Fluids Overview 2008

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Introduction To Fluid Simulation

Basic Terms:

Velocity
Pressure
Density
(Temperature)

Continuous over space (dx) and time (dt)
Mass, Momentum, and Energy are conserved

Lagrangian vs. Eulerian:

Lagrangian - values are tracked as particles moving through the space
Eulerian - values are tracked on a fixed grid

Viscous vs. Inviscid:

Viscous - fluid friction has significant effects on the fluid motion
Inviscid - inertial forces are more significant than the viscous forces

Laminar vs. Turbulent:

Turbulent - flow is dominated by recirculation, eddies, and apparent randomness
Laminar - no turbulence (but could have recirculation)

Compressible vs. Incompressible:

Liquid is assumed to be incompressible (Dp/Dt = 0)
Smoke and other gasses are compressible

Material Derivative:

A derivative taken along a path moving with velocity v

describes time rate of change of a quantity (i.e. heat) that is being transported by fluid

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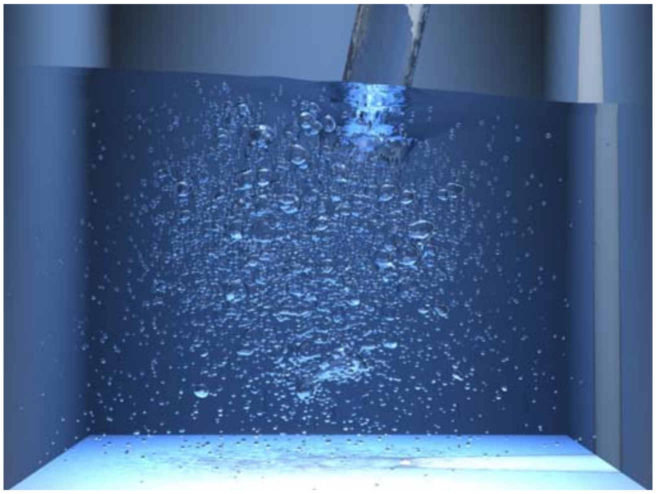
Multi-Phase Fluids

"Bubbles Alive" by Hong, Lee, Yoon, & Kim

Korea University (SIGGRAPH)



- Hybrid System (Eulerian + Lagrangian)
- Large volumes (water and atmosphere) simulated on an adaptive Eulerian grid
- Bubbles too small for the grid to capture accurately simulated with SPH
- Used heuristic to model the interface between SPH and Eulerian grid

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Smoke (Turbulence & Low Viscosity)

"Wavelet Turbulence for Fluid Simulation" by Kim, Thurey, James, Gross

Cornell & Zurich (SIGGRAPH)

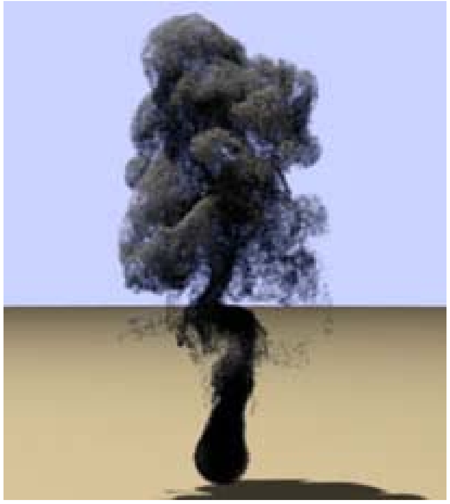
- Uses a low-res Navier-Stokes simulation to generate the general shape
- Then high-frequency components can be added in later as a post-processing step
- Wavelet decomposition provides input for an incompressible turbulence function that produces the high-freqency details

"Low Viscosity Flow Simulations for Animation" by Molemaker, Cohen, Patel, Noh

Rhythm & Hues, UCLA, NVIDIA, KAIST (SCA)

- Models basic Navier-Stokes flow through a regular grid
- Uses QUICK advection algorithm over a globally high-res grid
- Introduces the Iterated Orthogonal Projection framework to calculate pressure
- Provides accurate solutions to scenarios with multiple, complex non-divergence and boundary conditions

"Evolving Subgrid Turbulence for Smoke Animation" by Schechter & Bridson



University of British Columbia (SCA)

- **Tracks the mean kinetic energy per octave of turbulence in each grid cell**
- **Tracks a novel "net rotation" variable for modeling self-advection of turbulent eddies**
- **This data drives a procedural post-process, layering dynamically evolving turbulent details on top of large-scale simulated motion**
- **Includes a new multistep predictor to alleviate nonphysical dissipation of angular momentum**

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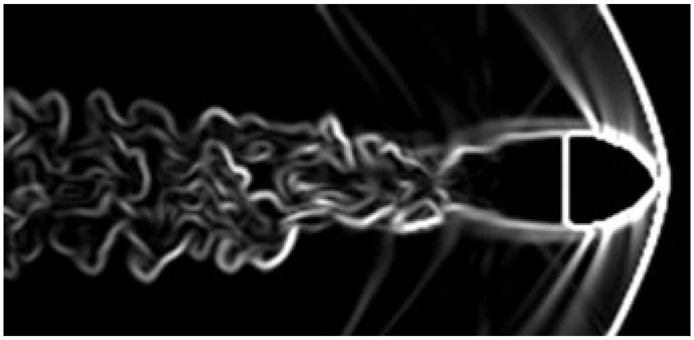
Shockwaves

"Visual Simulation of Shockwaves" by Sewall, Galoppo, Tsankov, Lin



UNC at Chapel Hill (SCA)

- Simulates shock phenomena in compressible, inviscid fluids
- Well suited for parallel implementation on multicore architectures
- Handles complex, bidirectional object-shock interactions

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Fluid-Solid Interaction

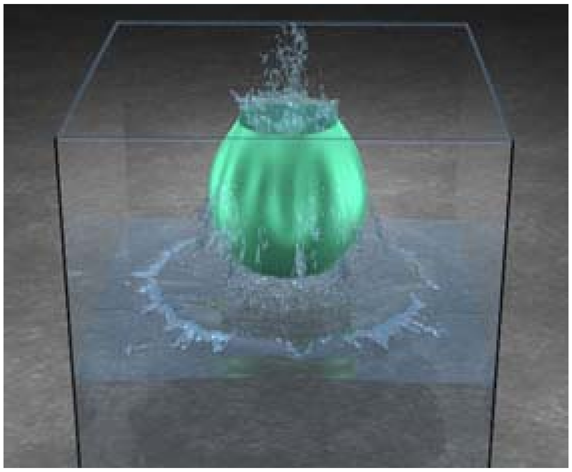
"Porous Flow in Particle-Based Fluid Simulations" by Lenaerts, Adams, Dutre

Stanford & Katholieke Universitet Leuven (SIGGRAPH)

Adds the physical principles governing porous flow expressed by the Law of Darcy to SPH
Macroscopic porous flow assumption
Models the changing behavior of the wet material as well as the full two-way coupling between the fluid and the porous material

"Two-way Coupling of Fluids to Rigid and Deformable Solids and Shells" by Robinson-Mosher, Shinar, Gretarsson, Su, Fedkiw

Stanford, Intel, & ILM (SIGGRAPH)



Fully Implicit method for simulating fluid/solid coupling
Works with smoke, water, and multi-phase fluid
Works with rigid and

- deformable solids

"Interactive Terrain Modeling Using Hydraulic Erosion" by Stava, Benes, Brisbin, Kfivanek

Czech Tech University & Purdue University (SCA)

- Terrain composed of layers of different materials plus sediment
- Editing based on erosion and deposition algorithms
- Dissolution erosion + force-based erosion + slippage

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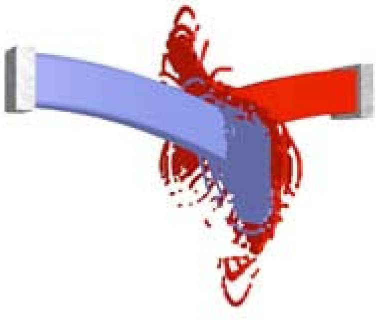
Fluid-Fluid Interaction

"Density Contrast SPH Interfaces" by Solenthaler & Pajarola



University of Zurich (SCA)

- Enhances SPH to be able to handle miscible fluids with large density ratios without raising computational cost
- User can specify desired level of interface tension

"A Unified Handling of Immiscible and Miscible Fluids" by Park, Kim, Wi, Kang, Shin, Noh

Kaist (CASA)

- Presents a unified framework for handling miscible and immiscible fluids based on chemical potential energy
- Describes the evolution of multiple fluids as time varying concentration fields
- Uses advanced lattice Boltzmann methods for computational efficiency in computing Navier-Stokes eqns

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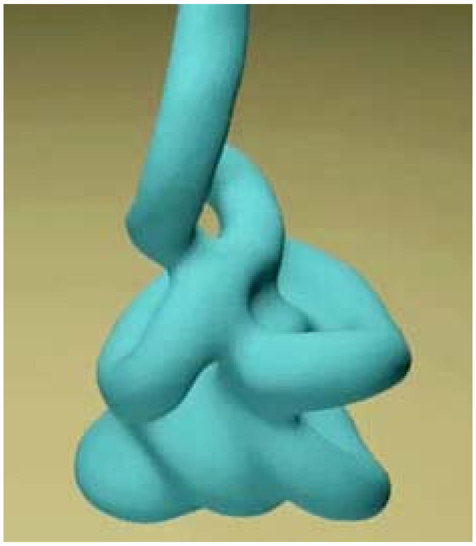
Squishy Materials

"Accurate Viscous Free Surfaces for Buckling, Coiling, and Rotating Liquids" by Batty, Bridson



University of British Columbia (SCA)

- **Simulates fully implicit Eulerian technique for simulating free surface viscous liquids**
- **Efficiently supports variable viscosity**
- **Captures realistic buckling, folding and coiling behavior**

"Fast Viscoelastic Behavior with Thin Features" by Wojtan, Turk

Georgia Institute of Technology (SIGGRAPH)

- **Combines a high resolution surface mesh with a tetrahedral finite element simulator that makes use of frequent re-meshing**
- **Allows for fast and detailed simulations of complex elastic and plastic behavior**
- **Significantly expand the range of physical parameters that can be simulated with a single technique**
- **Computes masses, collisions, and surface tension forces on the scale of the fine mesh (to help avoid**

visual artifacts)

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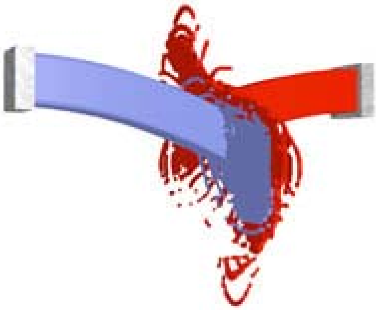
A Look Ahead...

Density Contrast SPH Interfaces



A Unified Handling of Immiscible and Miscible Fluids