipulated so that it was inline with the shape of the model as to ensure that it worked correctly. An example of how the manipulated cage looked can be seen in **Figure 5.1**.

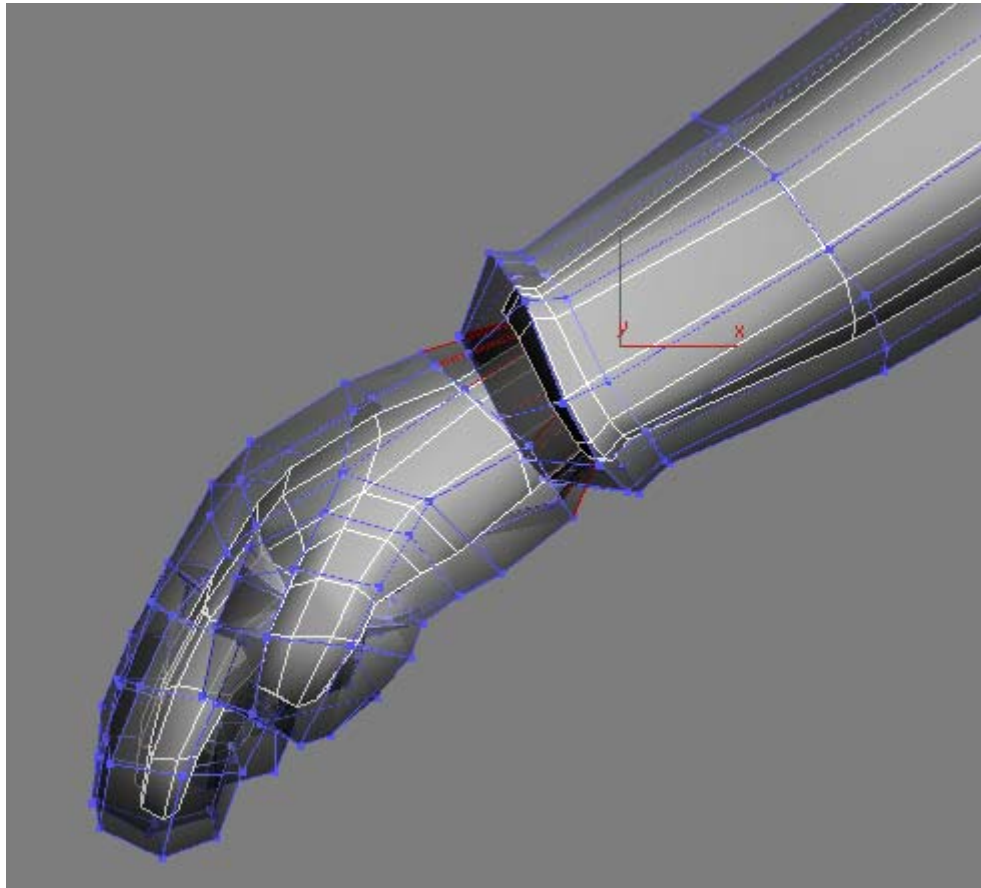


Figure 5.1 - Projection cage (Blue) surrounding the model (Grey)

The details of the high polygonal model were then translated into a Normal Map containing the UV coordinates of the low polygonal model, this is done through a process known as baking (**Gahan, 2009**). However while successful this process caused a rivet to be displayed down the centre of the model when rendered. Ergo manual tweaking of the Normal Map in Adobe Photoshop CS3 was required, which while a time consuming task did create a more polished Normal Map. The completed Normal Map was then applied to the model, with the aim of generating additional detail without the need for additional polygons.

The Ambient Occlusion Map was also generated within 3Ds Max 2008 using the process of baking, this enabled the detailed shading of the higher polygonal model to be captured. This process required the adjustment of rendering settings and the placement of a skylight in order to cast appropriate shadows onto the model. The Ambient Occlusion map contained realistic shading information with a sense of depth it was used in conjunction with the diffuse map.

Basic colours were assigned to the model, and baked into a Diffuse Map, which when coupled with the Ambient Occlusion Map created a detailed starting point for further development. Adobe Photoshop CS3 was used to paint the final Diffuse Map, this was done via the use of a multitude of tools. A combination of brushes and filters were used to give a sense of realism to the image, allowing for example variations in skin tone to be created. Layers were used to differentiate between different elements such as shading, colour, detail, etc. Different blending options effecting how layers work together were used to form an overall more realistic finish.

Reference images were again pertinent to the development of the Diffuse Map, enabling shading and highlights to be created appropriately. It was necessary to ensure that these elements were captured correctly within the Diffuse Map. This was so that it would work correctly with other techniques such as the Specularity Map for example the tip of the nose needed to have a lighter colour tone than the rest of the face.

The Diffuse Map also contained the Alpha Map as an additional layer within the image; this was used to define areas of transparency within the model. This was used specifically for creating more realistic hair and preventing edges from being shown, which would detract from the overall quality of the artefact.

The design stated that the Specularity Map should add a sense of realism to the model, ergo it was again necessary to study reference images in order to ensure that shadows and highlights were correctly created. The Specularity Map was painted in Adobe Photoshop CS3, based upon a black and white version of the Diffuse Map. Highlighted areas were defined by lighter colours, and shaded areas by darker ones. It took into account specific elements such as the eyes and lips, in order to ensure that an appropriate amount of detail was created.

All developed techniques were applied to the model via the use of the 3Ds Max 2008 Material editor, ensuring that each was assigned to the correct slot, Alpha to Opacity, Normal to Bump, etc. This enabled the techniques to be rendered out in 3Ds Max 2008 to ensure that they worked correctly before exporting the model for use in the Unreal Engine 3.

5.3 Unreal Engine 3 Implementation

The design specified that the final model should be implemented within the Unreal Engine 3. Doing so determined that the model would indeed work within a game engine, and allowed the applied techniques to be rendered in real time. The implementation of this stage required the use of the Unreal Engine 3 Editor, allowing the creation of maps.

The Unreal Engine 3 is limited in terms of what file types it supports, ergo it was essential to convert the produced assets in order to prepare them for use. Model files were exported to the .ASE format, and image files to .TGA. In order to place the model within the game world it was necessary to develop a basic map, this consisted of a single large box room with simple materials, and skylight lighting applied.

The Unreal Engine 3 manages assets via the use of packages, each containing textures, models, audio clips etc, thus the development of a custom package was necessary. This package was created, and the relevant model and texture assets were imported. The model was then placed within the game world, however initially consisted of nothing more than the base mesh. To resolve this issue a new material was created within the package, and as was done within 3Ds Max 2008, each Map was applied to its relevant slot, as shown in **Figure 5.2**

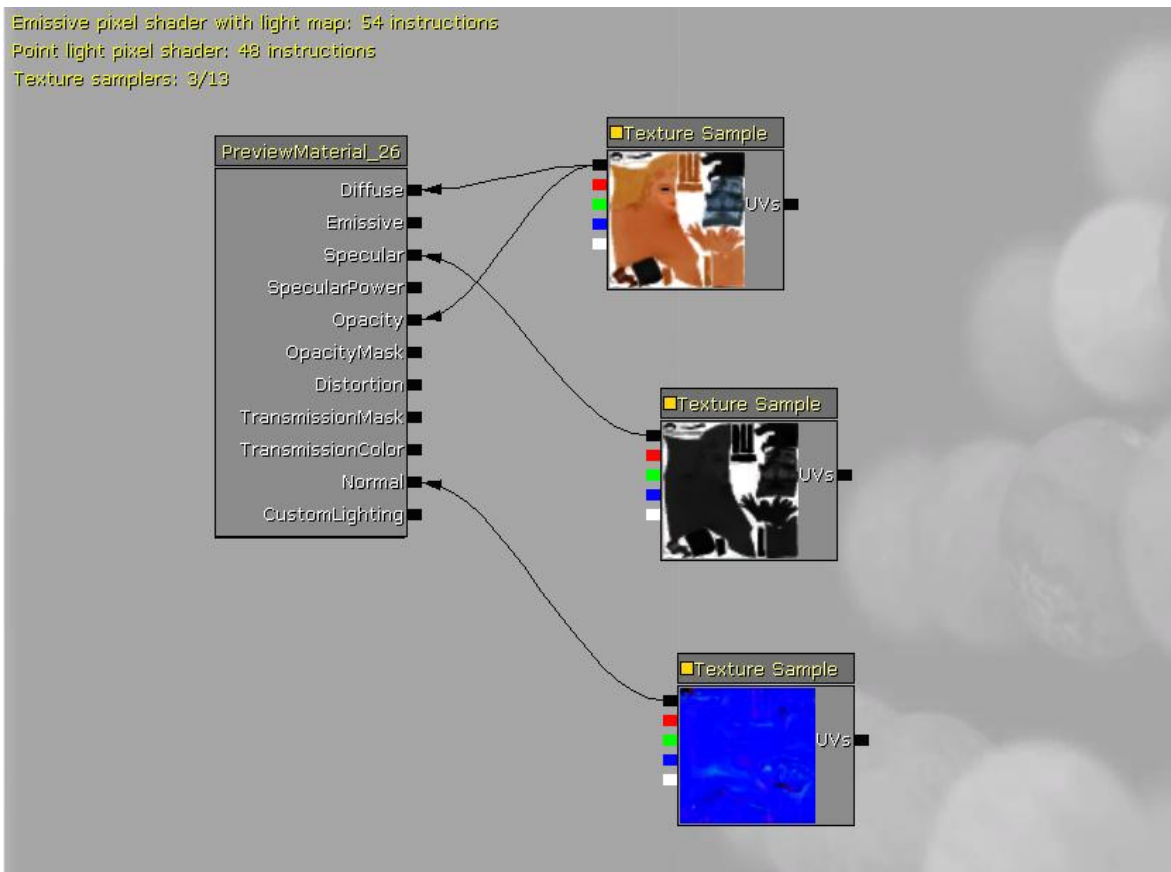


Figure 5.2 - Unreal Engine 3 - Material editor

After the material was applied to the model there were two main issues, one being that the Alpha Map was working incorrectly, not displaying any opacity within the hair. This issue was however overcome via further investigation of the material editor, requiring the alteration of specific settings. The second issue caused the character to be heavily shadowed from specific angles. However this issue was due to the incorrect setup of the maps lighting, and was quickly overcome.

Next a basic camera pan was developed using animation tools within the Unreal Engine 3, this was designed to rotate the camera around the custom model. In order to ensure that the camera pan would activate for the player, the use of a high level programming system native to the Unreal Engine 3 was implemented. This system is shown in **Figure 5.3**, a trigger was placed within the world, which once activated the camera pan would be played, simultaneously entering cinematic mode and removing the characters HUD.

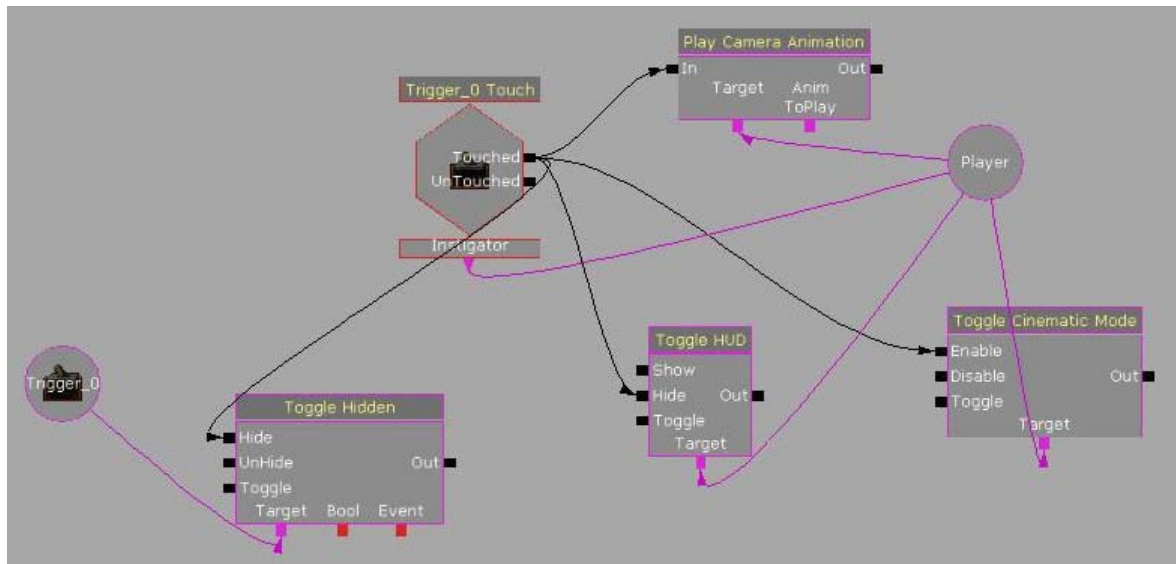


Figure 5.3 - Unreal Engine 3 - High Level Programming Overview

While the camera pan functioned correctly within the testing environment of the Unreal Engine 3 editor, it would not work within the Unreal 3 game when loading a published map. While this issue was not overcome, the required camera pan animation could still be demonstrated and recoded via use of the testing environment.

5.4 Artefact Overview

The final artefact comprised of a 3D character model based upon original designs, and consisting of 7,358 triangular polygons. It also applied the researched techniques of Normal Mapping, Ambient Occlusion Mapping, Diffuse Mapping and Specularity Mapping, each complying with the imposed 1024x1024 image resolution limitation. The final model was implemented within the Unreal Engine 3, which enabled the animation of a simple camera pan. Multiple animated camera pans, and still image renders were produced both within 3Ds Max 2008 and the Unreal Engine 3 for use within the evaluation.

Some issues were discovered during the implementation of the artefact, creating the Normal Map, implementing the model within the Unreal Engine 3, etc. The main issue discovered during final testing was due to the symmetrical nature of the produced artefact, while the impact of this was reduced the realism of the model could have been improved with some variation in modelling, for example different creases on each leg.

The final implemented artefact followed the design as closely as possible, with very few changes being made, however due to technical issues, some changes were necessary. **Table 5.1** discusses what was produced, and highlights any changes from the original design.

Table 5.1 - Outline of implementation, discussing any changes from the design.

Produced Asset	Design Limitations	Changes From Design
Low Polygonal Model – 7,358 Triangular Polygons	Maximum of 8,000 Triangular Polygons	Mesh layout, in order to maintain quality
High Polygonal Model	None	None
1024 x1024 Normal Map	1024x1024 Image Resolution	Created in 3Ds Max 2008, instead of Pixologic ZBrush due to technical issues
1024 x1024 Ambient Occlusion Map	1024x1024 Image Resolution	None
1024 x1024 Diffuse Map	1024x1024 Image Resolution	None
1024 x1024 Specularity Map	1024x1024 Image Resolution	None
Implementation In Unreal Engine 3	None	Addition of animated camera pan for use in evaluation
Camera Pan Animations	None	Not in design, used for evaluation
Still Image Renders	None	Not in design, used for evaluation

5.5 Chapter Summary

This chapter has discussed the involved stages of implementing the project artefact, identifying how and why they were conducted. It has also presented the issues encountered during the artefacts development and how they were overcome. Finally it presented an overview of the created artefact, discussing any changes from the original design.

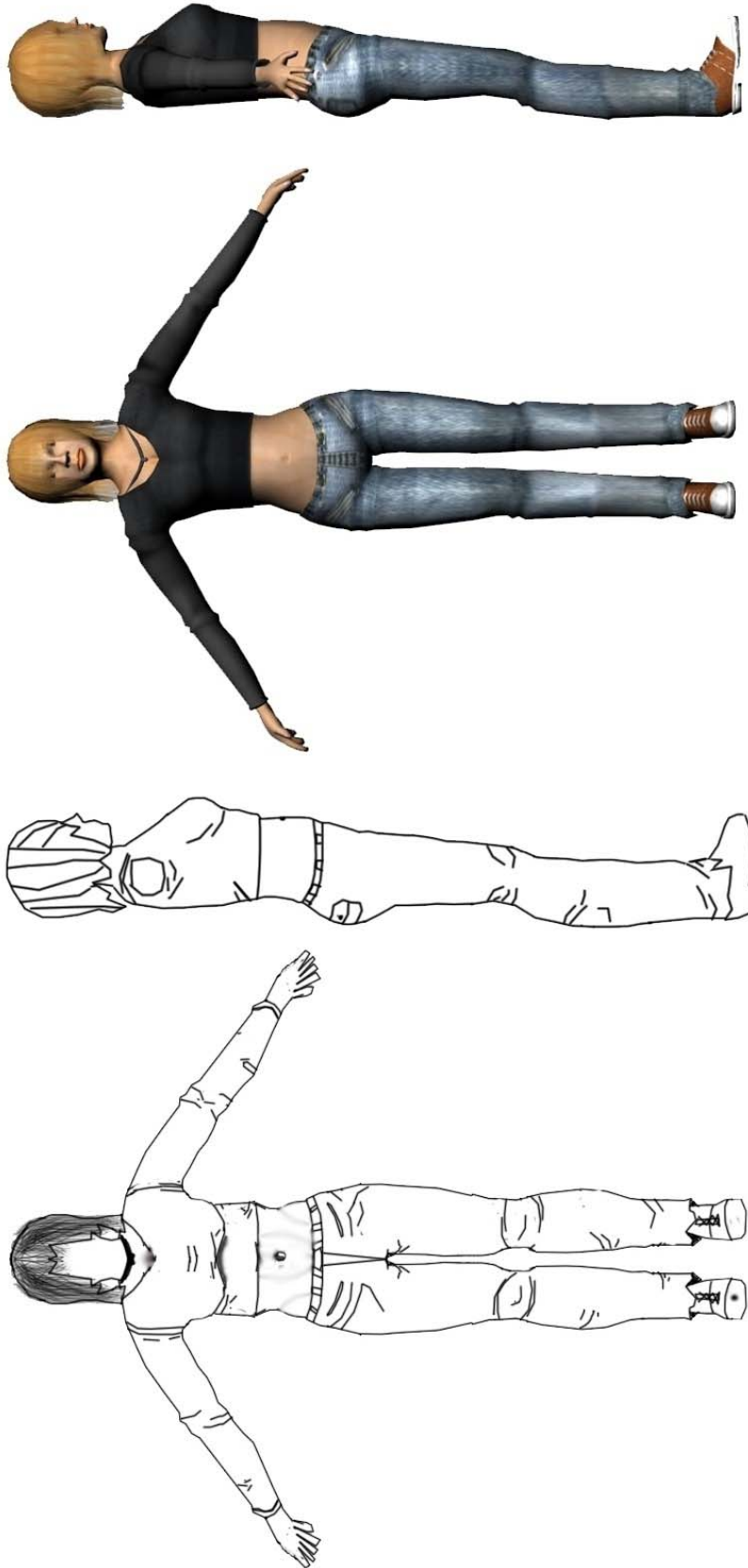


Figure 5.4 - Concept art (Left) and implemented model (Right)



Figure 5.5 - Concept art (Left) and implemented model (Right)

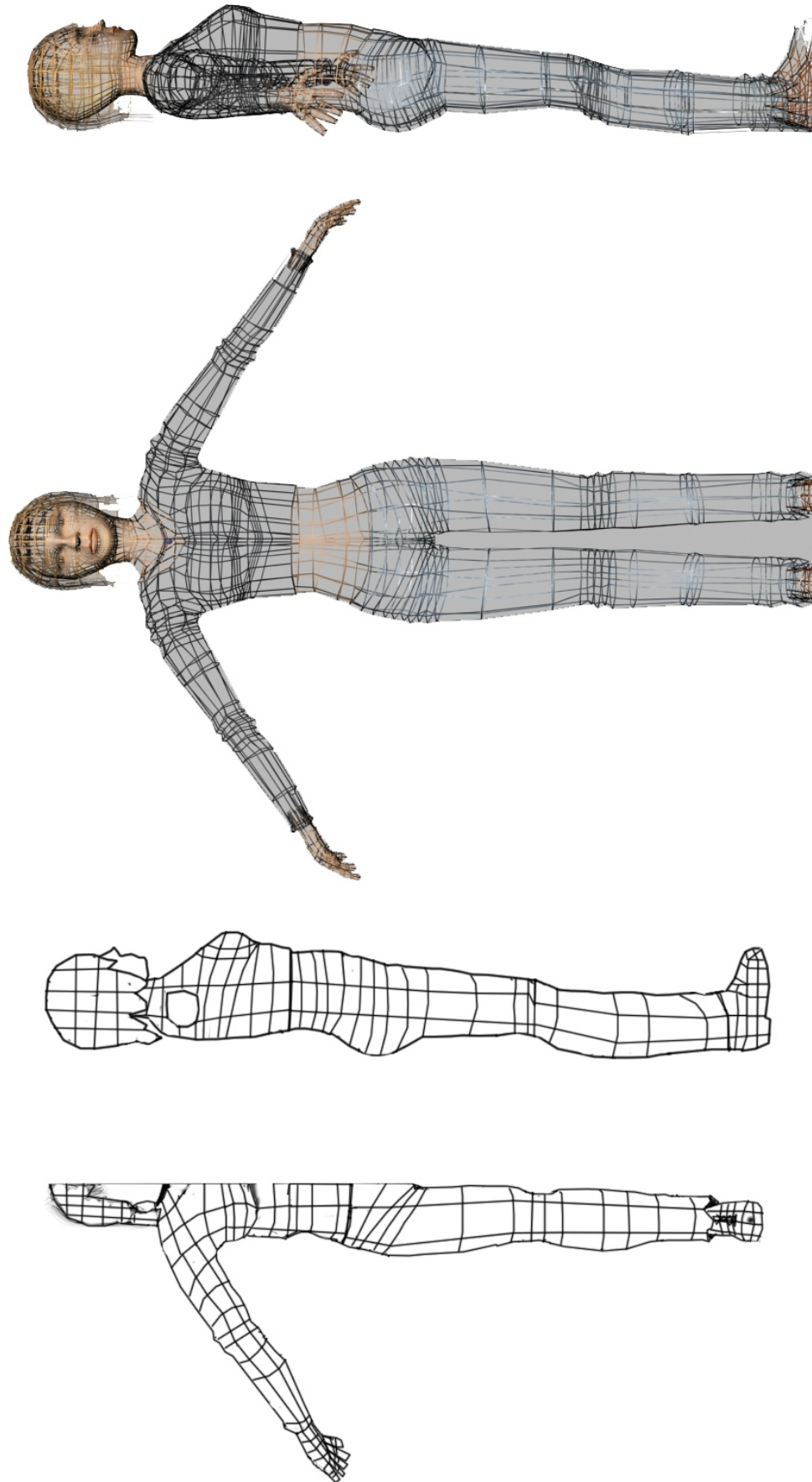


Figure 5.6 - Technical overview (Left) and implemented mesh (Right)

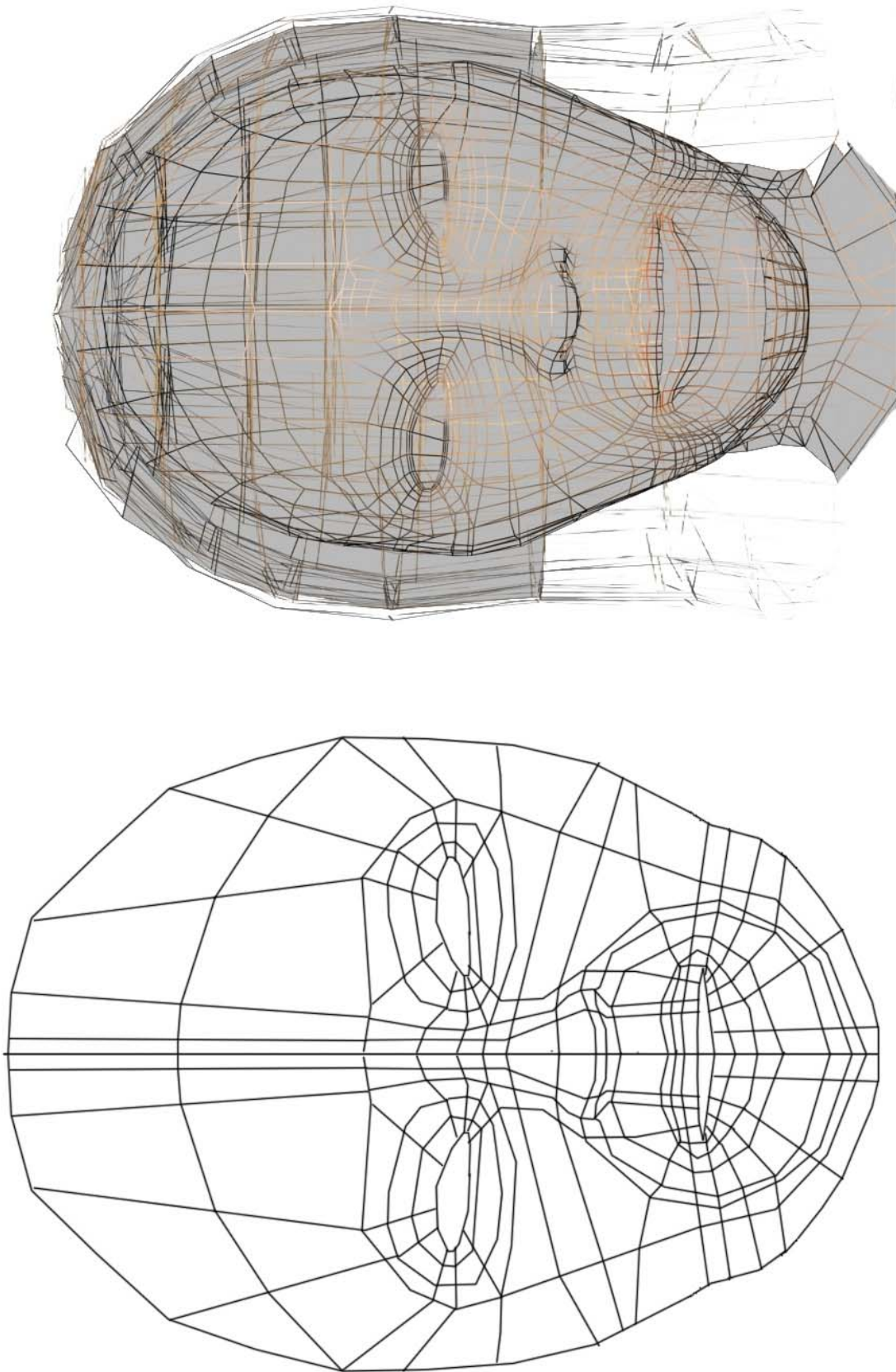


Figure 5.7 - Technical overview (Left) and implemented mesh (Right)



Figure 5.8 - Artefact without techniques (Left) and with (Right)



Figure 5.9 - High polygonal model (Left) and artefact implemented in the Unreal Engine 3 (Right)



Figure 5.10 - Diffuse Map (Left) and Specularity Map (Right)

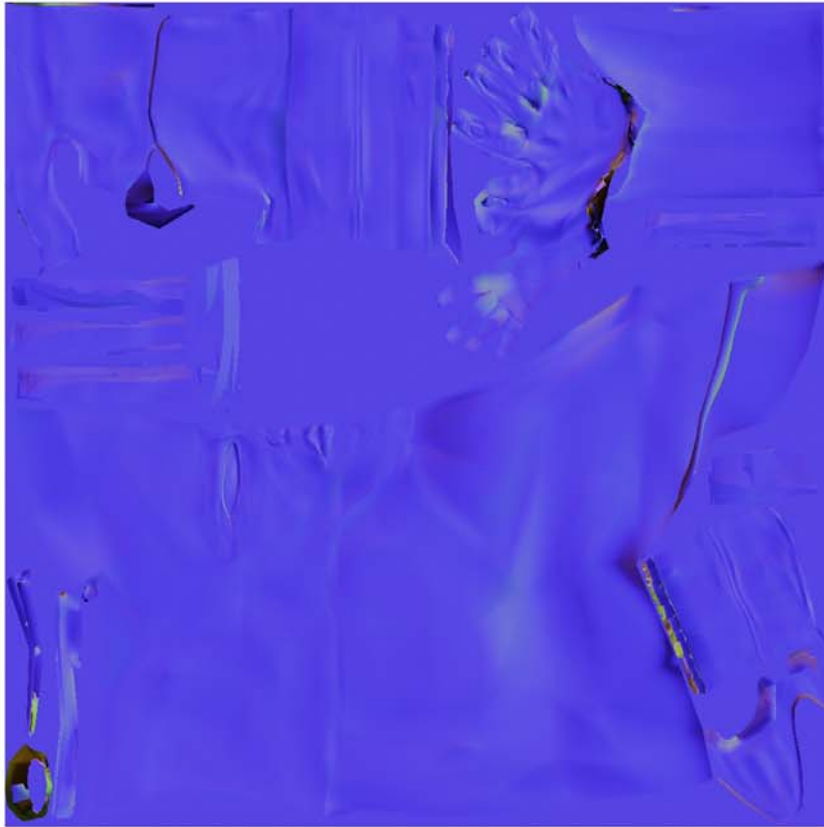


Figure 5.11 - Ambient Occlusion Map (Left) and Normal Map (Right)

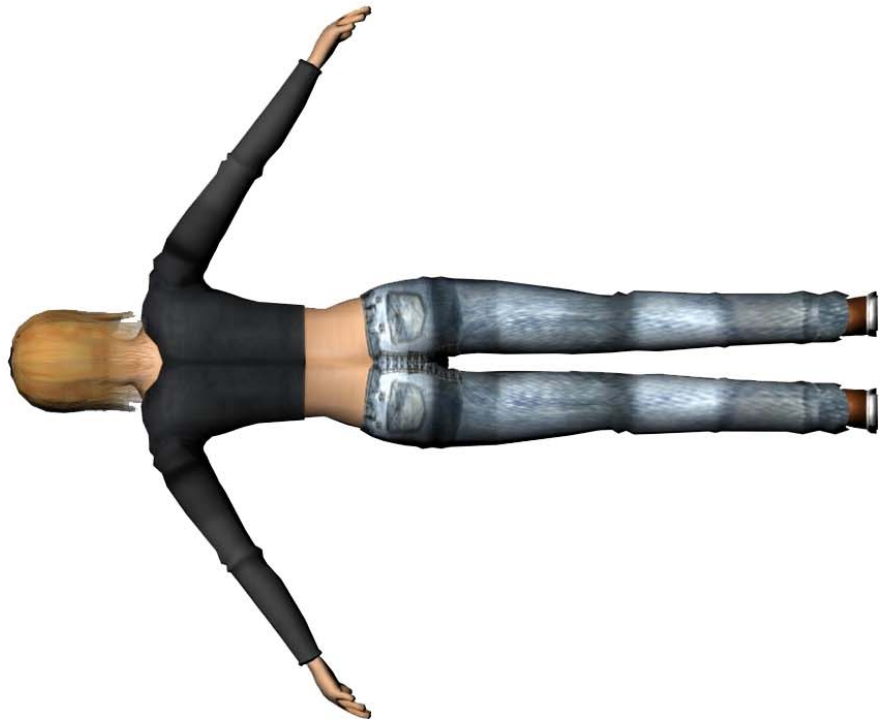


Figure 5.12 - Final artefact

6.Results And Evaluation

This chapter presents a discussion about the produced questionnaire, defining what each statement aimed to determine. It also discusses the results of the questionnaire, giving an overview and interpretation of what they show. An overall evaluation of the project is also presented, determining the projects success in meeting its aims and objectives. Finally the evaluation and results are discussed in further detail, highlighting relevant findings and determining how they relate to the problem area.

6.1 Questionnaire Development

In order to conduct a valid evaluation of the produced artefact it was necessary to develop a questionnaire. The questionnaire would be used as an evaluation tool, capturing results relevant to the problem area of the project. The questionnaire was comprised of 6 statements, each with the overall aim of determining the effect of applied techniques, and presenting the opportunity to investigate the reason for their success or failure. The data was captured via the use of a Likert scale, presenting options from 1 to 5, 1 relating to Strongly Disagree, and 5 Relating to Strongly Agree.

The questionnaire was aimed at a specific target group consisting of 10 individuals, each with a prior technical understanding relating to the 3D modelling field. This would enable the collected results to be more critical due to pre-existing knowledge of the technical processes involved in creating the artefact. It also meant that the questionnaire could be completed with greater ease, due to the individuals having an understanding in regards to terms such as “Textured”. Overall the research was aimed at a concentrated group in order to produce more relevant results.

The evaluation was treated in a professional manner, all research participants were reassured that any collected data would be kept confidential. It was also stated that should participants wish to remove their results from the study at any time, they elect to do so. (See Appendix 2) for a copy of the produced questionnaire.

In order to complete the questionnaire the research participants were shown a series of still and animated renders of the artefact. The first renders displayed were of the artefact minus the application of any high end modelling techniques, this was to demonstrate how the model would look in its base form. Further renders were then shown of the final artefact, with applied techniques both from within 3Ds Max 2008, and the Unreal Engine 3 in order to demonstrate the effect the applied techniques had upon the model. Next produced still renders of the high polygonal model created within Pixologic ZBrush were shown, in order to form a comparison between it and the final artefact. Finally a render of an industry standard high end model was shown to the individuals in order to evaluate the overall success of the applied techniques, the questionnaire was then completed.

Upon completion the obtained results for each statement were collated into the form of a bar chart, displaying each option 1 – 5 and the number of times each was selected. (See Appendix 3) for full statistical results obtained from the completion of the questionnaire.

Different methods for analysis of the obtained results were investigated, however calculation of the Modal score was determined as the most appropriate method for use within the evaluation. Results from all investigated methods generated similar findings, for example in relation to statement 1, the Modal score was determined as 4, and the majority of 60% chose 4 as their answer. While the use of percentage analysis would allow for more varied discussion in relation to results, it was determined that a more focused evaluation would be beneficial. The results obtained from the Modal score were in compliance with the employed Likert scale evaluation system. **Figure 6.1** shows the Modal score for each statement before rounding is applied.

6.2 Results Analysis

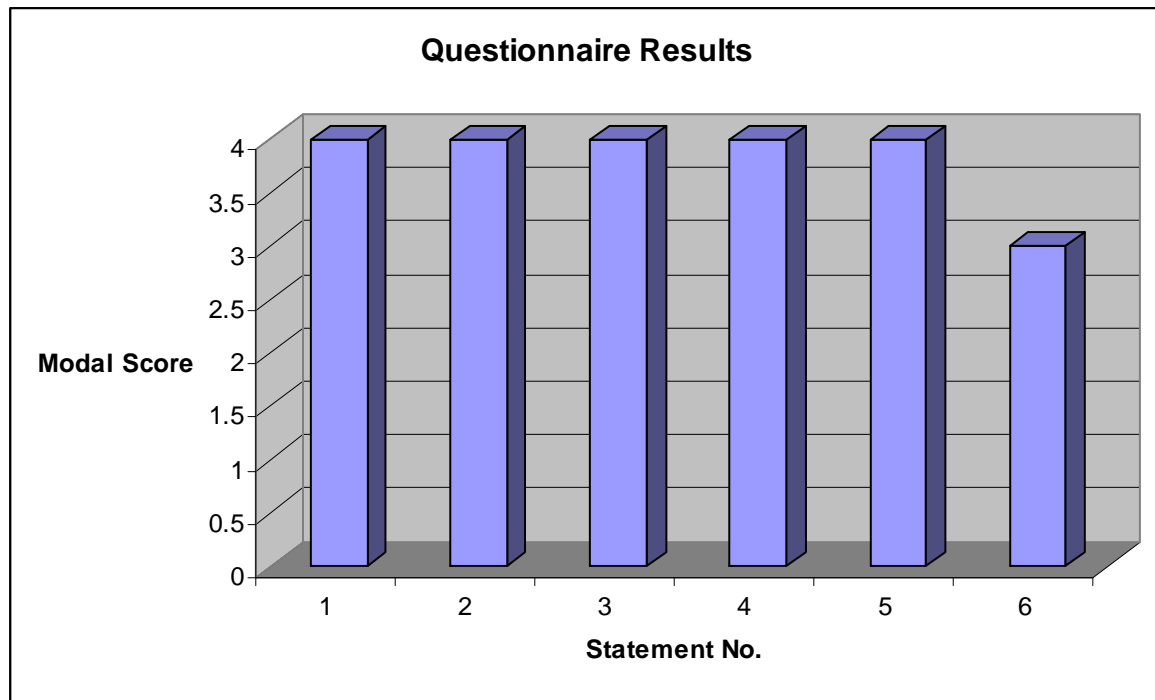


Figure 6.1 - Questionnaire Results - Modal Score

This section discusses the statements used within the conducted questionnaire (See Appendix 2) and the related results (See Appendix 3).

Statement 1 was designed to gather results measuring if an improvement affecting the overall graphical quality of the produced low polygonal model, is made by applying specific techniques.

The produced results for statement 1 were primarily positive, with the Modal score of 4 having been selected, this shows that participants generally agreed with the presented statement. Although there were 2 participants that disagreed with the statement, the over arching results out weighted this The Modal score of 4 did however suggest that there was still room for improvement in terms of graphical quality. The overall results suggested that the applied high end modelling techniques did have a positive effect upon the produced low polygonal model, in relation to its overall graphical quality. Helping to determine that the applied techniques, were indeed beneficial to the overall modelling process involved in creating the project artefact.

Statement 2 was designed to gather results determining if the research participants felt that the improvement was both worthwhile, and beneficial in the enhancement of the produced artefact.

The gathered results for statement 2 were again mostly positive, with the Modal score of 4 showing that the research participants generally agreed with the presented statement. There were however 3 participants who were either unsure about or disagreed with the statement, although the average response outweighed this result. The Modal score of 4 suggested that the enhancement of the artefact could have been more beneficial if the overall quality had been improved. The overarching results suggested that the improvement was indeed beneficial to the graphical improvement of the produced low polygonal model. In turn this showed that the application of the researched techniques, was a worthwhile process. Although the process of applying such techniques is more time consuming than standard low polygonal modelling, the developed artefact did benefit by appearing of a higher overall quality.

Statement 3 was designed to gather results determining if the research participants felt that the artefact was well modelled, both from an aesthetic and technical standpoint. This was required in order to help identify how the modelling factored into the overall quality of the artefact.

The gathered results for statement 3 showed again a mostly positive view, with the Modal score of 4 showing the research participants generally agreed with the presented statement. 3 research participants were either unsure about or disagreed with the statement, this was however outweighed by the majority of results. The Modal score of 4 suggested that the quality of the modelling could have been improved, which could have improved the artefact. However overall the results showed that the research participants felt that the artefact was quite well modelled.

Statement 4 was designed to gather results determining if the research participants felt that the produced artefact was well textured, again both from an aesthetic and technical standpoint. This would enable the identification of how the texturing process factored into the overall quality of the produced artefact.

The gathered results from statement 4 presented a mostly positive view, with the Modal score of 4, showing that research participants generally agreed with the presented statement. There were however 3 research participants who were unsure if they agreed or disagreed with the statement, however this was again outweighed by the Modal score. The Modal score of 4 suggested that the models texturing could have been enhanced, potentially improving the artefacts overall quality. The overarching results showed that research participants felt that the artefact was well textured.

Statement 5 was designed to gather results determining if the research participants felt that the produced artefact was of a similar graphical quality to its high detail counterpart. This was to determine how successful the techniques had been in improving the overall quality of the artefact.

The gathered results from statement 5 presented a mostly positive view, with the Modal score being 4, showing that research participants generally agreed with the presented statement. There were 2 research participants who either disagreed, or were unsure if they agreed with the statement, however the overall results again outweighed these selections. The Modal score of 4 showed that the average result stated that the artefact did appear of a similar quality to its high detail counterpart, however that the overall quality still had scope for improvement.

Statement 6 was designed to gather results determining if the research participants felt that the produced artefact was of a similar graphical quality, to the demonstrated high end game model. This again aimed to determine the overall success of the artefact, and its employed techniques.

The results relating to statement 6 presented a view suggesting uncertainty, with the Modal score being 3, showing that research participants were undecided in regard to their view of the statement. 3 Research participants disagreed with the statement, while 2 agreed with it, this shows the gathered results are widely varied. The Modal score of 3 shows that while most people do not feel that the artefact is of a similar graphical quality to the high end game model, they do not believe that it is either. This would suggest that the overall graphical quality of the produced artefact would have needed to be further improved to be on par with the demonstrated model

6.3 Project Evaluation

It was determined that it was beneficial to evaluate the produced artefact against the original aims and objectives outlined within chapter 1 of the project report. This evaluation would be used to appraise the overall success of the project and the production of the related artefact.

The scope of the project required that an extensive array of sources be investigated in order to gather information pertaining to the problem area. The limitations imposed for the creation of low polygonal models for older hardware were determined, in terms of both Polycount and texture resolutions. The techniques used to develop high end game models were also determined, and an investigation of their function was presented. Further research into the problem area was also presented, discussing the necessity for low polygonal modelling, and evaluating the appropriate tools, game engines and techniques for application in the development of the project artefact. This research satisfied the projects overall aims and objectives relating to research.

The researched constraints were analysed and translated into design limitations for the creation of the project artefact. These limitations specified the technical constraints that would effect the creation of the model, and defined the relevant techniques to be developed and employed within its creation. Basic concept art and technical overviews were developed to aid in the implementation of the artefact. These concept designs took all relevant constraints into consideration with the aim of helping implement a well developed project artefact. This design satisfied the overall aims and objectives of the project relating to the design of the project artefact.

The design was followed to enable the implementation of a valid and relevant project artefact, which could ultimately be used as an evaluation tool. The implementation adhered to the constraints of the design, ensuring that the developed artefact would be technically valid in accordance with the limitations of both older, hardware and game engines. The implementation process followed the development structures of researched methodologies. The functions of the researched techniques were further investigated, in order to allow for their application within the final artefact. The techniques were applied in accordance with the development processes of modern high end games such as Gears of War **Lanning *et al* (2007)**. The produced artefact was then implemented within the determined relevant game engine. The implementation within the Unreal Engine 3, allowed for real time testing of the applied techniques and the development of a basic camera pan animation. The implementation of the project artefact took relevant factors into consideration and fulfilled the projects overall aims and objectives in relation to the artefacts implementation.

In order to effectively evaluate the project artefact, and determine relevant findings in relation to the problem area, specific evaluation tools were developed. Both still and animated renders of the artefact were produced, demonstrating its graphical quality both with and without the applied techniques. A questionnaire was also developed taking into account relevant methodologies, in order to ensure a decent level of validity within the produced results. The questionnaires statements aimed to capture data relating to the effectiveness of the employed high end game modelling techniques. The results were analysed in order to generate appropriate data, relating to the problem area. The evaluation of the project artefact fulfilled the projects overall aims and objectives in relation to the artefacts evaluation.

6.4 Evaluation Overview

An overview of the obtained results (See Appendix 3), shows that the majority of research participants believed that the graphical quality of the artefact was improved, this was due to the use of the employed techniques. They stated that they thought these enhancements were both beneficial and worthwhile. This evidences that the researched high end game techniques are beneficial to the construction of low polygonal models. They allow for a higher level of graphical quality to be achieved, without the need for an increased Polycount.

It was generally stated that the model was well constructed from a technical and aesthetic standpoint. It was also stated that the produced textures were well constructed, and that they were on par with the quality of the model. However the results demonstrated that there was still scope to improve both the model and the produced textures. This suggests that while the techniques were beneficial to the artefact, that the overall quality could have been improved further.

The participants expressed that they felt the artefact was of a similar quality to the produced high detail model, however showing that there was again scope for improvement. This demonstrates that the applied techniques were effective in improving the quality of the low polygonal model. This was a significant improvement taking into account that the high detail model consisted of over 450,000 triangular polygons, in comparison to the final artefacts 7,358.

It was finally found that while the participants felt overall that the techniques had improved the model, that they did not feel it was of an equal quality to the demonstrated high end game model. Although this shows that the final artefact is not of an equal quality to the current high end game model, the author's level of skill within the 3D modelling field, and the overall results must be taken into consideration. These results suggest that the overall quality of the artefact could have been improved, and in turn potentially have been of a closer graphical quality to the demonstrated high end game model.

Overall the implementation of the researched techniques was successful, demonstrating that the low polygonal model could appear of a much higher graphical quality. Although the artefact was not on par with the graphical quality of the demonstrated high end game model, the overall improvement was still significant.

The evaluation stated that the overall project was successful in meeting its aims and objectives, giving an investigation into the problem area. The produced artefact successfully demonstrated the applied techniques, although had scope for improvement. The applied techniques were determined to be beneficial to the development of low polygonal models.

6.5 Chapter Summary

This chapter has detailed the development of the evaluation process involving the use of a questionnaire, demonstrating how it was conducted, and what it aimed to achieve. It has also given an overview of the generated results discussing what they show, and how this relates to the project artefact. A further evaluation of the project was given discussing the original aims and objectives and determining if they had been fulfilled. Finally an overview of the evaluation results was given, summarising the findings and detailing how they relate to the problem area of the project.

7.Conclusions

This chapter reflects upon the processes involved in completing the project, discussing time management, and related elements. It also gives an overview of the produced artefact, stating how it affected the project findings, and giving suggestions for how it could have been improved. The important findings of the project are highlighted, relating to research, design, implementation and evaluation. Finally a discussion of the projects scope for further work, and the potential motivation for its undertaking.

7.1 Project Reflection

In order to facilitate the completion of the project a large range of research was conducted into the relevant topics. This research enabled the creation of the artefact design, and ultimately enabled an evaluation to be formed relating to the problem area. The implementation of the artefact required further research, and the development of new skills such as the use of Pixologic ZBrush to be formed.

Discussed methodologies such as those for development and evaluation were employed. This was to ensure that the overall project was completed in a logical manner. The projects aims and objectives outlined what should be researched and developed, allowing for a clear structure to be followed throughout its duration. Regular supervisor meetings were also conducted, allowing for the progress of the project to be discussed and managed more appropriately.

The majority of the project was completed to set deadlines, with each component being completed before the next began, it was however inevitable that some delays would occur. Gaining access to specific research sources initially proved troublesome, thus a small delay to the project was incurred. The development of the project artefact also suffered from some set backs due to technical reasons, primarily relating to the production of the high polygonal model, and the implementation of the final artefact within the Unreal Engine 3. While these issues did delay the projects completion, the loss of time was within acceptable parameters. Time was allocated to each element of the project appropriately, taking into consideration potential issues, this meant that delays were dealt with without causing a large set back for the project.

While the time management used within the project was adequate, it lacked foresight in determining many of the external factors effecting the completion of the project. Therefore an improved time management methodology could have been beneficial to the project. This for example would have allowed time for further investigation into the function of each technique, potentially improving their application within the artefact.

As stated the project fulfilled its overall aims and objectives, this was achieved due to the conducted research, and production of the project artefact. This meant that the project had been successful in presenting an effective evaluation in regards to the problem area.

While the project was completed successfully it could have benefited from a more in depth investigation of the applied techniques. This could have been achieved via a secondary evaluation stage which focused on determining the success, and level of improvement of individual techniques, as opposed to evaluating them collectively. This would have allowed the project to determine which techniques were most beneficial, as opposed to only discovering if they were beneficial as a whole.

The project presented the opportunity to assimilate a wealth of new knowledge relating to the development of 3D assets. It consisted of an investigation into the limitations of older hardware, and game engines, which would help form an understanding as to the importance of low polygonal modelling. It also discovered the techniques used within the development of current high end game models, thus allowing a greater understanding of the more recent games modelling techniques to be formed. The application of specific techniques required an investigation into a large range of software tools, giving the opportunity to develop new skills.

7.2 Artefact Reflection

In order to successfully determine the effect that specific techniques had upon low polygonal models, the project required the production of an artefact. The produced artefact consisted of a 3D character model, constrained by the researched limitations of older game technologies. The discovered techniques utilised specific leading software tools such as 3Ds Max 2008. In accordance with the conducted research a Normal Map, Specularity Map, Ambient Occlusion Map and Diffuse Map were generated and applied to the produced model. The artefact demonstrated the researched techniques and limitations, allowing for a suitable evaluation to be formed. Although this fulfilled the aims of the project it is potential that the quality of the final artefact could have been improved.

The creation of the artefact allowed for a greater understanding of the time required to complete each stage of production. This suggests that more time allocated to the application of specific techniques such as Normal Mapping could have been beneficial.

The results of the evaluation could have been affected in a positive manner if further refinement of both the model and techniques had been allowed for. It is also potential that the Author's skill level within relation to the 3D modelling field could have factored into the quality of the produced artefact, this could however be argued as true for any project.

As stated the creation of the artefact required the development of a range of new skills, and presented an opportunity to understand the production phases involved in creating an industry standard 3D character model.

The development of the artefact was broken down into several stages, initially the requirements of the project were discovered and translated into a design brief. The design was then used to ensure that the implemented model met the requirements of the overall project. The implementation consisted of 3 main sections, modelling of the character, creation of the appropriate techniques and application of the artefact within an appropriate game engine. Once implemented the model, techniques, and other assets were tested to ensure that they functioned in the correct manner. Finally any required fixes or improvements were made to ensure that the model was of a decent level of quality for use within the evaluation.

7.3 Project Findings

The overall aim of the project was to determine suitable limitations relating to the creation of low polygonal models, and to evaluate the effect that current high end game modelling techniques have upon them. This was determined as a valid research area as it would potentially allow the optimization of game models. This could benefit the users of older hardware platforms, which were shown to still be popular for purchase (**Carless, 2008**). It could also benefit the users of newer systems, allowing more objects to be on screen at any one time.

It was found that the chosen tools for use in developing modern games such as Gears of War **Lanning et al (2007)** were Autodesk 3Ds Max, Pixologic ZBrush and Adobe Photoshop. Although these were found to be industry standard tools, as discussed **Autodesk (2006)** it was shown that the choice of tool depends more on the artists preference, than on the technical benefits of any particular software.

An investigation into the function of game engines showed them to be a very powerful tool for use in developing modern games (**Al-Najdawi, 2007**). It was shown that game engines provide development tools such as map editors and custom content support. This is in order to facilitate the production of both small game modifications, and large scale game productions. It was identified that the features available within a game engine very significantly dependant upon several factors such as its age. However it was shown that older engines can be updated to support newer technologies, for example the Source Engine (**Valve Corporation, 2008**). This helps identify that support for specific techniques could be implemented without the need for an increase in Polycount.

A hardware survey (**STEAM, 2009c**) showed that a large amount of Steam users have access to systems capable of playing its older games such as Half Life 2. It was shown that the demand upon hardware has increased significantly throughout the life span of the Source engine (**STEAM, 2009a**), (**STEAM, 2009b**). While this requires more powerful hardware it was noted that the quality of produced models was improved with less severe limitations (**Durrand, 2009**).

It was discovered that while polygonal limitations are constantly becoming less restrictive (**Gahan, 2009**), it is not always necessary to push the boundaries of technologies, especially if doing so is detrimental to the users experience of a game (**Wetterschneider, et al, 2005**). This helps to confirm that the optimization of models could be a beneficial process.

It was found that development of modern high end game models involves the use of 4 main techniques to improve the overall look of the model. Diffuse Mapping, Specularity Mapping, Alpha Mapping, Ambient Occlusion Mapping and Normal Mapping **Lanning et al (2007)**. Each technique was shown to offer specific advantages to the creation of the model, such as more realistic lighting.

It was also discovered that not only could older game engines be made to support new features, but that older hardware could to. This is shown in a report describing how it is possible to implement Normal Mapping upon the Sony Playstation 2 (**Mikkelsen, 2004**).

It was determined that older technologies constrain models both in terms of Polycount and texture resolution. It was shown that the average Polycount of models within the Half Life 2 game were between 7,000 and 10,000 polygons (**Wood, D, 2009**). It was also shown that for a more recent game Zeno Clash which developed for the Source Engine that the average texture maps are comprised of 2 image files, 1 for the head at a resolution of 512x512 and one for the body at 1024x1024. It was shown that these limitations are considerably restrictive in comparison to more modern games, for example the Unreal Engine 3 supports character models of over 15,000 polygons, and the use of 2 texture maps both with a resolution of 2048x204. It was also determined that the visual design of a 3D model is important when working within industry standard projects (**Bioware, 2009**).

Implementation of the artefact allowed for an exploration of software tools and techniques, it was shown that each technique needed to be developed in a different manner. Issues with the creation of the Normal Map showed that while ZBrush was the tool of choice for developing the high polygonal model, 3Ds Studio Max 2008 was more appropriate for creating the Normal Map. It was also found that the Unreal Engine 3 is a powerful tool allowing for the development of levels, use of custom asserts and generation of aspects such as camera pan animations.

Research (see Appendix 3) results showed that participants generally felt that the artefact was both well modelled and textured, although some room for improvement was shown to be available. The general findings were that the final artefact was of a higher graphical quality due to the application of the researched techniques. Participants found to be worthwhile and beneficial in enhancing the quality of the low polygonal model..

It was shown that the techniques improved the artefact to such an extent that it appeared of similar quality to its high detail counterpart. Although it was also shown that the model was not of equal quality to the demonstrated industry standard character model.

Overall the project was successful in determining the effect that specific high end modelling techniques have upon low polygonal models. that the application of Diffuse Maps, Normal Maps, Alpha Maps, Specularity Maps and Ambient Occlusion Maps is beneficial to low polygonal models in terms of graphical quality.

7.4 Future Research and Work

The research field could be taken further by conducting a more in depth study into the hardware usage of consumers, helping to determine exactly how beneficial the optimization of models could be. Further research into the limitations effecting game engines, and the creation of models could be used to further refine the development process. It would also be beneficial to develop a wider variety of artefacts, this would allow an evaluation to conclude if the applied techniques are more beneficial to specific model types, or equally beneficial to all.

A further development of the Author's skills would enable further research to be conducted in a more accurate manner, ensuring that the overall quality of the produced artefact, and its related assets would be of a higher standard. This would allow for a fairer comparison between the produced artefact and current high end game models to be investigated.

A more focused evaluation could be conducted with a wider range of research participants in order to evaluate the exact improvement given by the techniques. Also to allow an evaluation of individual techniques to be formed determining which is most beneficial, and if it is necessary to apply them all in order to improve the quality of the model.

The long term benefits of such research would potentially enable higher quality models to be produced across all hardware platforms. More optimized models could also allow for game engines to hand more objects at any one time. Higher quality models would make the graphics feel of an overall higher standard, which findings show is both beneficial and worthwhile.

7.5 Chapter Summary

This chapter has presented a discussion into the processes involved in completing the project, detailing how the project was managed overall. It also discussed potential improvements to the project, which could have altered results, and opportunities for new knowledge to be obtained. An overview of the created artefact was also giving detailing its aims and stages of development and a discussion of the projects major findings was given, detailing important areas of research, design, implementation and evaluation. Finally a further work section was presented, discussing the potential to further expand upon the study.

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Appendix 1 – Artefact CD:

The artefact is comprised of several assets **Table 1** shows these, and the required programs to view them.

Table 1 - CD Contents

Asset Name	Required Program	Available In Lincoln University
Low Polygonal Model – Asset Files	Autodesk 3Ds Max 2008	Yes
High Polygonal Model – OBJ File	Pixologic ZBrush or Autodesk 3Ds Max 2008	No/Yes
Camera Pan Animation - Creation Files	Autodesk 3Ds Max 2008	Yes
Normal Map	Adobe Photoshop	Yes
Ambient Occlusion Map	Adobe Photoshop	Yes
Diffuse Map	Adobe Photoshop	Yes
Specularity Map	Adobe Photoshop	Yes
Unreal Engine 3 Asset Files – Map, Model, Textures, Packages	EPIC Unreal Editor 3	No
Camera Pan Animations	Media Player and Xvid MPEG-4 Codec	Yes
Still Image Renders	Image Viewer	Yes

To view the finished Low Polygonal Model extract the archive file via the use of Winrar.

Appendix 2 – Questionnaire

Evaluation of Produced Artefact

This questionnaire is pertinent to generating the appraisal for a final year project, investigating the effect that high end modelling techniques have upon low polygonal models. This evaluation requires the viewing of produced video, and still renders of the final artefact, once viewing is concluded, please complete the below questionnaire.

The below statements require rating on a scale of “1 – 5”, with “5” meaning completely agree and “1” meaning completely disagree. Please highlight your selection.

1. The final artefact appears of a higher graphical quality due to the employed techniques:

1 2 3 4 5

2. The improvement is worthwhile, and is beneficial in the enhancement of the artefact:

1 2 3 4 5

3. The artefact is well modelled:

1 2 3 4 5

4. The artefact is well textured:

1 2 3 4 5

5. The final artefact appears of a similar graphical quality to its high detail counterpart:

1 2 3 4 5

6. The final artefact is of similar quality to the demonstrated high end game model:

1 2 3 4 5

Thank you for participating in this questionnaire, all results will be kept confidential and should you wish to retract your participation at any time please contact the project author via email: 06039966@students.lincoln.ac.uk

Participant Name:

Participant Signature:

Appendix 3 – Questionnaire Results

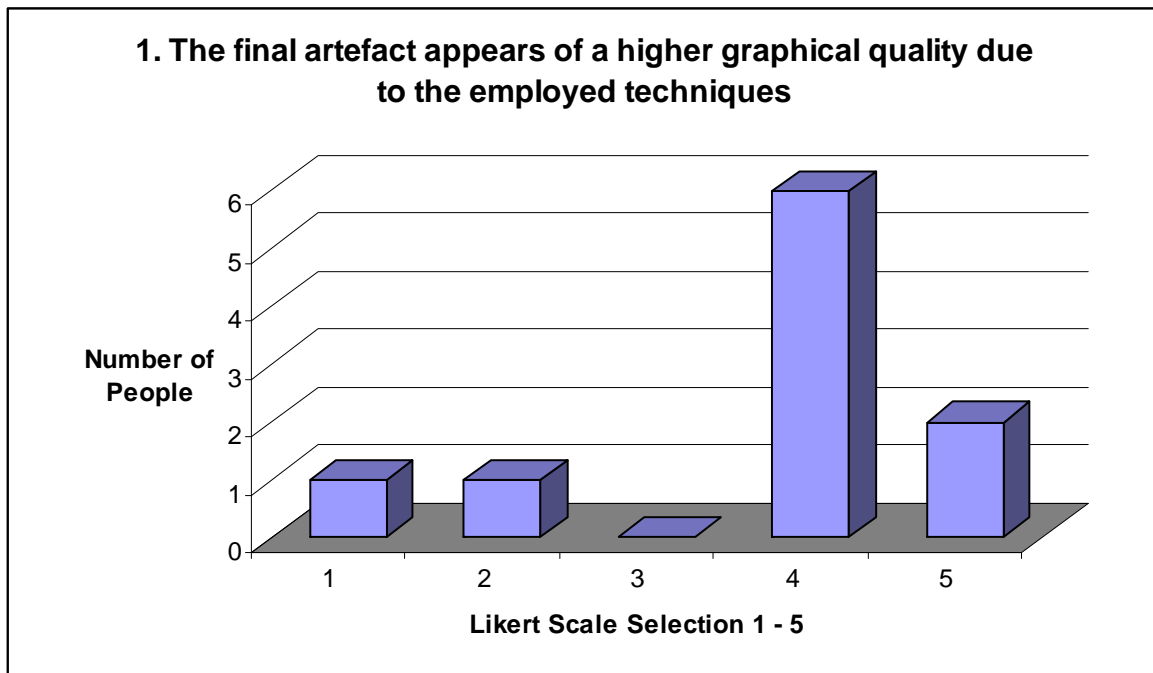


Figure 7.1 - Questionnaire Results - Statement 1

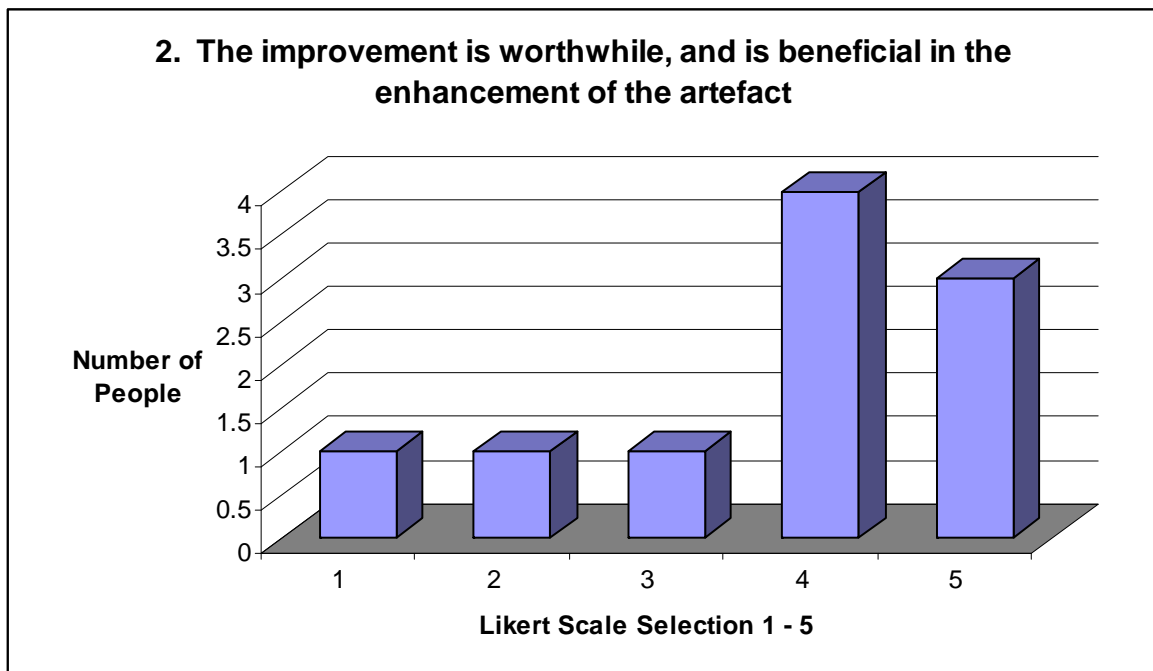


Figure 7.2 - Questionnaire Results - Statement 2

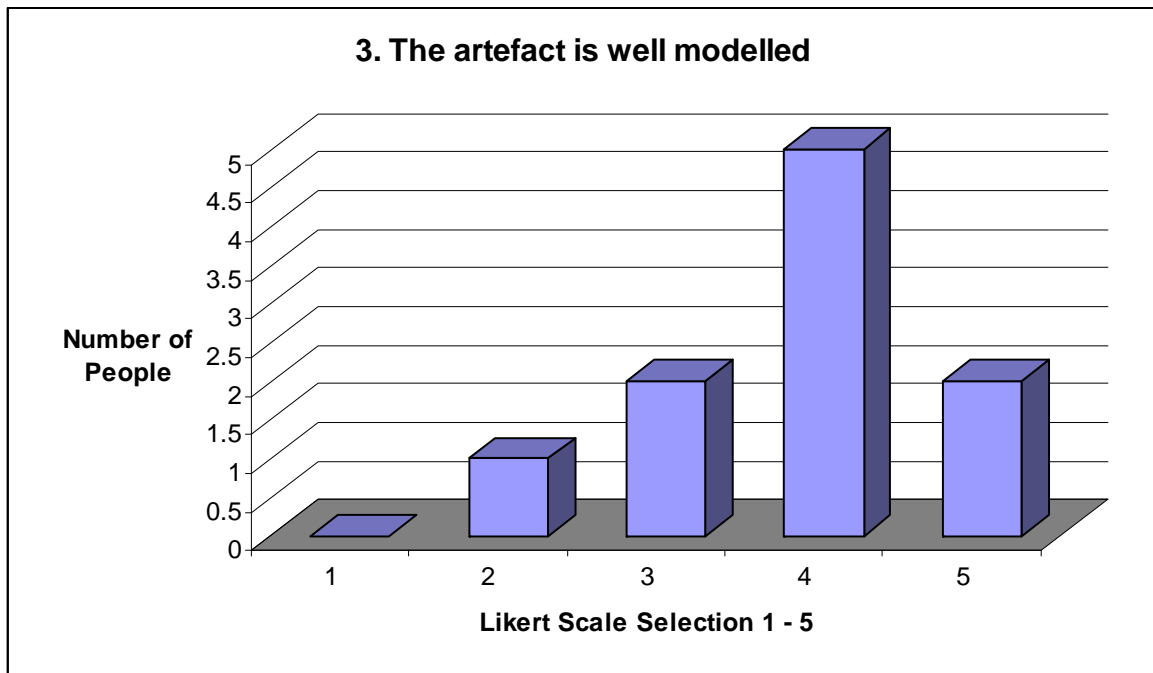


Figure 7.3 - Questionnaire Results - Statement 3

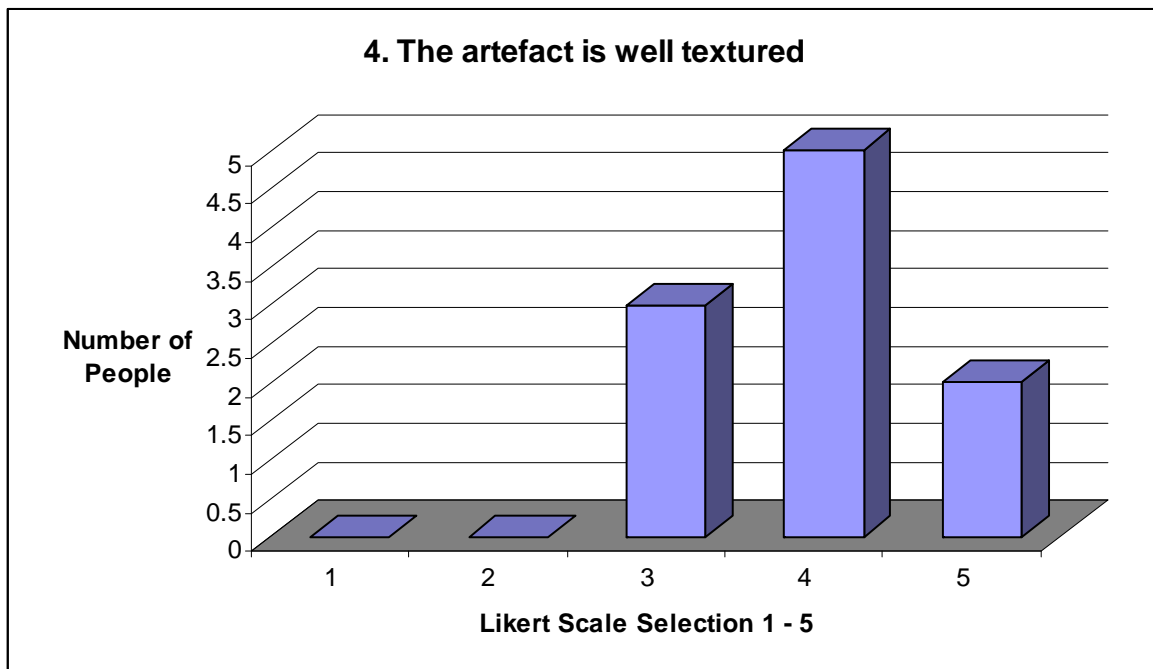


Figure 7.4 - Questionnaire Results - Statement 4

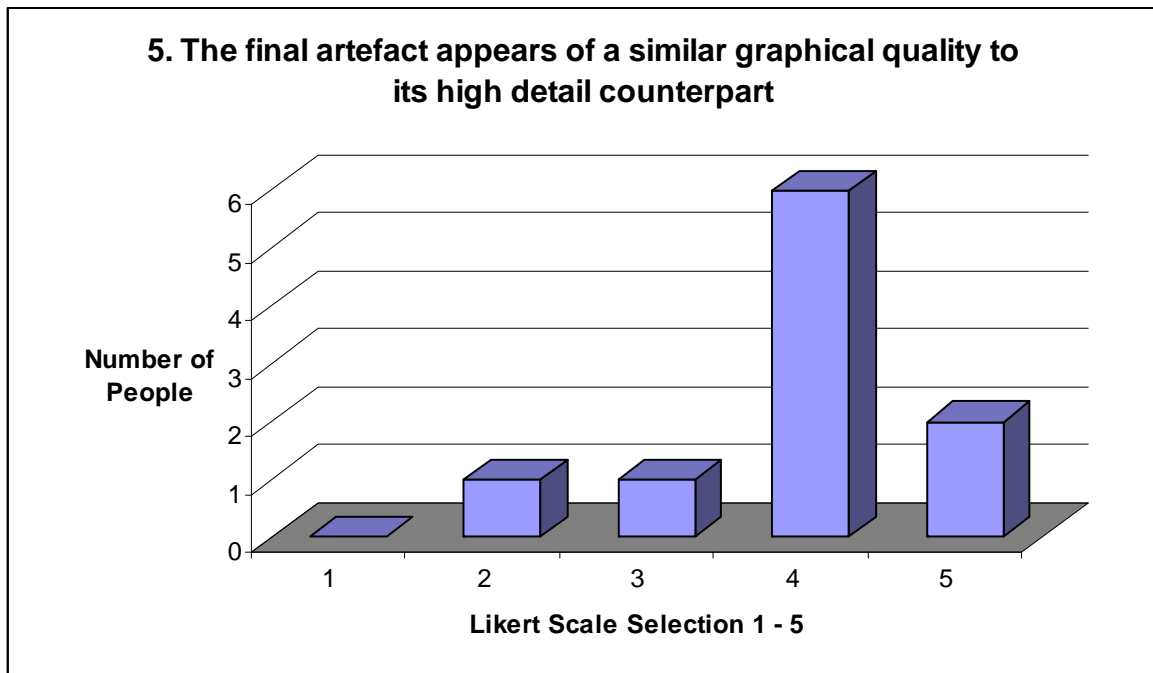


Figure 7.5 - Questionnaire Results - Statement 5

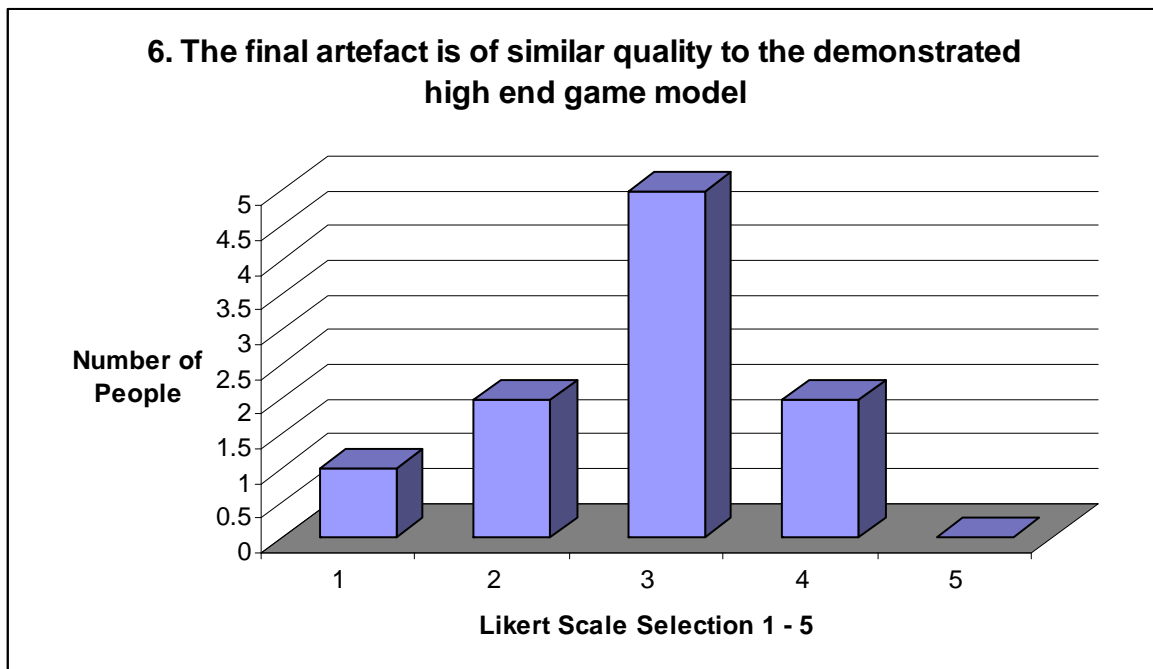


Figure 7.6 - Questionnaire Results - Statement 6