Methods of Simulation Fluid Motion in a Shallow Context in 3-Dimensions

Jacob Dominy
Computer Systems Lab 2009-2010

Abstract

As computer graphics become more advanced and realistic, it becomes necessary to learn how to recreate real-life events in a virtual environment. The events that have proved most problematic in this regard are those that occur in nature. In this project I will investigate techniques to automate simple, shallow fluid motion found in everyday life.

Background

Recreation of the motion of fluids has proved to be an enduring conundrum for graphic designers. This is because all computer graphics are based on the combined use of many 3-Dimensional objects. This makes modeling solids very simple, but very difficult when it comes to fluids. A deep understanding of physics is also required to recreate the motion of fluids as they are dictated by a large set of rules in nature. Because there are countless different situations and conditions that occur in nature, encompassing all of these possiblities has made it hard to code realistic fluid motion. Several different methods to approaching this problem have been researched in this field.

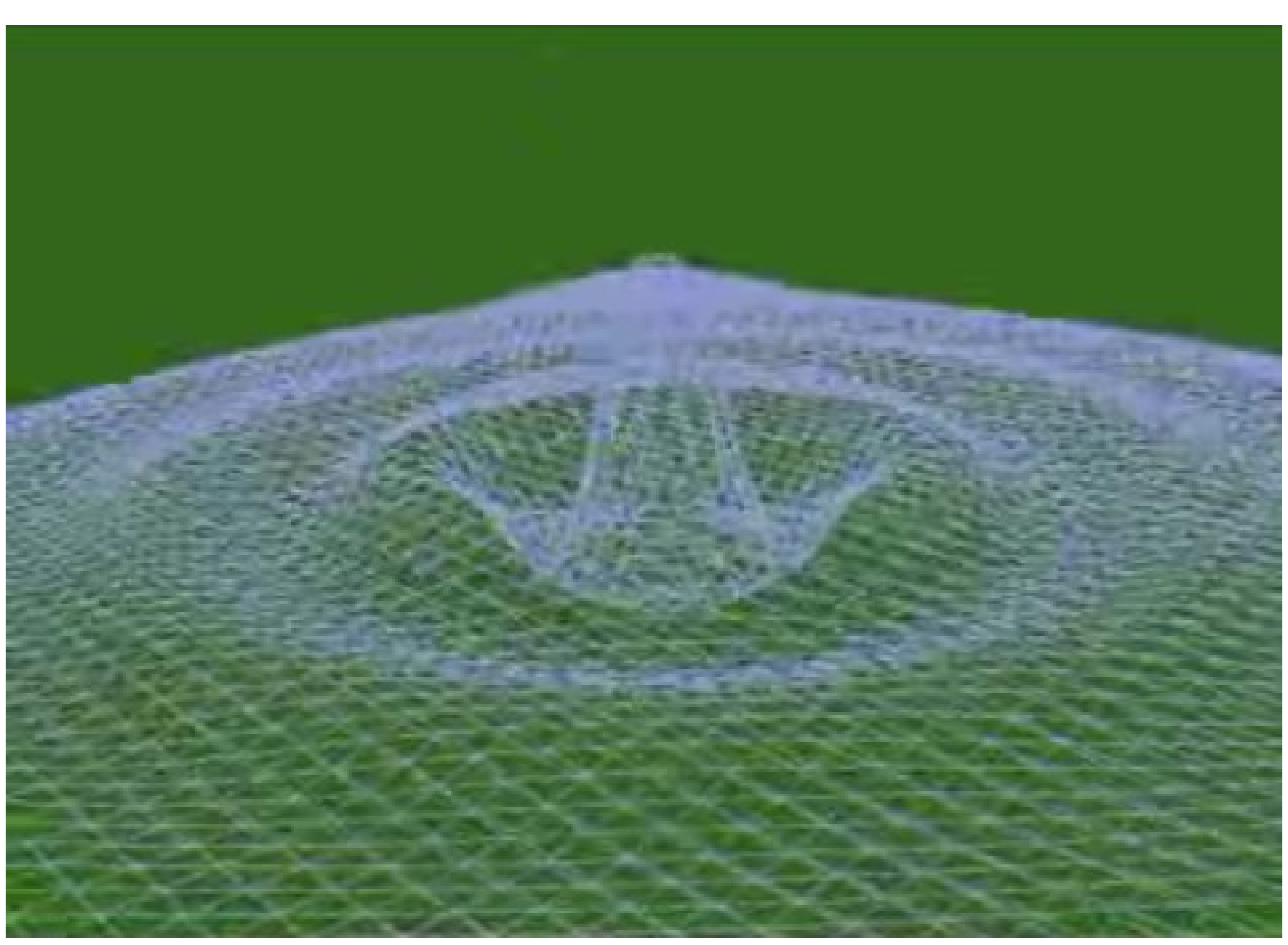

Fig. 1. An example program using a height field to simulate water ripples.
http://www.youtube.com/watch?v=TcVrEZ0i_u0

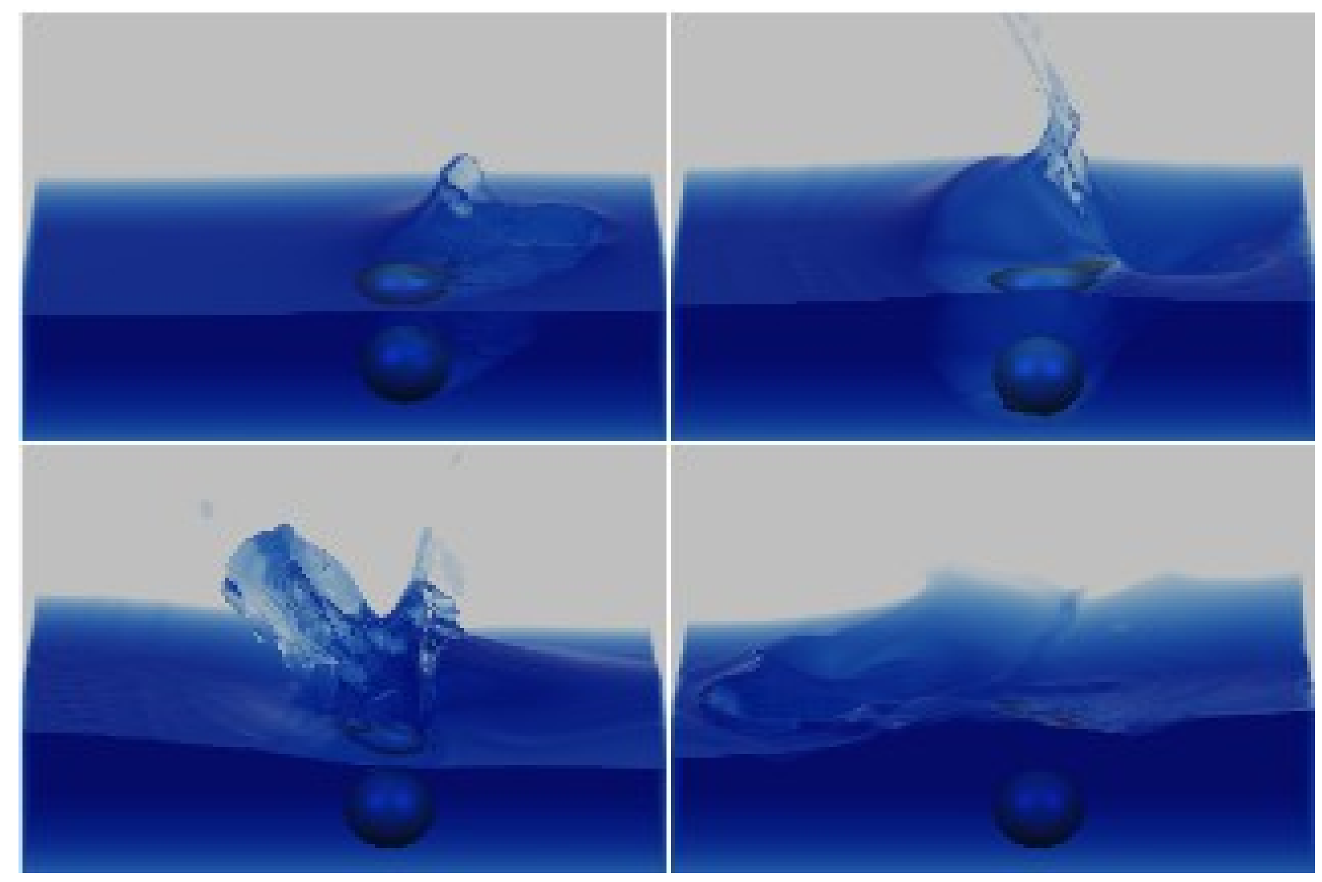

Fig. 2. Screenshots of a simulated ball splashing into water

Discussion

There are many methods of representing fluids in a simulated environment. A body of water can be simulated using a particle system or a 3-Dimensional grid of cells. The program then will calculate the forces and velocities in all directions on every single particle or cell. However, for our purposes, this will most likely prove too complicated and too hard on computer resources. A more practical method, especially in a shallow body environment, is to use a hight field. This is a 2-D matrix that is then calculated for accelerations, velocities and the heights of each point are determined and then graphed. As for actual physics, the most common method for determining velocities of fluids is the Navier-Stokes equation.

$$\frac{\partial^2 s}{\partial t^2} = -g\left[\frac{d_{x-1}+d_x}{2(\Delta x)^2}\right](s_x - s_{x-1}) + g\left[\frac{d_x + d_{x+1}}{2(\Delta x)^2}\right](s_{x+1} - s_x)$$

Fig. 3. A simplification and discretization of the Navier-Stokes equation that evaluates for the vertical acceleration of any point on the height field.

Results and Conclusions

The expected results of this project will be the successful application of concepts of fluid dynamics to computer graphics in the context of a small, standing, shallow body of water. With these methods applied, the expected output will be realistic ripples and waves on the surface of the body. The current results are a successful displaying of height fields, but the implementation of the Navier-Stokes equation is not yet correct and often fails.