Utilising ray marching and signed distance functions to render a scene of primitives

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# Glossary

SDF – Signed Distance Function

# Key Words

*6x phrases/words that represent this paper.*

Xbox, PlayStation, Mobile Gaming, Games Industry, Games Development, Monetisation

# Abstract

This research explores using ray marching as a method of rendering. Ray marching steps along a ray toward a specified direction, until a collision is found. The distance of each step is determined by the shortest distance to any object in the scene. The signed distance function which each object uses, defines the shape of the object.

For each pixel on the screen, a direction can be determined by its position on the screen and the cameras FOV. Each object in the scene is sampled for its distance from the starting point and the shortest distance is used to determine how far the ray can be stepped without colliding with any object. This step is repeated until the distance becomes less than a specified threshold, which is then considered to be a collision.

This method of using a signed distance function to determine the shape of objects in the scene allows for many effects which are difficult to achieve using traditional rasterised rendering. For example, object smoothing/morphing, real-time CSG (Boolean operators), rendering fractals, and more. Ray marching is commonly used for rendering volumetric objects, such as clouds.

# Introduction

Recent advances in graphics processing hardware have brought ray tracing into the forefront of real-time rendering (Akenine-Möller et al., 2018). Ray tracing can be used to simulate how light travels which results in a higher fidelity render than traditional methods of rendering.

Whereas ray tracing tests for an intersection between a ray segment and objects in the scene in order to find the nearest object (Whitted & Foley, 1980), ray marching differs by stepping along a ray incrementally until a collision is found.

A common ray marching technique is known as sphere tracing. Sphere tracing utilises signed distance functions (SDFs) to calculate the distance of each step along the ray. At each ray step, all objects are sampled for their distance to the current point, the ray can then be stepped forward by the shortest distance which ensures the ray will not travel inside, nor skip over, any object in the scene (Hart, 1996). Due to the type of SDF defining the shape of that object, it is possible to render fractals or modify the output distance to manipulate the shape or appearance of the object.

## Aim

This research aims to produce a game engine which utilises ray marching as a method of rendering a 3D scene, and to take advantage of the properties of ray marching to achieve various visual effects.

## Objectives

To achieve this aim, the research will enable the development of:

* A performant, real-time ray marching renderer.
* An engine framework surrounding the renderer, providing a platform to produce games/real-time applications.
* GUI controls to interact with the engine and scene at runtime.
* A 3D modelling tool which allows for primitives to be combined and visual effects to be applied in order to output a detailed model, which can then be imported to the engine.

# Literature Review

A description of the background to the project, including an identification of the problem situation and the rationale for carrying out the project.

# Research Methodology

A description of the choice of investigation method and review of the available literature. This will be waterfall, agile, hybrid, etc.

# Project Plan

The project planning process (actual plan should be placed in an appendix), scope with a statement of the evaluation criteria and how the project will proceed. Reflect upon your Aim and Objectives.

## Gantt Chart

See appendix 1: Gantt Chart *(for example)*

## Scope

Is the project achievable?

# Analysis

A description of the choice of an analysis or problem-solving method. It is important to describe the process by which the method is chosen to show that it is appropriate for the problem situation.

A narrative description of the application of the analysis method, indicating the problems which arose during this process and how they were identified and overcome. Obviously, most projects will include models, charts, or diagrams at this stage. These may be included in the chapter or in an appendix.

In short, investigate all possible options available to you in order to successfully achieve the scope of the project in the time given.

# Design

Here you will justify your chosen tools and processes from your previous research into the background of the project and the options available to you in the analysis.

Identify and justify:

* The choice of an appropriate method.
* Your experience of its application.

# Implementation

The Implementation chapter should show clearly how the solution to the problem is realised. As with the other parts of the project, the selection of the implementation method should be described and justified. Also, the nature of the solution will depend on the nature of the project and the course.

# Testing

This chapter should address the evaluation of the solution against its objectives and success criteria.

Consider:

* A description of the testing strategy and the choice of testing method.
* The planning and application of the tests. How have you concluded this is the correct type of test to run?

# Results

The conclusions that may be drawn from the results of the tests and any modifications to the design and implementation that could be recommended.

What are you results?

What analysis can you identify from them?

Did you find something you did not expect?

Or was it exactly what you expected?

# Critical Evaluation

This chapter is of **crucial importance** to the whole work. It deals with the success of the project in academic terms, rather than the success criteria for the solution. Even the best analysis, design and implementation will be let down by an inadequate critical evaluation. The examiners will look at this chapter most carefully when determining the success (or otherwise) of the project. Although the exact nature of the evaluation will vary between projects, it is possible to identify certain issues which should be addressed:

* Your evaluation of the degree of success in carrying out the project
* What you have learned by doing the project
* What you would do differently if the project were to be repeated
* Any extra features you would recommend if the project could be extended
* The value to you of the learning process and the extent to which the project has added to your professional and academic expertise
* What future projects open the next chapter, should this projects research be continued further into Master Degree for example?

# Bibliography

Harvard Referencing examples:

**Website**:

**Bibliography format:**

BBC News (2008) Factory Gloom worst since 1980 [Online]. Available from: http://news.bbc.co.uk/1/hi/business/7681569.stm [Accessed: 21 October 2008]

**In-text example:**

(BBC News 2008)  
…as reported on BBC News (2008)

**Book (1 Author)**:

**Bibliography format:**

Neville, C. (2007). The Complete Guide to Referencing and Avoiding Plagiarism. Maidenhead: Open University Press

**In-text example:**

(Neville, 2007)  
Neville (2007) commented that…  
“Direct quotations are placed in double quotations marks” (Author’s Surname, Year of Publication, p. – followed by page number – in brackets)

**Journal**:

**Bibliography format:**

Trefts, K. & Blaksee, S. (2000). Did you hear the one about Boolean operators? Incorporating comedy into library instruction. Reference Services Review. 28 (4) p. 369-378.

**In-text example:**

(Trefts & Blaksee 2000)

This supports Trefts & Blaksee’s (2000) evidence that……  
“direct quotations are placed in double quotations marks” (Author’s Surname, Year of Publication, p. – followed by page number – in brackets)

# Appendices

Add here anything you could not quite fit into your report word count. However, do not start a paragraph in the main body and finish it here in order to squeeze it into the word count. That would be very bad structuring. Instead add here additional content that supports your statement but will not be considered as part of your word count.

Graph and table data should also be put in the appendix, along with any sample questionnaires or similar supporting documents.

It also helps if the appendix has its own content page and naming conventions.

## Appendix 1: Gantt Chart

## Appendix 2: Title