Project Proposal: Cellular Simulation of Fluid Behavior

I. Purpose

To simulate the behavior of a pool of water when disturbed using cells of water that interact with each other using a small, simple set of rules. To simplify the complexity of fluid dynamics simulation into a set of intuitive rules based off real world observations.

II. Procedure

Syzygy implemented with C++. A grid of cells in the X-Z plane that each represent a section of the pool. The cells are rectangular prisms whose height in the positive Y direction indicates the fluid level for that section of the pool. The cells communicate with each other, and by comparing their respective levels, determine how they will change over time.

III. Observations

The Behavior of the fluid cells will be based off of two very simple observations.
   1. Fluid tends towards even volume throughout
    2. When fluid is motion it tends towards continuing that motion

IV. Rules
With these two observations in mind the rules for the cells behavior will be formulated.

    1. Cells even out their levels: Cells will move towards and eventually attain a level equivalent to that of the average of its level and its neighbors. The rate at which the level moves towards this average value is proportional to the difference in level between the cells and indirectly proportional to the viscosity.

Figure 1: The level between the cells equals out(this will occur after a long time)
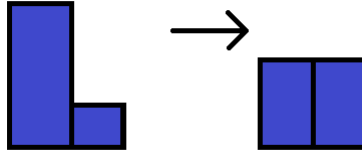
2. Cells have momentum: When a cell's level increases, it gains momentum in the direction that the fluid is moving (i.e. the opposite direction as where it originated). This is what gives the fluid a tendency to continue moving and forming the distinct fluid ripples. Conversely, as a cell loses volume, it loses momentum in the direction that the water is moving (i.e. the direction towards the cell of lower level). This in effect transfers momentum from one cell to the other. Momentum is used in the calculation of rule 1 to determine the level a cell moves towards attaining and the rate at which it does so. The rate at which momentum is generated and its impact in the rule 1 calculation can be tweaked to alter the fluid's behavior.

Figure 2: The middle cell gains momentum from its level gain allowing it to suck fluid out of the left cell and exceed its level. This momentum is then passed on to the right cell leaving the left and middle to even out in accordance to rule 1. (Note that the right cell does not reach the original level of the left cell. As the ripple continues, it loses momentum in the process of passing through cells)
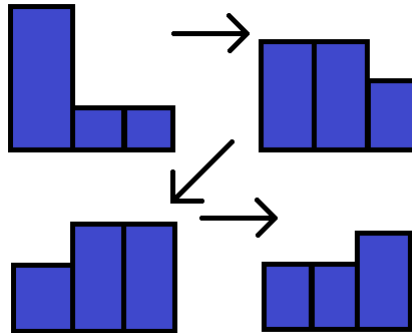
V. Additional Features

   1. Sources and Drains
A feature that can be implemented to create scenarios are sources and drains. A source maintains its level at or above a certain threshold, adding fluid the the system. A drain always maintains a level of zero, removing fluid from the system. Sources and drains can be arranged as initial conditions and varied to investigate the fluid's behavior.

   2. Walls and Solid Objects
The entire pool can be surrounded by walls. Walls are made of solid material. They have the property of having no effect on fluid level (not adding to or subtracting from the fluid level of its neighbors. The exact same properties can also be given to certain cells in the pool, hopefully allowing one to simulate solid objects within the pool. Solid walls/objects also have the very important property of reflecting momentum vectors. If a momentum vector reaches a solid object or wall, it will be reflected back in the opposite direction.

VI. Graphical Representation
Each cell is has a rectangular top face. The y-value of points that define the corners of the rectangular faces are determined by the average value the levels of the cells it is a part of. This creates a smooth, continuous surface determined by the gradient of the cell levels.

VII. User Interface
The main possible implementation of user interface in the simulation is the use of the wand to place sources and drains. This can be done in real time to see immediate effects or when paused to set up a complex set of initial conditions.