

Technical Design Document

**Realistic Ocean Surface Rendering and Simulation**

Version 1.0

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# Introduction

Inspired by the game Sea of Thieves, created by Rare, the idea of this project was to recreate the ocean surface simulation achieved in that game. Using the Fast Fourier Transform (FFT) the project achieves a realistic simulation of the ocean’s surface that runs at interactive speeds even on a large scale. This coupled with an additional simulation method called the iWave method allows objects to move across the surface creating ripples and wakes as well as react to variable ocean floor depths. To discover exactly what performance implications these formulas and methods have profiling data was collected for different wave settings.

# Overview

*Add a more detailed overview to this section explaining why this project is interesting to do and describe the level of detail needed in this document in order to assure the success of the project.*

## Scope

*Give a brief statement of the scope of the project from a technical point and view. Tie this to the design vision and introduce the overarching development plan for this project. Insert as much detail as necessary.*

## End Product

*Describe the pieces that are going to be built in order to develop the final game as defined in the Game Design Document. This sets expectations for amount of work necessary.*

*Gameplay*

* *List separately all game mechanics that need to be implemented*

*Game Objects*

* *List separately all game objects that need to be implemented*
* *For example:*
* *Player Character(s)*
* *Enemies (list with description)*
* *Pick-ups*
* *Destructible objects*
* *Vehicles*
* *Etc.*

*HUD & UI*

* *All GUI attributes implemented*
  + *List each aspect of the UI separately*

*Menu Systems*

* *All systems implemented*
* *List menus separately, with purpose and placement*

*Etc.*

# System Requirements

*If your system has requirements other than a roughly standard PC, list those here. What are the minimum and recommended systems needed to play your game? What are the requirements for a developer system? If the latter differs between different disciplines, list all separately.*

## Target System

### Minimum

*Processor:*

*Memory:*

*Video Card:*

*Operating System:*

*Software:*

*Peripheral:*

### Recommended

*Processor:*

*Memory:*

*Video Card:*

*Operating System:*

*Software:*

*Peripheral:*

### Development System

*Processor:*

*Memory:*

*Video Card:*

*Operating System:*

*Software:*

*Peripheral:*

# Technology Sources

*Describe the external tools and technology used during production. May be omitted if nothing applies.*

# Theory

### Navier-Stokes Equation

The Navier-Stokes equations determines the motion of a fluid based on velocity u(x,t), pressure p(x,t), force F(x,t), and density [1]. Where x is the position of the fluid and t is time.

#### Bernoulli’s Equation

Bernoulli’s Equation takes the Navier-Stokes equation and simplifies the complex nature of the equation to only give the velocity one degree of freedom instead of three [2]. Where velocity u is converted into potential flow ɸ.

This allows the Navier-Stokes Equation to become a fully nonlinear equation. Where U(x,t) is some potential energy function [2].

#### Linearization

To achieve interactive speeds for the simulation Bernoulli’s equation needs to be further simplified to linearize the equations of motion and restrict the evaluation to only the points on the surface of the fluid.

### Dispersion Relation

The Navier-Stokes Equation, simplified and with approximated values can be expressed in a single equation imposing the constraint that the temporal frequency ω of surface height movements is connected to the spatial extent of the propagating wave k = |k|.

### Gerstner Waves

A simple implementation for modeling the surface of the ocean as a wave passes over a point. A good approximation of any point on the surface of an ocean reacting to a wave is in a circular motion [2]. This means that the equations boil down to simple sin and cos equations.

Where x is the point on the horizontal plane, x(x,y), and the height of the surface at that point is z. Where k is the magnitude of the wave, A is the amplitude of the wave, and the length of the wave is λ.

This equation for a single sin wave can be incorporated into a summation that allows for the modeling of a more complex wave pattern. Where ɸ is the wave’s phase.

### Fourier Transform

#### Discrete Fourier Transform

#### Fast Fourier Transform

### iWave

The iWave method is designed to simulate minor changes in an already simulated ocean surface. Its goal is to create interactive waves. This means that it accounts for objects in the water, shallow water, and creating ripple effects.

# Artifact

### Gerstner Waves

### Discrete Fourier Transform

### Fast Fourier Transform

### Reflections and Skybox

### iWave Implementation

#### Objects

#### Environment

# Implementation

*Add sections under this heading as appropriate to describe the artifact.*

# Architecture

*Add sections under this heading as appropriate to describe the artifact.*

# Results

### DFT versus FFT

### Not Threaded versus Threaded versus Compute Shader

### Adding iWave

# Profiling Results

*Add sections under this heading as appropriate to describe any data, test results or conclusions.*

# Data Analysis

*Add sections under this heading as appropriate to describe any data, test results or conclusions.*

# Bibliography

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| --- | --- |
| [1] | "Navier-Stokes Equations," Comsol, 22 February 2017. [Online]. Available: https://www.comsol.com/multiphysics/navier-stokes-equations. [Accessed 9 July 2020]. |
| [2] | J. Tessendorf, "Simulating Ocean Water," 2004. [Online]. Available: https://people.cs.clemson.edu/~jtessen/reports/papers\_files/coursenotes2004.pdf. |