Artist Away: Procedural Generation of Terrain

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A project report submitted in partial fulfilment for the degree of

**Bachelor of Science in Computer Games Development**

**School of Physical Sciences and Computing**

**University of Central Lancashire**

Abstract

The abstract is the summary of the project report within one page (aim for about 500 words). Unnumbered chapter headings, as above, are entered using the ‘Heading (Unnumbered)’ style, which automatically starts a new page.

This template starts the page numbering at the foot of this page. That is, the first page does not have a number.

It is suggested that the abstract be structured as follows:

Problem: What you tackled, and why this needed a solution

Objectives: What you set out to achieve, and how this addressed the problem

Methodology: How you went about solving the problem

Achievements: What you managed to achieve, and how far it meets your objectives.

**TODO: MODIFY UPON PROJECT COMPLETION, DO NOT TURN IN LIGHT THIS**

Currently throughout the modern-day games industry, artists are required to work alongside games developers to assist with the creation of models and levels. This presents problems throughout industry as artists and developers frequently have very different ideas about what is required from art assets, and how they should be implemented. There is a balance between implementing realistic models and artwork, and efficient rendering of an entire scene, however frequently this balance is not met due to a difference of opinion between artists and developers. Constant battling between artists and developers can be a drain on company funds, with so many games studios going out of business, if a company can save money by not having to hire an artist or have an artist’s input on a technical solution then it makes sense not to.

Artist Away set out to generate a realistic looking terrain which could be used as a level of a game, without having to plan the game level beforehand. This would involve the generation of the shape of the level, layering textures on the generated level shape to represent real world terrain, creating level entities such as trees and plants, presenting realistic day and night scenes, and finally presenting a body of water which runs underneath the level. I believe these are the core components of a game level, and all can be generated without the requirement for an artist. Artist Away would do all of this, and could save a company the salary of an artist, and potentially keep that company in business.

Artist Away makes use of procedural generation by generating a height map, the engine then controls plotting vertices per the provided height map, and decides which type of terrain area each vertex belongs to per the vertex’s relative height. The engine then textures the vertices with the appropriate texture depending on the area type, and then generates entities in each area. The engine then defines the vertices for a body of water, and positions it underneath the terrain, all properties of the water will be controlled through the engine. The body of water adds realism to the scene. Finally, day and night cycles are triggered through the engine class, it should simply perform a gradual change of the skybox colour which will represent a time of day in which the sun is at a different position.

Artist Away successfully uses Simplex Noise to generate a height map, and the engine then loads in this height map through one of two interfaces, a pre-generated ‘.map’ file or a dynamic two dimensional array of values. The engine is responsible for dictating which vertex of the terrain belongs in which area, it then makes use of HLSL shaders to render the appropriate texture to each area of the terrain model. The engine also has a small change to generate a tree or plant in grass areas, and position them at a random rotation. Day and night cycles area achieved by changing the colour of the skybox. Water is created as a plane which sits underneath the terrain, and the properties of the water are controlled through the engine.

Attestation

I understand the nature of plagiarism, and I am aware of the University’s

policy on this.

I certify that this document reports original work by me during my University project.

**Signature**  **Date**

Acknowledgements

Acknowledge anyone who has helped you in your work such as your supervisor, technical support staff, fellow students or external organisations. Acknowledge the source of any work that is not your own.

Laurent Noel is my project supervisor and has helped with technical explanations of areas which I then went on to implement within my project.

ASSIMP model library is a third-party library which I used for the loading of models within my engine, while I have set up this library myself I have not implemented the core mechanics behind most model loading.

AntTweakBar is a third-party library which provides an interface for controlling things within my engine, while I have set up this library myself, I have not implemented the core mechanics behind drawing the tweakbar and responding to events in the tweakbar.

3D Game Programming with DirectX 11 – Book by Frank Luna which heavily influenced my implementation of the game engine timer class. While my implementation is not identical, the structure of the timer is the same.

<http://www.rastertek.com> is a group of tutorials which supplied me with the structure for my Direct X 11 engine, while there are similarities between my classes and shaders, there are also a wide variety of differences.

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Sometimes Word does not automatically update references to other parts of the document, such as captions, Table of Contents and cross-references. To update everything, select the whole document by pressing Ctrl+A and then either press F9 or right-click anywhere and click on ‘Update Field’. Confirm all prompts by selecting ‘Update entire table’ and clicking OK.

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Similarly, you can automatically generate a list of ‘Figures’. Right-click a figure (e.g. image or diagram) and add a caption labelled ‘Figure’ and ‘below selected item’. To update this after revisions, right-click in this table and choose Update Field (or use F9) and then choose to update the entire table. Delete this paragraph before submission.

[Figure 1 - Highly Technical Diagram 3](#_Toc476373580)

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Similarly, you can automatically generate a list of ‘Tables’. Select a table, right-click it and add a caption labelled ‘Table’ and ‘above selected item’. To update this after revisions, right-click in this table and choose Update Field (or use F9) and then choose to update the entire table. Delete this paragraph before submission.

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This list only applies to you if you use code snippets in your report. If you don’t have any listings, remove this whole section including the heading ‘List of Listings’.

You can automatically generate a list of ‘Listings’. After formatting your Code, move the cursor to the first line below your code block and click ‘References’ -> ‘Insert Caption’ in the ribbon menu. Select the label ‘Listing’ or add a new Label called ‘Listing’ if it does not yet exist. To update this after revisions, right-click the table and choose Update Field (or use F9) and then choose to update the entire table. Delete this paragraph before submission.

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# Introduction

For editorial consistency, it is important to use Word styles properly. Word 2003 onwards has so-called ‘quick styles’. If the styles referred to below are not visible on the Home ribbon in the Styles category, choose ‘Apply Styles’ from the down arrow at the bottom right of the Styles category. Styles can then be applied from the drop-down box. To make a style visible as a quick style, choose Apply Styles, then click Styles (the AA icon) or use ‘Alt + Ctrl + Shift + S’, then right-click on the style and then ‘Add to Style Gallery’.

Chapters are entered using the ‘Heading 1’ paragraph style. The Heading 1 style automatically moves to the start of a new page, and supplies the next chapter number. Pressing enter on a ‘Heading 1’ heading automatically inserts a ‘Heading 2’ heading underneath.

There should not be any text between a parent heading and its first sub-heading. For example, when you want to write an introductory section for the following sections, give that introductory section an own ‘Introduction’ heading instead of writing it between the heading preceding these sections and the first sub-heading.  
As an example: This comment text is incorrectly placed between a ‘Heading 1’ (‘Introduction’) and a ‘Heading 2’ (‘Background and Context’).

Most text uses the ‘Normal’ paragraph style with 12 point Arial, 1.5-line spacing, single-sided pages.

In general, use the default spacing that headings and paragraphs give you. Avoid using new-lines or spaces to format text. If you need to use quotes, preferably use single curly quotes ‘…’. If you wish to emphasise something, use the ‘Emphasis’ style. In addition, also a ‘**Strong’** style is preconfigured.

Remember to Save frequently while you are working! Check that AutoSaving is enabled under options -> save -> 'Save AutoRecover information every 5 minutes'.

## Background and Context

Procedural Generation of terrain has been a topic rising in popularity over recent years, especially with the release of No Man’s Sky which presented a game in which every entity including the level was procedurally generated. Artist Away presented a similar idea, to generate a game for a level without the requirement for an artist, a programmer should be able to instruct the program to design a level and it would be carried out by the game engine.

Give the background to your project and context of what you have done. Sections are entered using the ‘Heading 2’ paragraph style.

## Scope and Objectives

Artist Away consists of two core components. The first component is procedural generation, it covers generating height maps through Simplex Noise. The second component is Prio Engine, a Direct X 11 engine which is responsible for loading, controlling and rendering models, accepting height maps, plotting terrains from height maps, dividing terrain into areas, creating terrain entities in relevant areas, drawing bodies of water which are attached to terrain, camera control and accepting user input. Prio Engine is to be kept separate from certain elements of Artist Away, this is so that Prio Engine can be used in future projects. For this purpose, I have chosen to use Prio Engine as a static library within Artist Away for my project. Time providing, a final aim of the project is to have every entity in it procedurally generated (except for the body of water). This would prove my original thesis that we in fact do not need an artist to be involved in the process of building a game.

Define the scope and objectives of your project.

## Achievements

I have successfully created a Direct X 11 Engine, which can be exported as a static library, and from the static library can be used to load, control and manipulate models. The engine can also accept height maps in one of two forms, a two-dimensional array, or a text file (exported from the Artist Away project) and from these height maps, procedurally generate terrain. The terrain is successfully textured using different textures per area, and a smooth blend is used between each of the textures. The engine defines a body of water, and successfully refracts the terrain tiling beneath the water.

I have also created a C++ program called Artist Away which uses Prio Engine as a static library, and can interface successfully with the engine to draw terrains, and supply the engine with height maps which are generated through Simplex Noise. Artist Away can also export ‘.map’ files which can be loaded using Prio Engine, as well as 2 dimensional arrays.

Summarise what you have achieved.

## Overview of Report

Briefly overview the contents of what follows in the report. Overview (1-2 lines per chapter):

'Chapter 3 describes the investigation of the problem and presents the top-level analysis as a Yourdon dataflow diagram. ... Chapter 4 contains an overview of the design architecture and examines the key design issues’.

# Literature Review

## Introduction

Each of your chapters should have an introduction to tell your readers what they will find in the chapter.

Summarise current knowledge and what others have done in the various topics of your dissertation – in the application area and in the various technologies that you might have used or did use. Write for someone familiar with computing, but not necessarily expert in the particular topics of your project. Give references to other work by using cross-references to entries in the References section, like this (Turner & Jennings, 2002).

## Section Heading

### First Subsection

If necessary, also use subsections. Subsections are entered using the ‘Heading 3’ paragraph style (all these heading styles are self-numbering).

‘Heading 4’ and ‘Heading 5’ are also styled but it is not recommended to use more than four levels of nesting. Bear in mind that the Table of Contents only contains the ‘Heading 1’ to ‘Heading 3’ styles and ‘Heading (Unnumbered)’.

As a continuation of what is explained on the previous page: Avoid writing text between a parent heading and its first sub-heading. As you can see, there is no text between ‘Section Heading’ (‘Heading 2’) and ‘First Subsection’ (‘Heading 3’).

### Second Subsection

And, as required, more subsections.

## Summary

Write a short summary at the end of each chapter.

# Project Planning

## Introduction

Writing a game engine is no small task, it requires a large amount of planning. Writing an engine which is to be flexible enough to be used by other applications in future complicates matters further. By planning the structure of how applications will interface with an engine, we can reduce unforeseen errors encountered when using the engine over a variety of applications. It also allows us to plan how the engine can be updated in future, as we know what can change and in what way the methods of the engine can change, if we are aware with how other applications will interact with the engine.

## Methodology

Gregory (2012, pp 11-12) defines a game engine as a piece of architecture in which the artistic resources are separated from the core components such as the rendering system, collision detection system or sound system. From this definition, we can interpret that users of the engine will be responsible for loading of resources, but not implementing the code behind it. This is applicable to our engine as a user may want to create a terrain height map as a resource, and have the engine load this. We accommodate for this feature by accepting a map file which simply contains the same information that would be contained in the two-dimensional array generated by Artist Away.

My first step was to planning was to research different game engine architectures which would enable Prio Engine to be used with a variety of projects. Continuing from architecture research, a class diagram was drawn up to help visualise interaction throughout the engine.

## Requirements

The engine must be able to be exported as an external library, this will enable other applications to use it. Furthermore, the engine must be able to generate terrain from a height map provided by another application. Another requirement from the engine is that it must be able to control model position, rotation and scale and render them correctly, outside of the engine, and without being exposed to the complexity of the engine.

The height map must be generated by Artist Away and be stored in a two-dimensional array or a ‘.map file’, the engine will be able to read either of these methods. Artist Away must make use of the Simplex Noise algorithm to smoothly generate a realistic looking terrain shape.

## Potential Solutions

To plan Prio Engine, I started with a diagram of how I expected the engine to look:

At a glance, it appeared this was a reasonably flexible solution that would account for future changes. For example, should I wish to change the engine from running on Direct X to OpenGL, theoretically, I should only be required to change the Direct3D class. However, this isn’t quite the case as there are some differences between the types of buffers and how they are used in Direct X and OpenGL. It also demonstrates that we could use it as a static library by providing methods for users through the Engine class, and allow the engine itself to handle the inner workings through a network of classes.

Another potential solution which was considered was an entity based system which would control all entities within the scene throughout an entity based manager. Overall, this may have been the better choice, however I believed it would not have brought enough benefit for the overall purpose of this game engine which is procedural generation of terrain to warrant implementation, it would only provide benefits in flexibility for future use.

## Tools and Techniques

GitHub was used as a tool for source control, it enabled modifications to be submit and the ability to roll back to previous versions of the code base for both Artist Away and Prio Engine.

AntTweakBar was used to give users of Artist Away control over select variables used throughout the application. The use case diagram below details how users can interact with Artist Away while it is running, and provide custom parameters to artist away.



ASSIMP was used to load a wide variety of models in different file formats into the engine. It is used within Prio Engine by parsing information about meshes and loading in the relevant files, and storing this information in member variables, before passing it over to buffers to be used with HLSL shaders. The class diagram below is an overview of how the mesh loading process works within Prio Engine.



## Legal and Ethical Issues

### Is It Ethical to Automate a Person’s Role?

As technology becomes more complex, users of technology are required to adapt to the latest versions of technology. In some scenarios this is perfectly acceptable, however in the modern-day games industry with the expectations of developers constantly rising, small independent companies simply cannot afford to spend time training their artists to use the latest technology and present it in the format required, as well as simultaneously developing the code behind the game. There is also no guarantee on how long it will take an artist to create a resource, due to a lack of reliability caused by human errors. According to (Neumann, 2016), we will continue to face these issues as they are a by-product of human labour. Automating the artistic process would result in a more consistent product being produced, as it programmatically executes a process, and there are very few variables involved in the production methodology. Given independent games companies are typically not renowned for being particularly wealthy, and are renowned for shutting down due to a lack of funds before games are released, it seems logical for smaller companies to risk hiring an artist to design levels, when a stable option of procedural generation can be used to complete the same process.

If necessary, also use subsections. Subsections are entered using the ‘Heading 3’ paragraph style (all these heading styles are self-numbering).

### Automation Within The UK

As automation becomes increasingly popular and more attractive to employers, regulations and legislation regarding automation are being introduced. Unfortunately, we cannot predict what laws will be introduced in the future, however we can analyse the legislation introduced surrounding driverless cars, a popular form of automation. The Vehicle Technology and Aviation Bill imposed the idea that insurance companies which insured the automated vehicle would be responsible for reimbursing any damage caused by that vehicle. If we take similar logic and apply it to the process of procedural generation within games, we can rule out the requirement to pay damages as no insurance companies are involved, and no physical damage can come of a computer program which generates a game level. Because the company would be responsible for any mistakes within the game level, it would not matter if it were an artist or a computer program which designed the level.

While the legal side of automation is clearly not much of a barrier to the games development process, the ethical question remains: is it acceptable to remove an entire role from the industry to save money? There is no clear-cut answer to this question, and the answer is entirely situational and depends on the size, budget, and longevity of a games studio. This author believes it is only acceptable to automate a process when all other options have been exhausted, and it is simply deemed not feasible to hire an artist as a level designer. Business owners have a responsibility to provide careers to working class people, particularly larger business owners. This keeps the economy within the country stable, and provides workers with money to spend on business products.

### Legal Use of Third Party Tools and Resources

Prio Engine makes use of two third party libraries (AntTweakBar and ASSIMP), we firstly need to ensure that the licensing on these products allows for use within a final year project. AntTweakBar uses the zlib/libpng license, which claims the library is both free to use and redistribute, meaning that it is a completely eligible choice for use with Prio Engine and Artist Away. ASSIMP holds a 3 clause BSD license, the three clauses summarise to claim that the copyright notice must be displayed unmodified on binary and source files, and that ASSIMP cannot be used to endorse Prio Engine or Artist Away. Prio Engine can meet these conditions and therefore licensing of third party libraries has provided no issues.

Prio Engine makes use of textures and models, to ensure there were no legal issues Prio Engine has exclusively used free to use and royalty free resources.

## Potential Technical Issues

The first issue I face is keeping the game engine separate from the height map generation, yet keeping procedural generation itself within the engine. My design research resulted in the model where Prio Engine is a static library, which is included within Artist Away. This enabled us to generate height maps in two dimensional arrays, and pass them to Prio Engine as two dimensional arrays, from which Prio Engine could procedurally generate terrain. However, it did not seem feasible for future use to tie the generation of terrain to Artist Away, so a method was placed into Artist Away to export ‘.map’ files, which were rows and columns of floating point numbers which represent a height map. After implementing the ability to import ‘.map’ files in Prio Engine, and place the extracted values into a two dimensional array, we ended up with a method which meant Prio Engine could be run without any requirement for Artist Away, unless you wanted to modify the height map during runtime.

## Algorithms

Procedural generation can take many forms, but for an effective and smooth transition in height as is with terrain, some form of noise generation algorithm is required. (Mikulicic and Mihajlovic, 2016) discuss the use of Perlin Noise to generate height maps, combined with Fractional Brownian Motion. This seems like a perfectly reasonable solution to generate height maps, however in 2001 Ken Perlin presented his improved version of Perlin Noise, known as Simplex Noise. According to Perlin (2002) Simplex Noise is quicker to generate than Perlin Noise, and in theory could be expanded into multiple dimensions rather than just two. While we aren’t particularly interested in the multiple dimension aspect of Simplex Noise, we are interested in improving the efficiency of generating height maps. Simplex Noise was chosen as the more appropriate algorithm to use within Artist Away, as there was very little change in the complexity of the algorithm and implementation was worthwhile given the performance benefits.

As an example of a figure, consider Figure 1.

To place a figure, insert the picture/diagram/etc. where you want it to be, make sure it is selected and then apply the ‘Figure Centre’ style which centres the figure horizontally.

Captions are entered through the ribbon menu under ‘References’ -> ‘Insert Caption’ or through right-clicking an image and selecting ‘Insert Caption’. Add the caption text in the box, separated with a dash as the example below shows.

Each figure is numbered automatically, and it is possible to make cross-references to figures.

diss-fig

Figure 1 - Highly Technical Diagram

## Summary

Write a short summary at the end of each chapter.

# Design

## Introduction

Each of your chapters should have an introduction to tell your readers what they will find in the chapter.

## System Design

Text goes here.

## User Interface Design

Text goes here.

## Summary

Write a short summary at the end of each chapter.

# Implementation

## Introduction

Each of your chapters should have an introduction to tell your readers what they will find in the chapter.

## Section

### Subsection 1

Code can be formatted using the ‘Code’ style. An example is shown below. It can be a little bit tricky to keep the formatting when pasting from an IDE but the following works for most IDEs: Copy the next from the IDE, paste it in word, select the pasted code and change the style to ‘code’. It is worth nothing that spell checking is deactivated for the ‘Code’ style.

public class Main {  
  
 public static void main(String[] args) {  
 System.*out*.println("Hello World!");  
 }  
}

Listing 1 - [Main.java] The main class of the program

Captions are entered through the ribbon menu under ‘References’ -> ‘Insert Caption’. Select ‘Listing’ (or add a new Label called ‘Listing’ if it does not already exist) and add the caption text in the white box, separated with a dash as the example above shows. Think about a naming convention for listings and stick to it throughout the report. For example, as seen above,  
‘[ClassName or Filename] Description’.

In case you are mixing multiple programming languages: Consider stating the language name in the caption if it is not obvious from the file name or when there is no file name to refer to. For example, when you use XML and HTML, JavaScript and TypeScript or other languages with similar syntax. A suggestion might be to add the language in parenthesis at the end.

It is also possible to use the ‘code’ style “inline” to highlight commands in normal text by selecting the words to highlight and choosing the ‘code’ style. For example:

This example demonstrates the ping 127.0.0.1 command.

Make sure to write the whole text first and select the part you want to highlight afterwards. When there is no selection, Word applies the selected style to the whole paragraph.

### Subsection 2

## Section

## Summary

Write a short summary at the end of each chapter.

# Test Strategy

## Introduction

Each of your chapters should have an introduction to tell your readers what they will find in the chapter.

## Section

To add a caption to a table, either select the whole table (e.g. by clicking on the + symbol in the upper left corner of the table), right-click the it and choose ‘Insert Caption’ or click in any table cell and select ‘References’ -> ‘Insert Caption’ from the ribbon menu. Choose ‘Table’ as label and ‘above the item’ as position. Add the caption text in the box, separated with a dash as the example below shows.

Table 1 - Test Results

|  |  |  |  |
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## Section

Text goes here.

## Summary

Write a short summary at the end of each chapter.

# Evaluation, Conclusions and Future Work

## Project Objectives

Summarise what you have achieved.

## Evaluation

Stand back and evaluate what you have achieved and how well you have met the objectives. Evaluate your achievements against your objectives in section 1.2. Demonstrate that you have tackled the project in a professional manner.

(The previous paragraph demonstrates the use of automatic cross-references: The ‘1.2’ is a Cross-reference to the text in a numbered item of the document, it is not literal text but a field. The number that appears here will change automatically if the number on the referred-to section is altered, for example if a chapter or section is added or deleted before it. Cross-references are entered using Word's **Insert** or **References** menu. Cross-references are set to update automatically when printed, but may not do so on-screen beforehand; you can update a field manually on-screen by right-clicking on it and selecting Update field from the pop-up menu or by selecting the whole document and pressing F9.)

## Applicability of Findings to the Commercial World

Summarise what you have achieved.

## Conclusions

Summarise what you have achieved.

## Future Work

Explain any limitations in your results and how things might be improved. Discuss how your work might be developed further. Reflect on your results in isolation and in relation to what others have achieved in the same field. This self-analysis is particularly important. You should give a critical evaluation of what went well, and what might be improved.

## Concluding Reflections

Summarise what you have achieved.

References

Gregory, J. (2012). *Game Engine Architecture*. (J. Lander & M. Whiting, Eds.) (2nd ed.). Natick, Massachusetts: A K Peters, Ltd.

The reference list above is generated by Word. Under ‘References’ -> ‘Manage Sources’ it is possible to add new references which can later be inserted in the report with ‘Insert Citation’. Example: (Cuevas, Cuevas, Cabellos-Aparicio, Jakab, & Guerrero, A collaborative P2P scheme for NAT Traversal server discovery based on topological information, 2010a)

Alternatively, you can add a new reference and immediately insert it as a citation by moving the cursor to the place where you want to insert the citation and then choosing ‘References’ -> ‘Insert Citation’ -> ‘Insert New Source’ from the ribbon menu.

You can hide parts of a citation by right-clicking on it, selecting ‘Edit Citation’ and ticking the checkboxes under ‘Suppress’. In the same dialog a reference to specific pages of the cited source can be added (which won’t be displayed in the references list). Example (same as above but with ‘Author’ suppressed and page 120): (A collaborative P2P scheme for NAT Traversal server discovery based on topological information, 2010a, S. 120)

Keep in mind that uncited sources will still appear in the references list above. Go to ‘References’ -> ‘Manage Sources’ to see which sources are cited and which aren’t. Sources in ‘Current List’ which have a checkmark are cited.

The UCLan styling for References is different than the default Harvard notation Word provides. Therefore, a custom style has been created. Download the file ‘HarvardUClan2017.xsl’ and copy it to: %appdata%\Microsoft\Bibliography\Style.

Keep word closed when doing this. To select the style click on ‘References’ -> ‘Style’ and select ‘Harvard – UCLan (2017)’.

There might be some cases the Word bibliography function can’t handle. If you have a tool that suits you better such as ‘RefWorks’, ‘Citethisforme’ or ‘RefMe’ use that instead, then remove the list above and copy the references over. Don’t forget to use the correct Harvard notation style.

Appendix 1 – Title of Appendix

You may have one or more appendices containing detail, bulky or reference material that is relevant though supplementary to the main text: perhaps additional specifications, tables or diagrams that would distract the reader if placed in the main part of the dissertation. Make sure that you place appropriate cross-references in the main text to direct the reader to the relevant appendices.

Do not blindly include all of your code in the appendix or the body. Only include the parts you refer to in the report. You can but those parts either in the appendix or in the body (e.g. in the “Implementation” part).

Appendix 2 – Title of Appendix

You may have one or more appendices containing detail, bulky or reference material that is relevant though supplementary to the main text: perhaps additional specifications, tables or diagrams that would distract the reader if placed in the main part of the dissertation. Make sure that you place appropriate cross-references in the main text to direct the reader to the relevant appendices.

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Appendix 3 – Title of Appendix

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