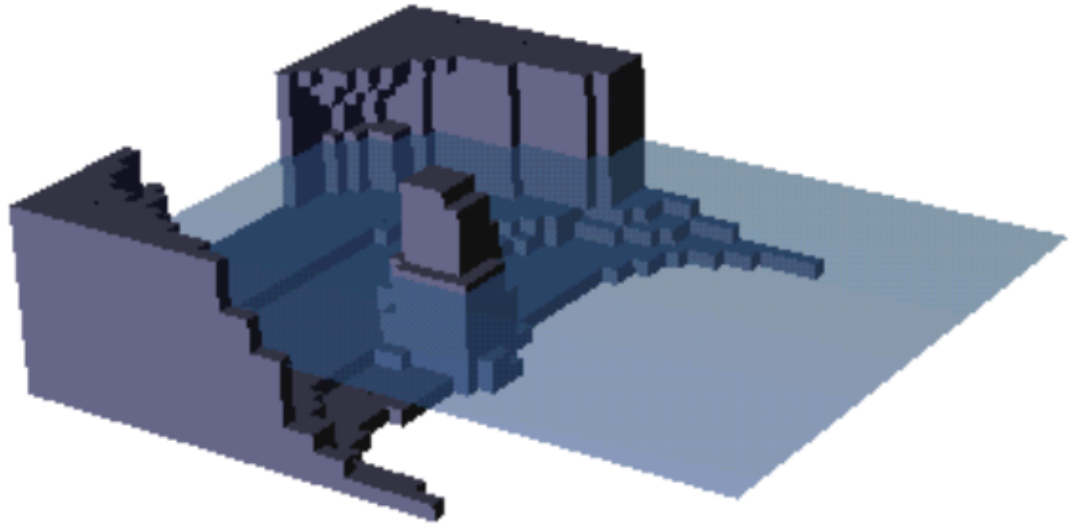


Realistic Animation of Liquids

February 8, 2008

Introduction

Realistically animate liquids

Based on Navier-Stokes equations

Computational fluid dynamics (CFD) versus non-physically accurate modeling

Navier-Stokes equations

Standard equations for fluid dynamics

Cartesian velocity components are u, v, and w

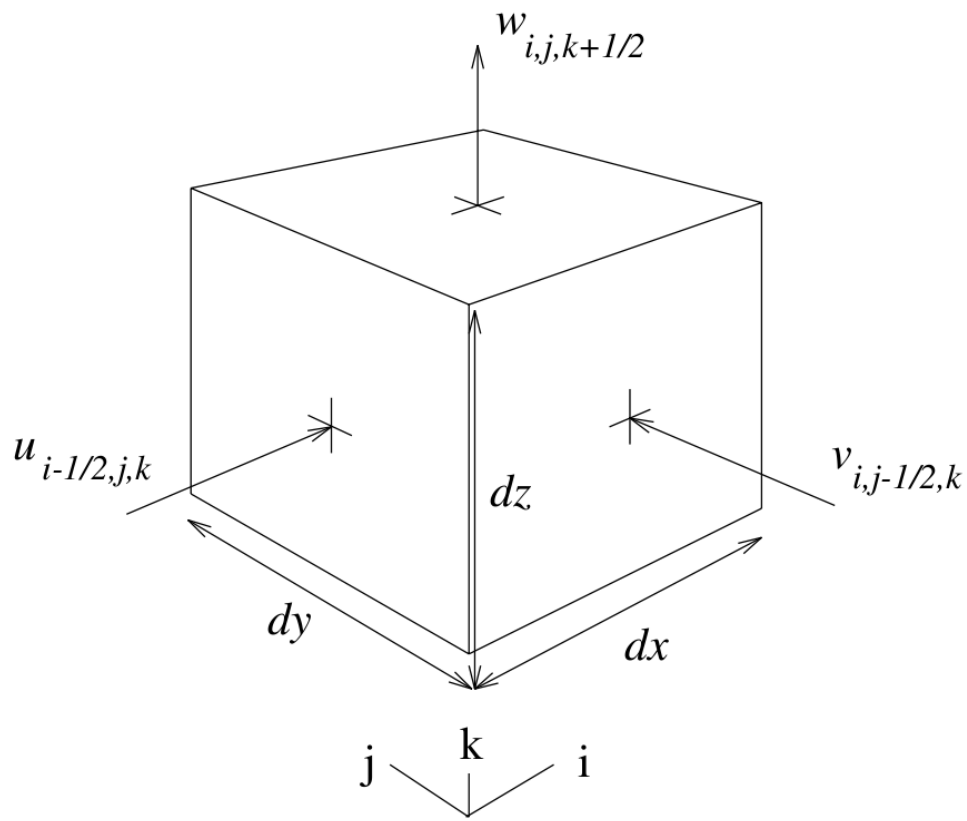
Unsteady acceleration and convective acceleration

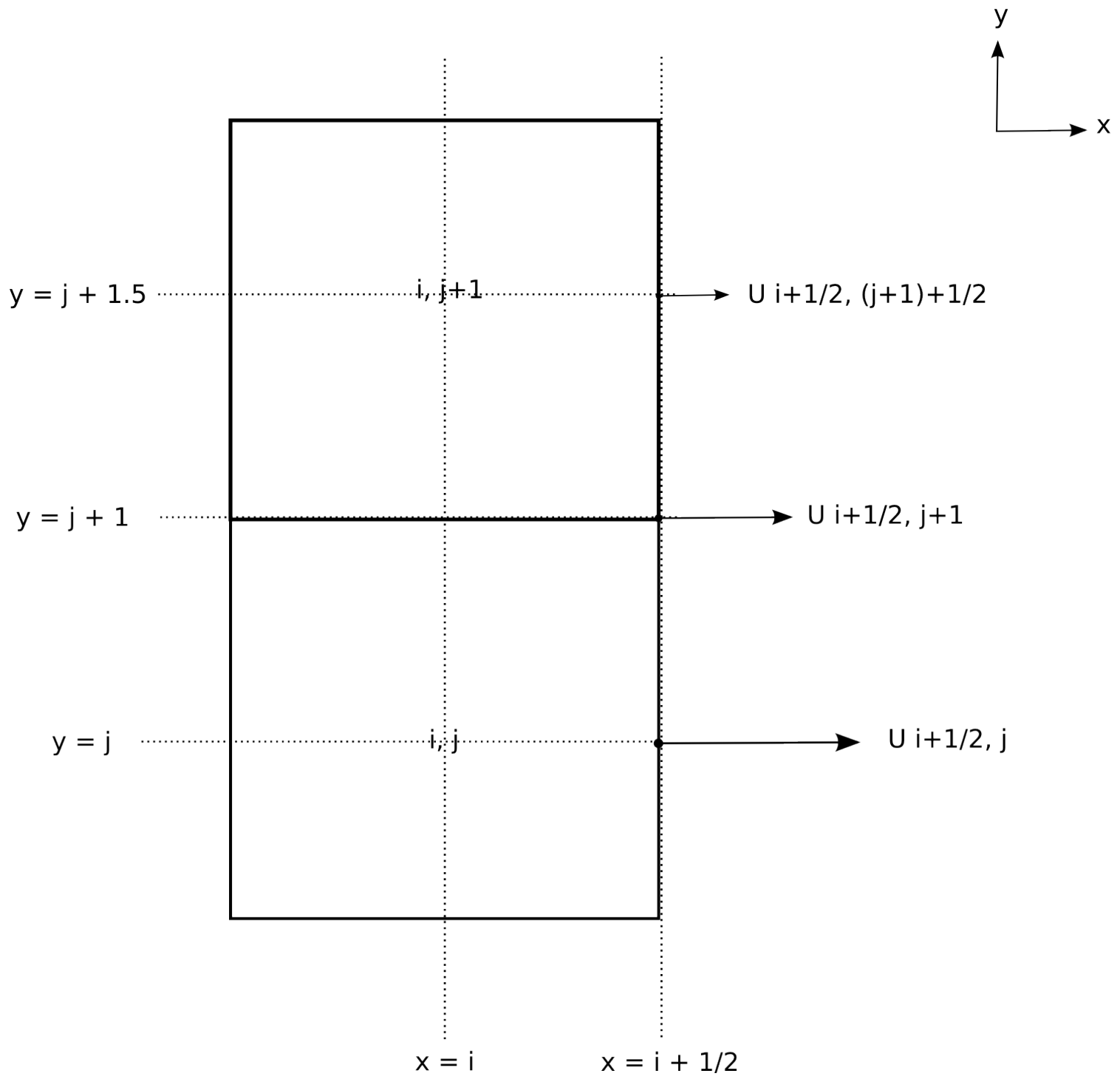
Pressure, viscosity, and other forces

Discretization

Front face velocity of a cell is the back face velocity of the next cell

Types of cells include solid, full, or surface




y
x
y = j + 1.5
i, j+1
U i+1/2, (j+1)+1/2
y = j + 1
U i+1/2, j+1
y = j
i, j
U i+1/2, j
x = i
x = i + 1/2

Finite difference approximation

Taken from *Numerical Calculation of Time-Dependent Viscous Incompressible Flow of Fluid with Free Surface*

Include a time step constraint

Iterative process continues until all cells have a divergence less than epsilon

Boundary conditions

Automatically set for the scene

No-slip and free-slip conditions

Inflow and outflow (source and sink) cells inject and consume flow

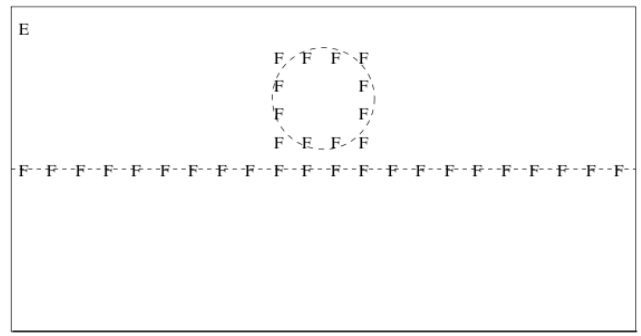
Free surface cells

Tracking fluid position

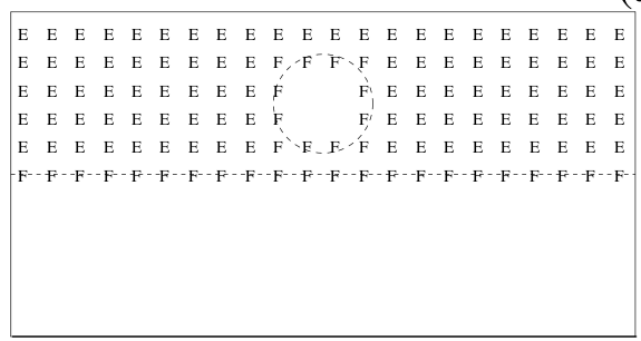
Marker particles are massless particles which travel with the fluid

Free surface particles are placed between fluid and obstacles or air

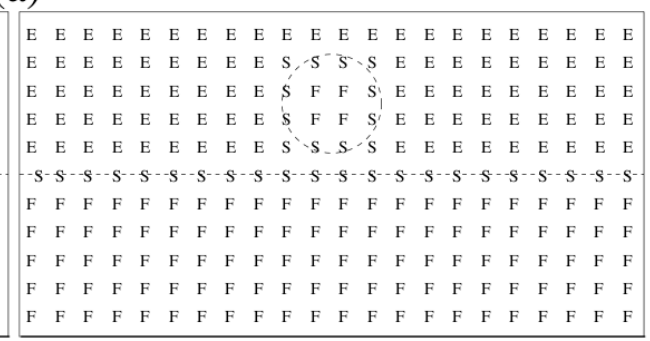
Height field works when there are no overturning waves



(a)



(b)



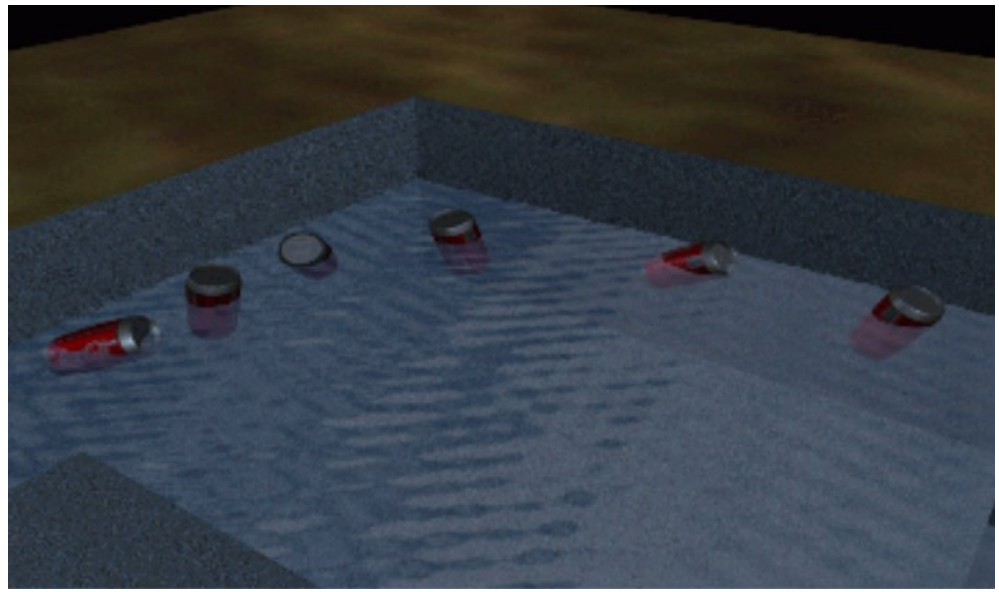
(c)

Other stuff

Rigid bodies are broken up into nodes

Apply collision detection to objects floating in the system

Mass flow rates for sources and sinks can change



Results

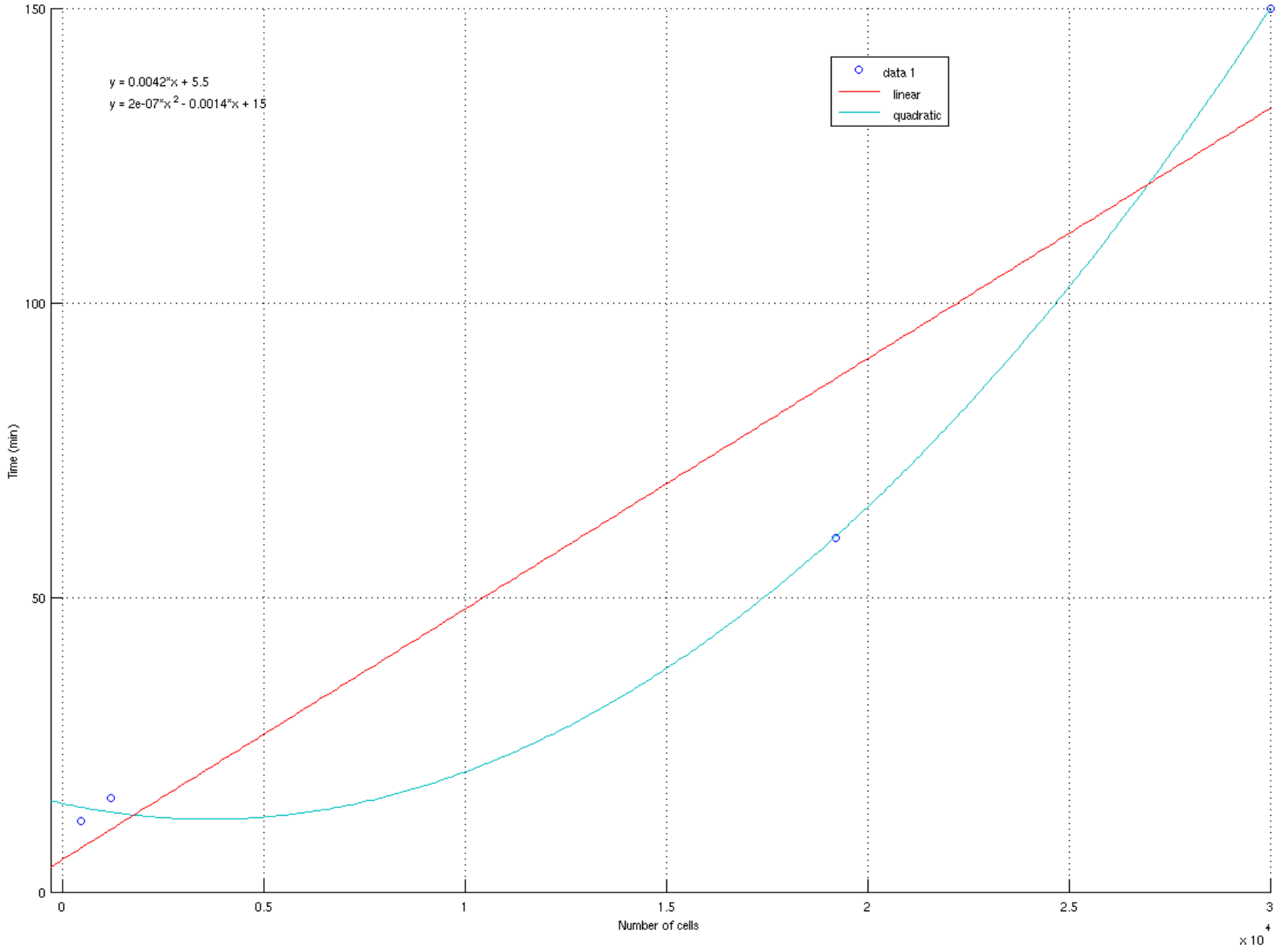
For rotational symmetric problems, 2D results can used

Soup drop: 30x40 grid (1200), 4500 iterations, 16 minutes

Moonlight cove: 15x30x1 grid (450), 2000 iterations, 12 minutes

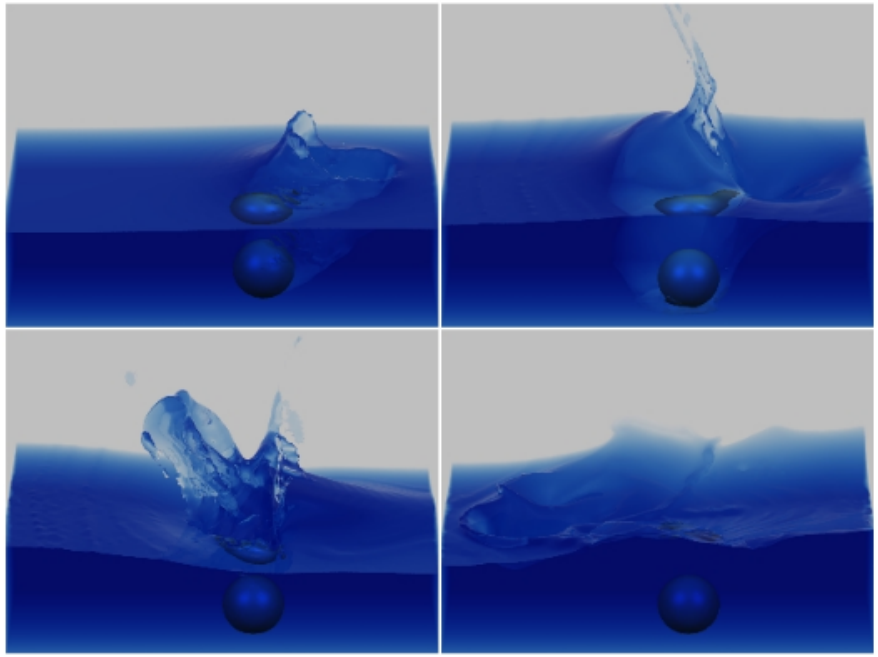
Sluice gate: 50x15x40 grid (30000), 20000 iterations, 2.5 hours

Soda cans: 40x12x40 grid (19200), 8000 iterations, 1 hour

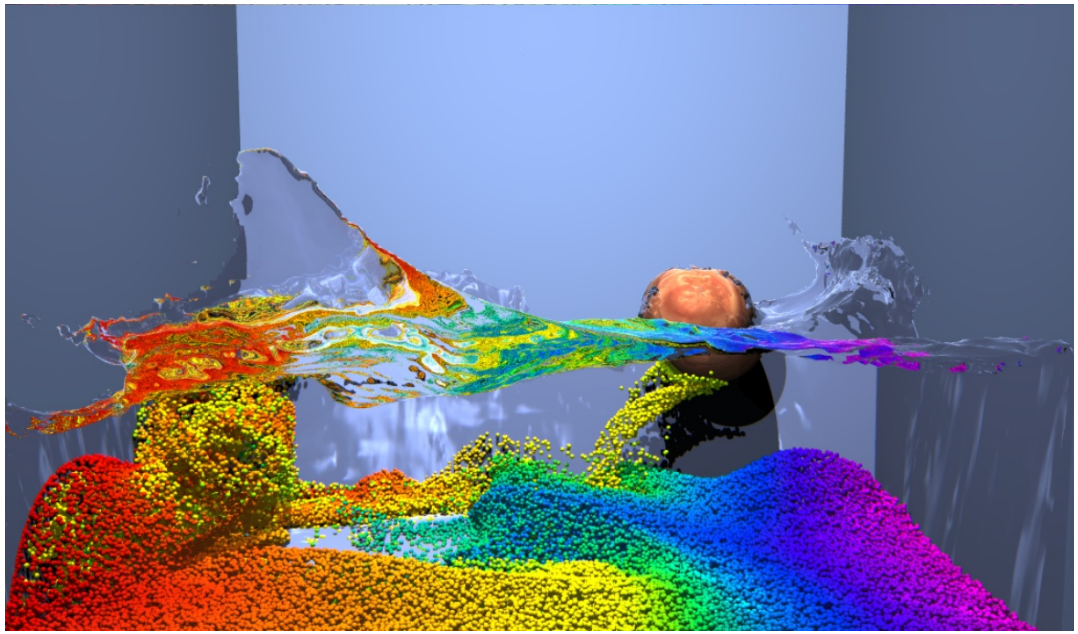

y = 0.0042*x + 5.5
y = 2e-07*x^2 - 0.0014*x + 15
data 1
linear
quadratic
Time (min)
Number of cells
x 10^4
150
100
50
0
0
0.5
1
1.5
2
2.5
3

Other works

Nick Foster
Practical Animation of Liquids (2001)



Mark Carlson
Rigid Fluid: Animating the Interplay Between Rigid Bodies and Fluid (2004)



Questions?