Practical Animation of Liquids
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Alleged Contributions

- Hybrid surface representation
- Moving object interaction
- Controls for animators
Actual Contribution

- Hybrid surface representation
Actual Contribution

• Hybrid surface representation
• Combines strengths of previously isolated techniques
  - Level set surfaces – smooth, don't evolve well during simulation
  - Particle surface tracking – very hard to make smooth, easy to evolve well during simulation
Some Level Set Background

- An Implicit Surface captures a shape as the set \( \{ x : f(x) = 0 \} \)
- A useful choice for \( f(x) \)? “Signed distance function”
- “Level Set Methods” discretize \( f(x) \) on a regular grid.
Some Level Set Background

• Robustly capture surfaces of arbitrary topology
• Rendering is easy
Some Level Set Background

- Rendering is easy
- Can Directly raytrace the implicit surface
Some Level Set Background

- Rendering is easy
- Can directly raytrace the implicit surface
- Or use “marching cubes” algorithm
  - Compute intersection points of the surface and a voxel grid
  - Result: triangle tesselated surface
  - Patented 1987!
Level Set Problems

- Grids have limited resolution
- Can't resolve small droplets or thin sheets
- Result: Lost volume!
What About Particles?

- Other Lagrangian methods?
- Marker-and-cell method already uses them
- Cheap to advect through a velocity field
- Smoothed Particle Hydrodynamics is entirely particle-based
Problems with Particles

- Try to extract a smooth surface!
Combine Techniques!

• Evolve a level set to achieve a smooth surface

• Also evolve particles
  – Use to “correct” the level set where small details are smeared out
  – Render droplets directly if they escape

• Use particles in areas of high curvature; ignore them in smooth areas.
Initializing the Level Set

• Given an initial fluid distribution implied by particles
• Only once, use particles to initialize level set function $f(x)$. 
Evolving the Level Set

- Only care about the surface, where $f(x)=0$

- They integrate using “upwind differencing”
Re-initializing the Level Set

- A pack of lies
Controls for Animators

- A pack of lies
Results

- Pretty Blue Water, Shrek Mud
Handling Moving Objects

- F
Controls for Animators

- Generalization of the last method
- Arbitrary velocity constraints
Conservation of Mass