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Technical Paper Session II - Making Waves: A 3D Software Simulation of Wave Creation and Propagation

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SPACE VISIONS CONGRESS 2007

**STUDENT TECHNICAL
PAPER SESSION 2**

**“MAKING WAVES: A 3D SOFTWARE SIMULATION OF
WAVE CREATION AND PROPAGATION”
JAMES DANIEL BRANDENBURG**



Making Waves: A 3D software simulation of wave creation and propagation

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Abstract

The purpose of this project was to develop software to model water wave creation and wave propagation in 3D, explicitly modeling interference, reflection, diffraction, and attenuation.

This project consisted of two distinct procedures; software development and laboratory work. Software Development resulted in the ability to specify wave pool dimensions, simulate wave propagation, and display the water surface in 3D. Three separate programs were created; a wave pool editor, a calculation compiler, and a program that plays the simulation. Laboratory Work consisted of building a wave pool one meter square by ½ a meter deep, developing measurement techniques, 102 drop tests and analyzing 3,460 digital photographs and 380 full motion videos. Spherical objects were tested to measure how object impacts affect amplitude, wavelength, and speed of resulting waves. Three five-variable functions were written to model waves. These functions were used to calibrate the calculation compiler.

The researcher created a software model that simulated wave creation and wave propagation.

The object of this project is to provide a software model of water that can be used to view and predict the behavior of water. To achieve this, the software model must allow the user to provide unique inputs such as the environmental data, wave creation data, and other options. Creating a complete and accurate software model requires overcoming many challenges.

The first important input is the environmental data. This means that a program must be written to design wave pools for the software to simulate the water in. The researcher wrote an environment editor in the programming language c++ using the DirectDraw and windows api. This program allows the user to define the surface of the water, the number and placement of barriers, the placement of wave generators with given attributes, and the properties of objects that create waves on impact with the water. This program also allows the user to save the files and export them to view in three dimensions.

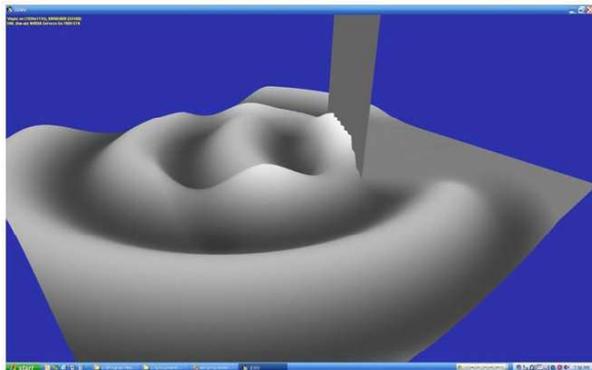
After the environmental data is set, the water must be simulated in that environment. The researcher began studying the programming and mathematical methods to model water accurately and completely in any given environment. It soon became apparent that a detailed simulation could not be calculated and viewed in real time even with modern personal computers. The researcher solved this problem by dividing the work into two programs. The first program uses all the input data to model the water. Then this program saves each frame in a binary file format. The researcher's model begins by modeling the waves that are defined in its environmental file. Then the program dynamically creates additional wave sources to model reflection, wave smoothing, and diffraction. These wave sources can themselves create even more wave sources for reflection, smoothing and diffraction. This recursive solution allows a simulation to begin with a single wave and model it accurately as it expands and changes.

The third program was created to view the binary frame files from the previous program. To accomplish this, the researcher used c++ along with the direct3d api. This program first reads the binary header which tells it the general properties of the file. Based on the frame number to display, it determines the location in the file and accesses just that area of the file. It then loads the data straight into a custom data structure. This data structure is then translated into vertex data upon display of the screen. In order to allow a professional and useable interface the researcher also wrote functions to rotate, move and zoom in on any point on the water surface.

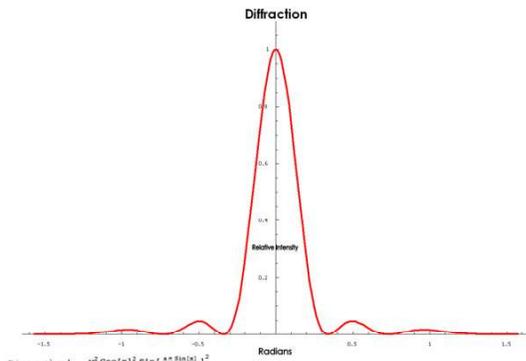
The researcher then began studying methods to simulate the creation of water waves based on an object dropping into the water. The researcher soon decided to construct an apparatus and collect data by dropping objects in the water and analyzing the resulting waves. To use the data in the wave simulation software it would have to be translated into functions that take inputs about the properties of an object and output the wavelength, amplitude and speed of a wave. To do this the researcher tested 17 spherical objects each with unique properties. The researcher independently altered the mass, volume, radius, density, and drop height for each test. Then Mathematica, a computer algebra system, was used to fit functions to the data. Three six dimensional functions were written. Each had the inputs of the five properties of the

object and the output was amplitude, wavelength and wave speed. These functions were then used in the wave simulation programs to provide realistic attributes for wave creation.

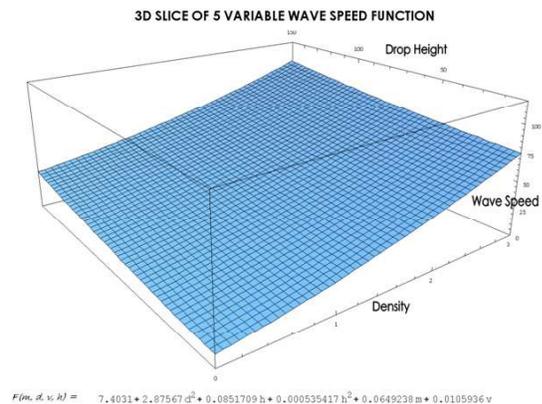
The purpose of this project was to accurately and correctly simulate wave behavior and wave creation and allow it to be viewed in 3 dimensions. This included modeling interference, reflection, attenuation, wave creation and wave creation attenuation. This project is the foundation for a study on water splashing, and even more complex wave behavior like wave breaking.



^Screen shot of 3D simulated wave pool viewer



^A graph of a 3d slice of the 5 dimensional function



^ A screen shot of development and compilation

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Making Waves

A 3D Software Simulation of Wave Creation and Propagation

Purpose

- Provide professional quality user interface and custom water environment designer
- Model propagation of waves accurately through a given environment
- Collect real world data for accurate wave creation and input

Software Layout

- Three programs written in C++ using the DirectX and Win32 APIs
 - Wave Pool Editor
 - Calculation Compiler
 - 3D Movie Viewer

User Interface & Editor

- Win32 API with C++ and DirectDraw
- Creating The Wave Pool Editor
 - Basic program architecture
 - 3D view via three 2D views
- Dialog based Calculation Compiler
- Camera Controls in 3D Movie Viewer

Modeling Wave Propagation

- Basic wave movement
- Interference
- Reflection
- Diffraction
- Attenuation

Dynamic Programming

- Dynamic Memory allocation
 - Classes
 - Arrays
- Recursive Sine Wave Class
 - Reflection
 - Diffraction

Data Collection

- Wave Pool Construction
- Wave creation through falling Styrofoam spheres
- Create three 5-dimensional functions

3D Movie Viewer

- Binary format allowing fast file i/o
- Direct3D and Rendering large 3D scenes
- Full motion animation
- Camera controls for POV movement

Making Waves

Thank You