Practical Animation of Liquids

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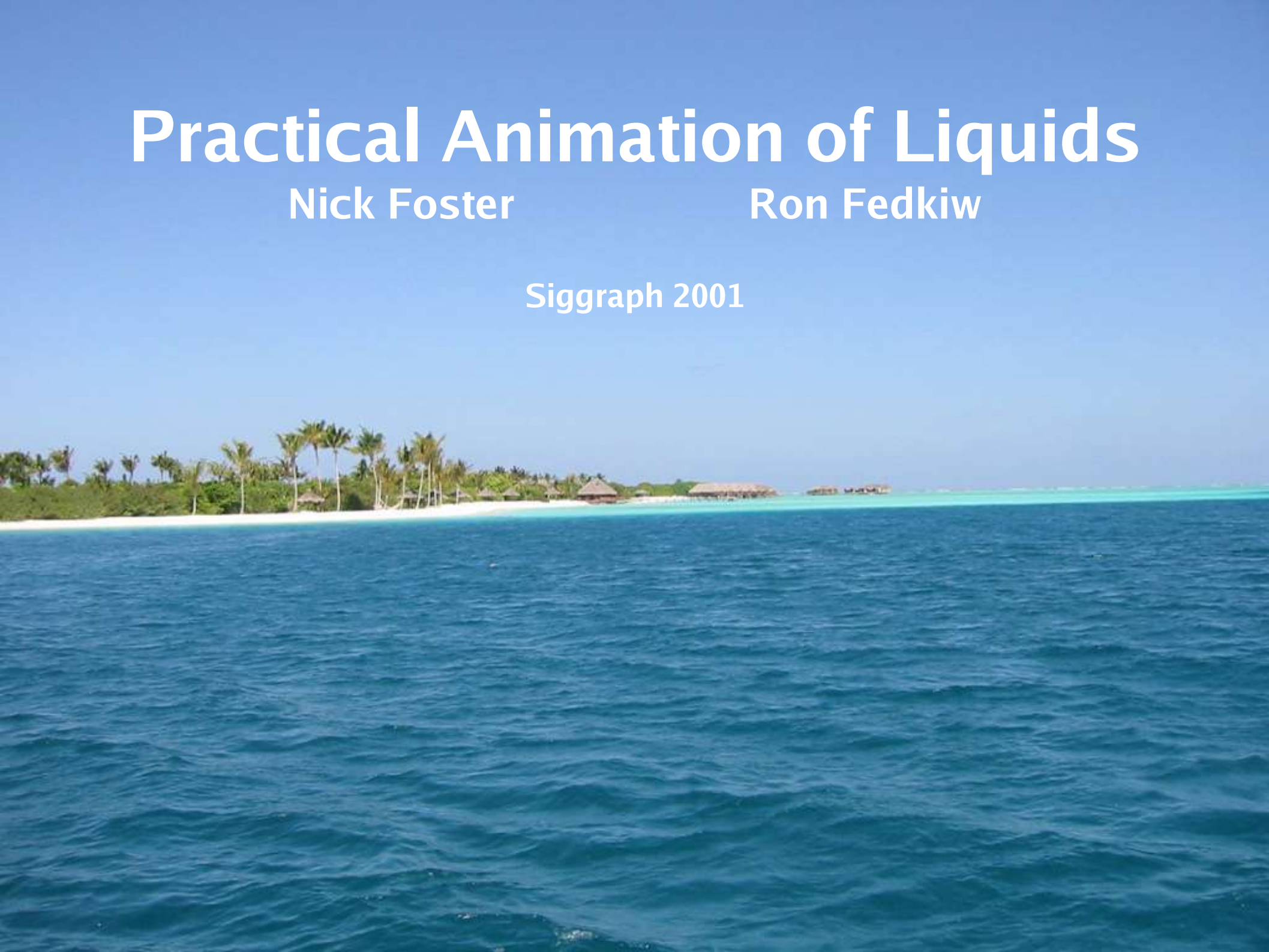
Siggraph 2001



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

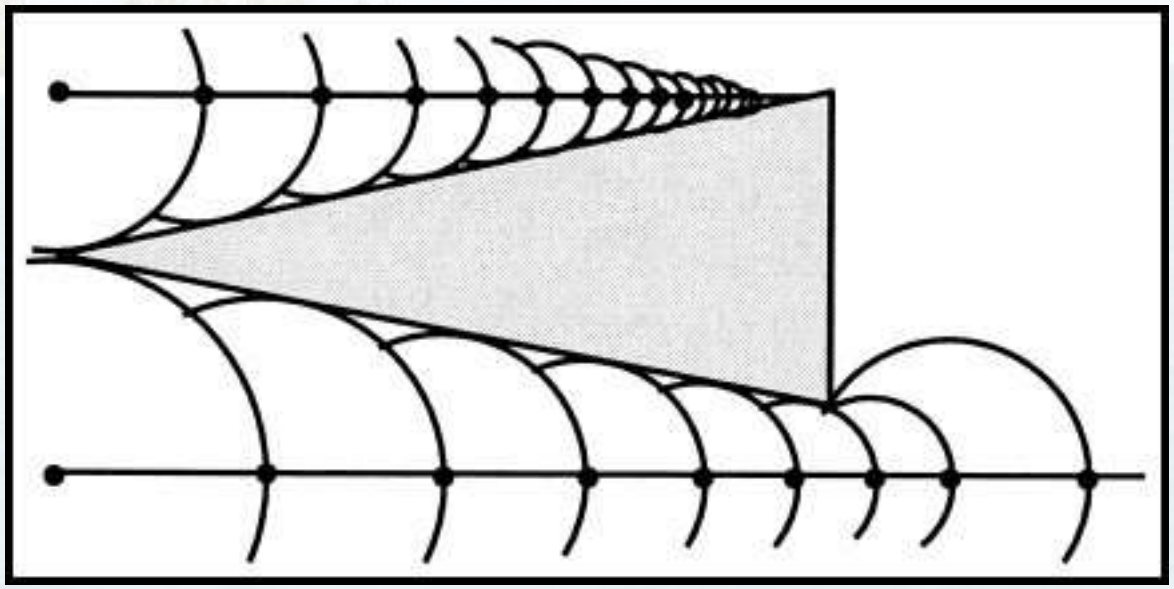
- *An Implicit Surface* captures a shape as the set $\{x : f(x) = 0\}$
- A useful choice for $f(x)$? "Signed distance function"
- *"Level Set Methods"* discretize $f(x)$ on a regular grid.

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 “u pwind differencing”

Re-initializing the Level Set

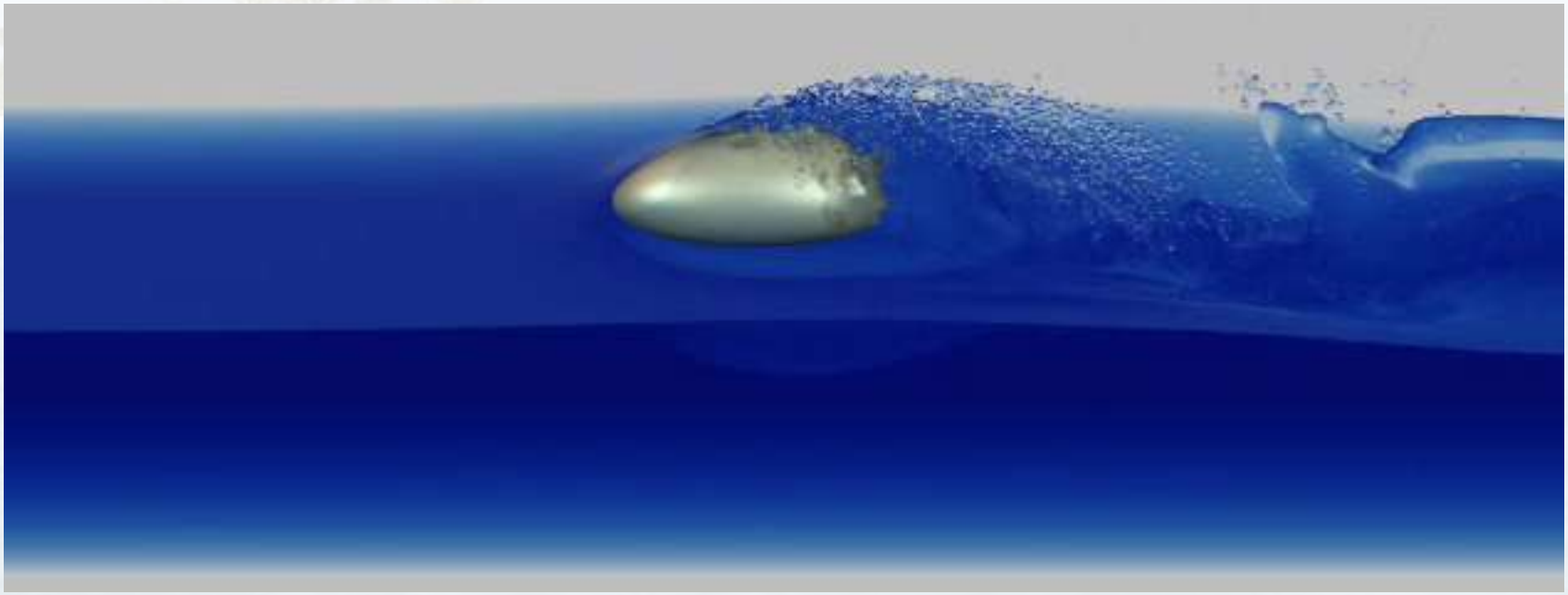
- A pack of lies

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

F

- F