

Rendering Invisibility

Report Name	Design Specification
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Module	CS39440
Degree Scheme	G451 (Computer Graphics, Vision and Games inc. Industrial Placement)
Date	February 23, 2015
Revision	1.0
Status	Final

1. Introduction

The purpose of this document is to lay out a design for the system as a whole and for the invisibility cloak model(s). This specification is intended to inform me and my supervisor of the design I have envisioned for the project and as a reference for my future work. Another aim of this specification is to work out the feature list which I will be building from, according to the feature driven development methodology I have chosen to work through. There will also be a section working through considerations I have had to make through research and limitations of what I have to work with. There will also be two overall designs, detailing the system design, including what I have already implemented, and the model design, which will be a design of different models I will aim to work through, applying previous research to creating them.

2. Design Considerations

Assumptions and Dependencies

The language I am using for this project is Javascript, mainly working with WebGL and Three.js as this is a graphics project. Therefore I am making the assumption that it will work on all operating systems but may not work on all web browsers. I am expecting it to run on Chrome, Safari and Firefox due to these having good support for WebGL. I know that Opera has it disabled by default but should support WebGL, and Internet Explorer has still got some issues with WebGL. I will make sure to include support for the three browsers as required, but I will make less of an effort to make it work for Opera and IE.

I will need to decide on what rendering technique I am using, as the research I have done has concluded for me that I need to be able to do complex refractions and the basic refraction support in WebGL or Three.js has some trouble modelling complex refractions. This means I am looking into real-time rendering techniques, as these will make for a better demo. I have decided that my final rendering technique it likely to be either ray tracing or photon mapping. I will intend to make the decision soon, after some more research into the dependencies of the two techniques.

Goals and Constraints

The goal of the system is to create a model or models of a theoretically possible invisibility cloak. This requires a large amount of research into current theories and therefore constrains the amount of implementation time I will have. I have taken this into account in my features, in that there will be an amount of optional features to be done if time is available.

I am also constrained by what kind of rendering technique I use and how that affects the rendering of refraction. If I cannot control the refraction ratio specifically, and also create negative refraction, I may not be able to accurately depict the invisibility cloak and will have to implement around the theory to produce a desired result.

Development Methods

The development methodology I am planning to follow is Feature Driven Development. The reason I have chosen this is due to the feature list and the

staggered planning/implementation stage at the end. The feature list works well with the staggered nature of this project, in that I have separate research and implementation requirements for each step.

I had considered the use of eXtreme Programming in this project but XP's practices were mainly focused around a small team and the communication within that team. I also feel the lack of design would be detrimental to my project as I need to research and plan the models I am planning on implementing.

3. Feature List

As I am following the Feature Driven Development methodology, I will be working through a list of features. These are the features I have come up with according to my research and prototyping.

1. Preliminary Research
 - a. Research into current Invisibility Theory including metamaterials, invisibility cloaks and transformation optics.
2. Preliminary Learning of New Technologies.
 - a. This will include WebGL, Three.js, Ray Tracing, Photon Mapping and any tutorials associated with these.
3. Outline Project Specification
 - a. This outlines the projects and any deliverables I require from the project.
4. Prototype of Sphere Shell Structure
 - a. Implementation of a spherical transparent shell structure with differing refraction ratios (if possible).
5. Prototype of Ray Tracer Rendering/Photon Mapping Rendering
 - a. Implementation of a ray tracing engine or photon mapping engine that will enable a more realistic light model.
6. Design Specification.
 - a. Discussion of feature list, model design and system design.
7. First Model – Spherical Invisibility Cloak
 - a. First fully implemented model created based on design specification and early prototyping.
8. Test Specification
 - a. Test specification detailing evaluations and tests to be used on current and future models.
9. Second Model – Cylindrical Invisibility Cloak
 - a. Second fully implemented model created based on design specification and first model.
10. Optional – Viewpoint from within cloaks.
 - a. The ability to look from inside the cloak and what kind of images would be shown.
11. Optional – Use of Polarized Light
 - a. Taking polarized light into account to create a more realistic model.
12. Optional – Further Models
 - a. Further models of invisibility cloaks using different geometrical structures and coloured light.
13. Project Diary
 - a. Will take the form of a blog and track the progress of the project.
14. Final Report

- a. Report detailing project progression, completion and results.

4. System Design

The system design is relatively simple as I am mainly interested in the creation of the model(s)

File Hierarchy

There will be a html file for each version, be that model or prototype. These will be published to a github page so that I can both display by webpages and have a decent version control system. I will also have a main weblog that contains a project diary, tracking my progress as required by FDD. There will also be a folder for each model/prototype that contains the JavaScript files necessary for the project, as well as any assets needed by the project. There will also be a folder for library files, such as three.js, that are used by all/most of the models/prototypes.

User Interaction

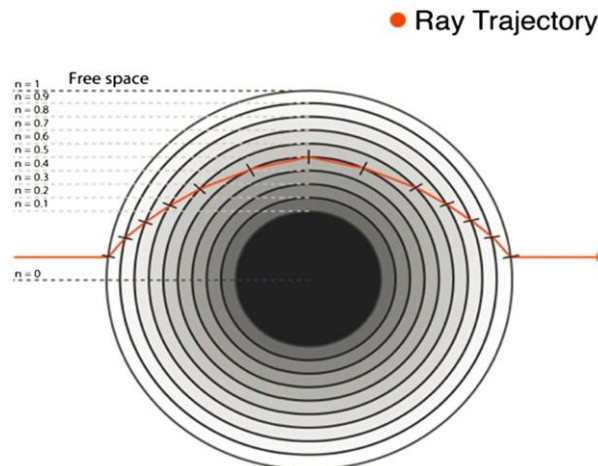
The user will be able to interact with the scene in a few ways. The user will be able to rotate the scene, as well as zoom in and out of the scene. The user will be able to change between invisible and non-invisible models, so that the difference can be seen. This will probably be done by using a shell model that contains normal refraction values and then switch these values to the invisibility values. The user should also be able to follow links through the system to access any version they wish to view.

5. Model Design

The design for the model(s) comes from the papers I have read and discussions with my supervisor. The model will be based on geometric structures and current theories on how an invisibility cloak would theoretically work.

Most models of the cloak show a layered structure that changes the refraction ratio through each layer, guiding the light waves around the inner object. This means that shell must also change from the back face to the front face of the object, having a negative refractive index at the back of the shell to guide the light back out of the shell at the correct point.

In a spherical model, the ray will need to curve around the center shell. In paper [2], values for a circular trajectory of the ray have been provided and it would be worth testing these values for a spherical model, though it is a cylindrical model that is being theorized.



Taken from [2] - These are the values of the refractive index at each shell and the trajectory the ray should follow.

For other geometrical shapes, they may be some more work involved, as the models may not have already been mapped by prior research. I have in one paper [1] equations for spherical, cylindrical, conical and ellipsoidal shells which should be enough geometrical shapes, though I would be intrigued to see how a cuboid shell would work, or if it even could work.

6. Bibliography

- [1] M. M. Crosskey, A. T. Nixon, L. M. Schick, and G. Kovačič, "Invisibility cloaking via non-smooth transformation optics and ray tracing," *Phys. Lett. A*, vol. 375, no. 18, pp. 1903–1911, May 2011.
- [2] K. S. Elassy, N. H. Rafat, M. E. Khedr, and M. H. Aly, "Fundamentals of designing cylindrical high-order transformation optics invisibility cloaks using silver–silica metamaterials," *Appl. Phys. A*, vol. 115, no. 2, pp. 531–539, Nov. 2013.
- [3] D. Schurig, J. J. Mock, B. J. Justice, S. a Cummer, J. B. Pendry, a F. Starr, and D. R. Smith, "Metamaterial electromagnetic cloak at microwave frequencies.," *Science*, vol. 314, no. 5801, pp. 977–980, 2006.