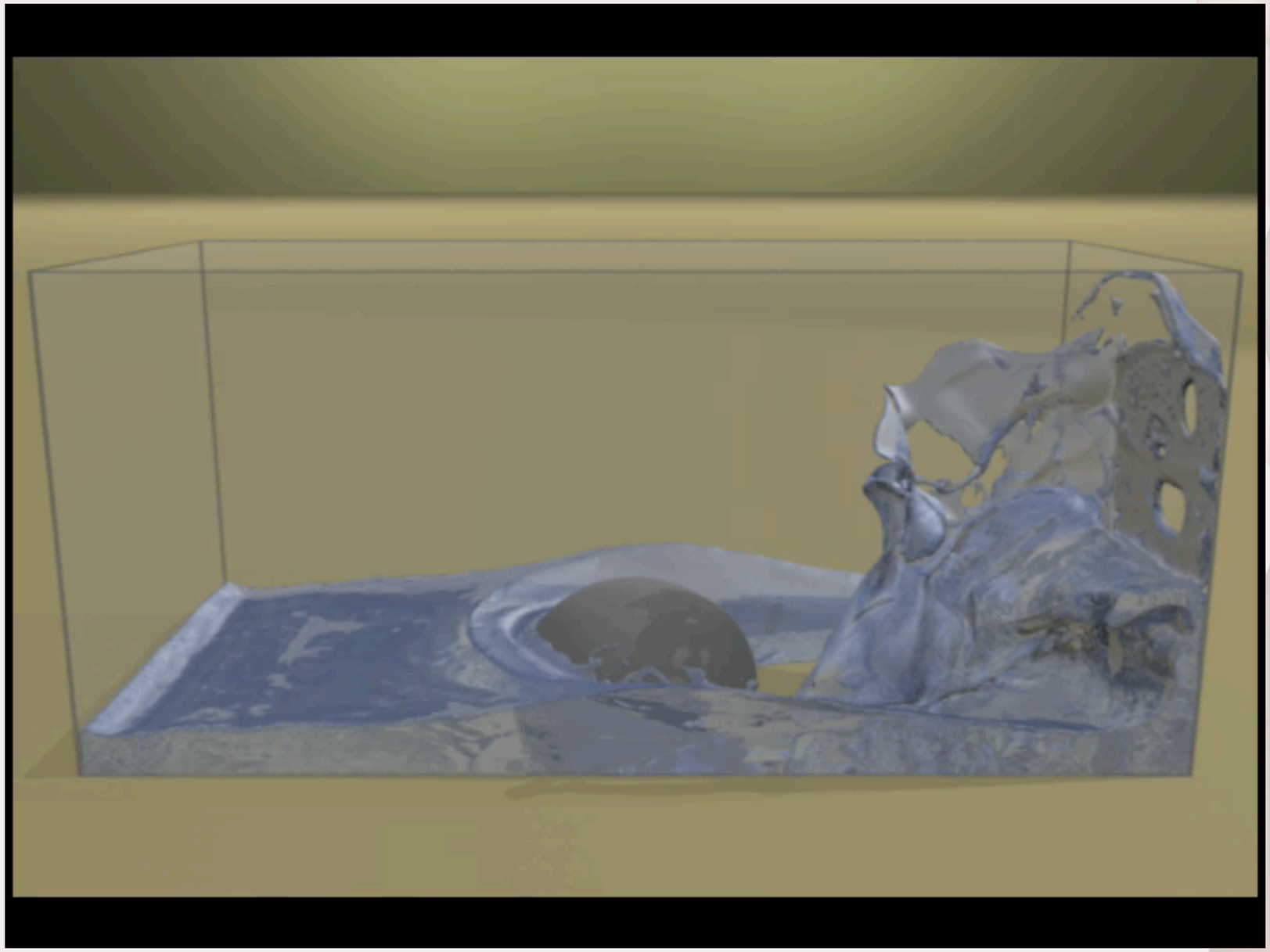
Free Surface Fluids

Adrien Treuille



source: Chentanez *et al* [2007]

Overview

- **Questions about project 2?**
- **Solid Boundaries.**
  - ***Affect on the advection step?***
  - ***Affect on the projection step?***
- **Free-surfaces.**
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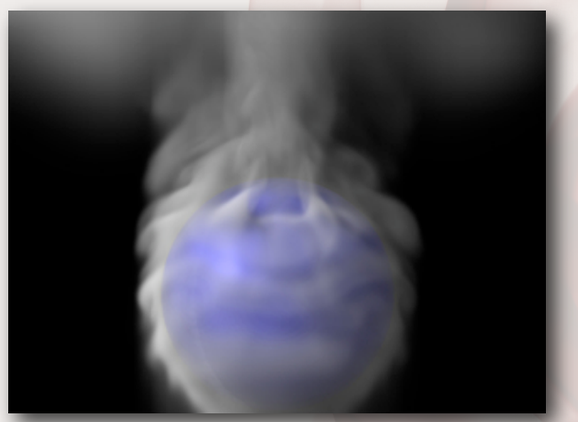
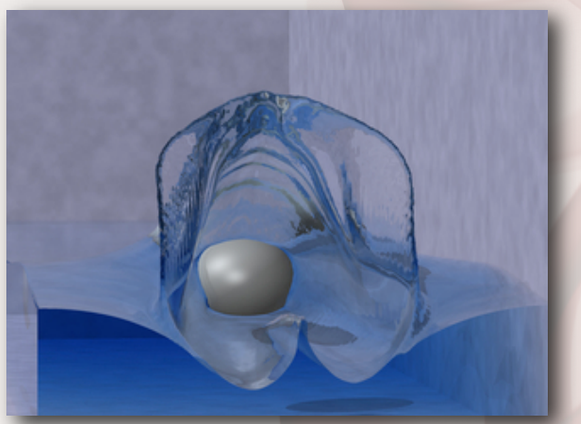
- **Open Challenges**
- **Closing Statements**





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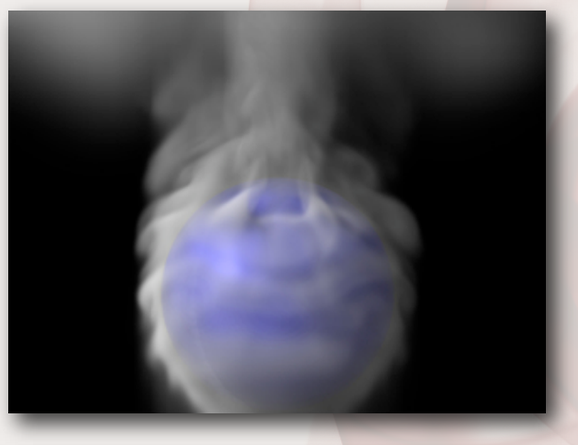

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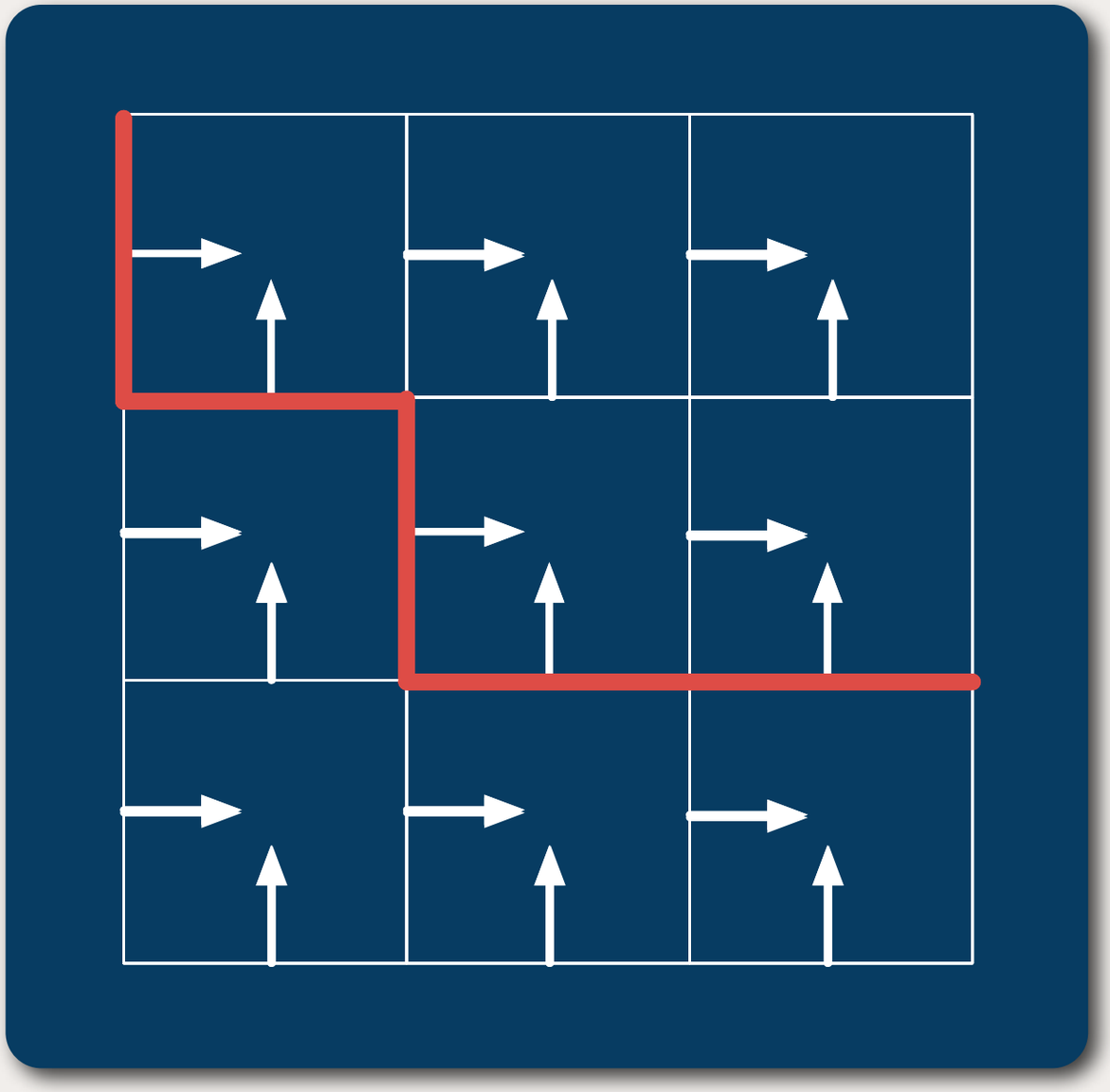
Solid Boundaries

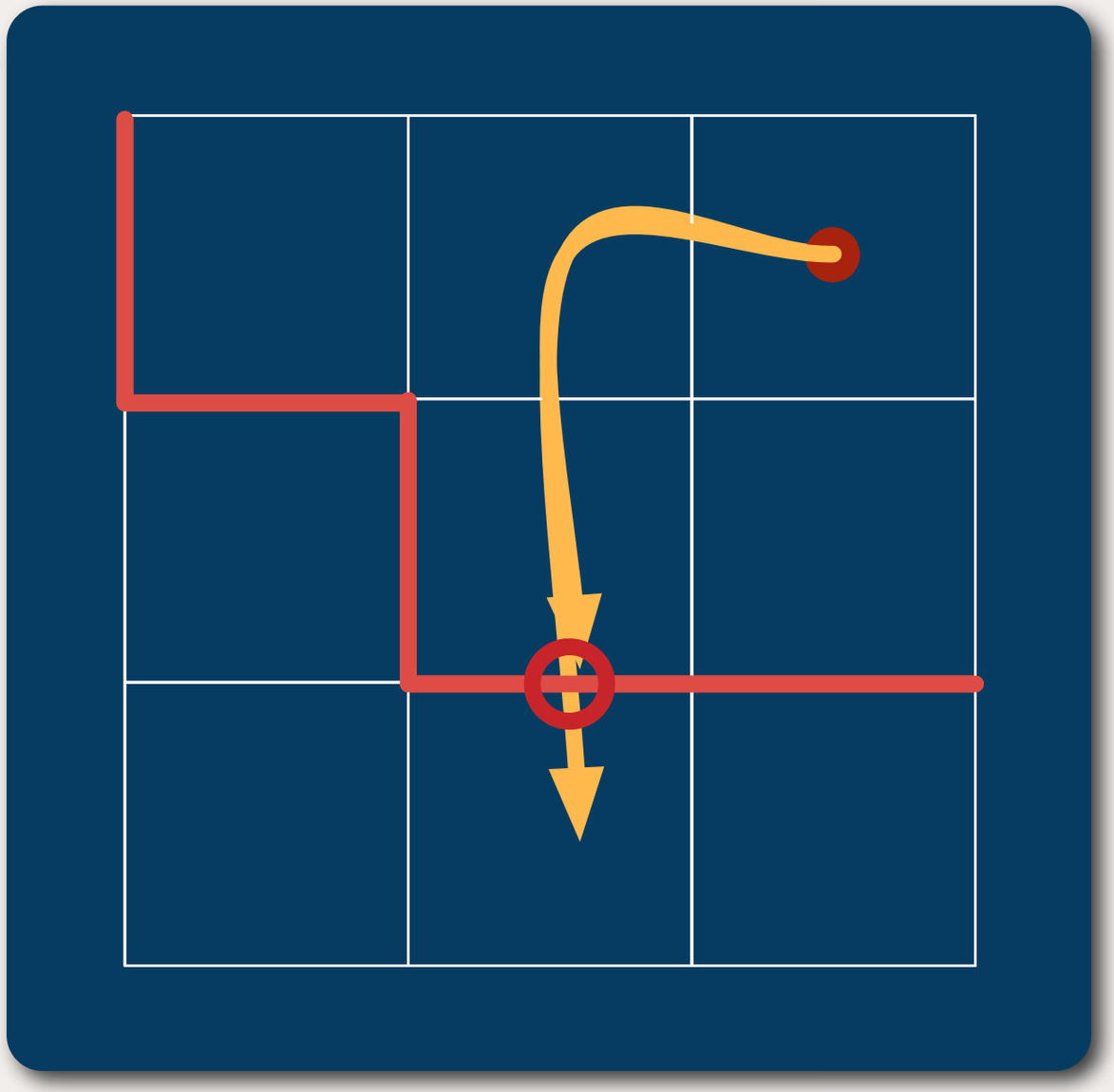


Condition:

$$\mathbf{u} \cdot \mathbf{n} = 0$$

- **How does this affect advection?**
- **How does this affect projection?**

Path Clipping



Pressure

$p_{-1,1}$	$p_{0,1}$	$p_{1,1}$
$p_{-1,0}$	$p_{0,0}$	$p_{1,0}$
$p_{-1,-1}$	$p_{0,-1}$	$p_{1,-1}$

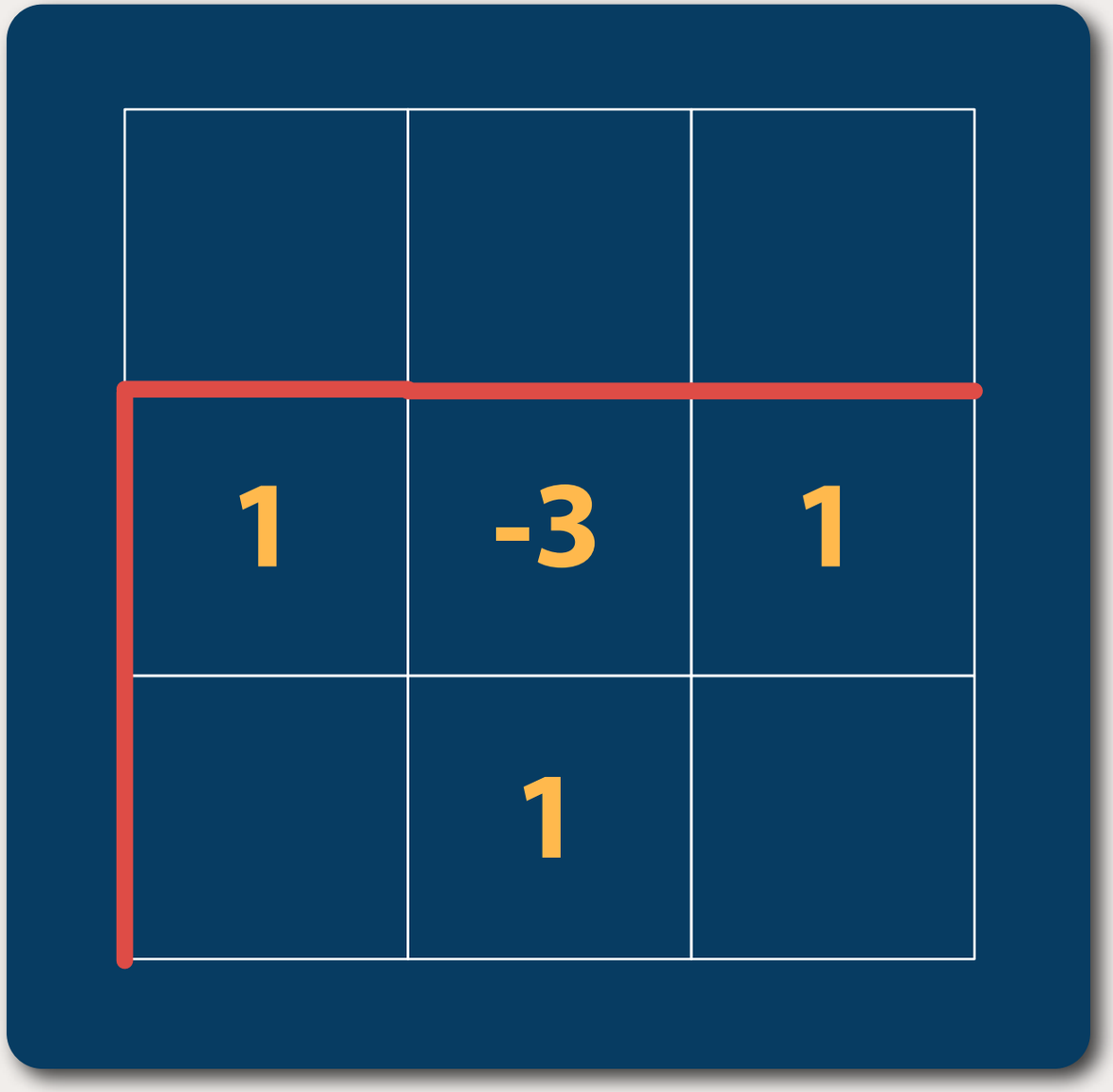
$$\nabla \mathbf{u}_{0,0} = p_{0,-1} + p_{0,1} + p_{-1,0} + p_{1,0} + 4p_{0,0}$$

Pressure

	1	
1	-4	1
	1	

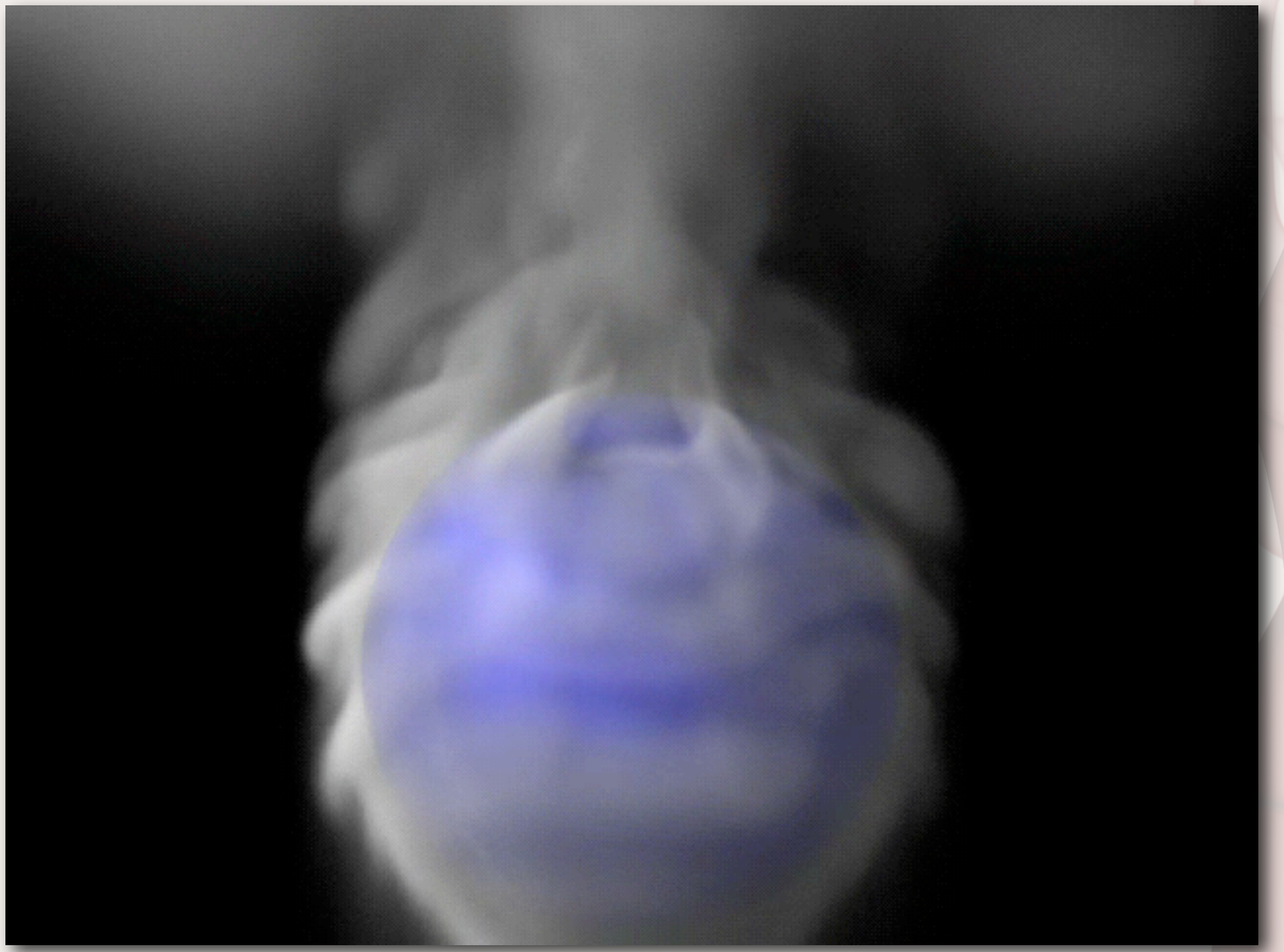
$$\nabla \mathbf{u}_{0,0} = p_{0,-1} + p_{0,1} + p_{-1,0} + p_{1,0} + 4p_{0,0}$$

Pressure



$$\nabla \mathbf{u}_{0,0} = p_{0,-1} + p_{0,1} + p_{1,0} - 3p_{0,0}$$

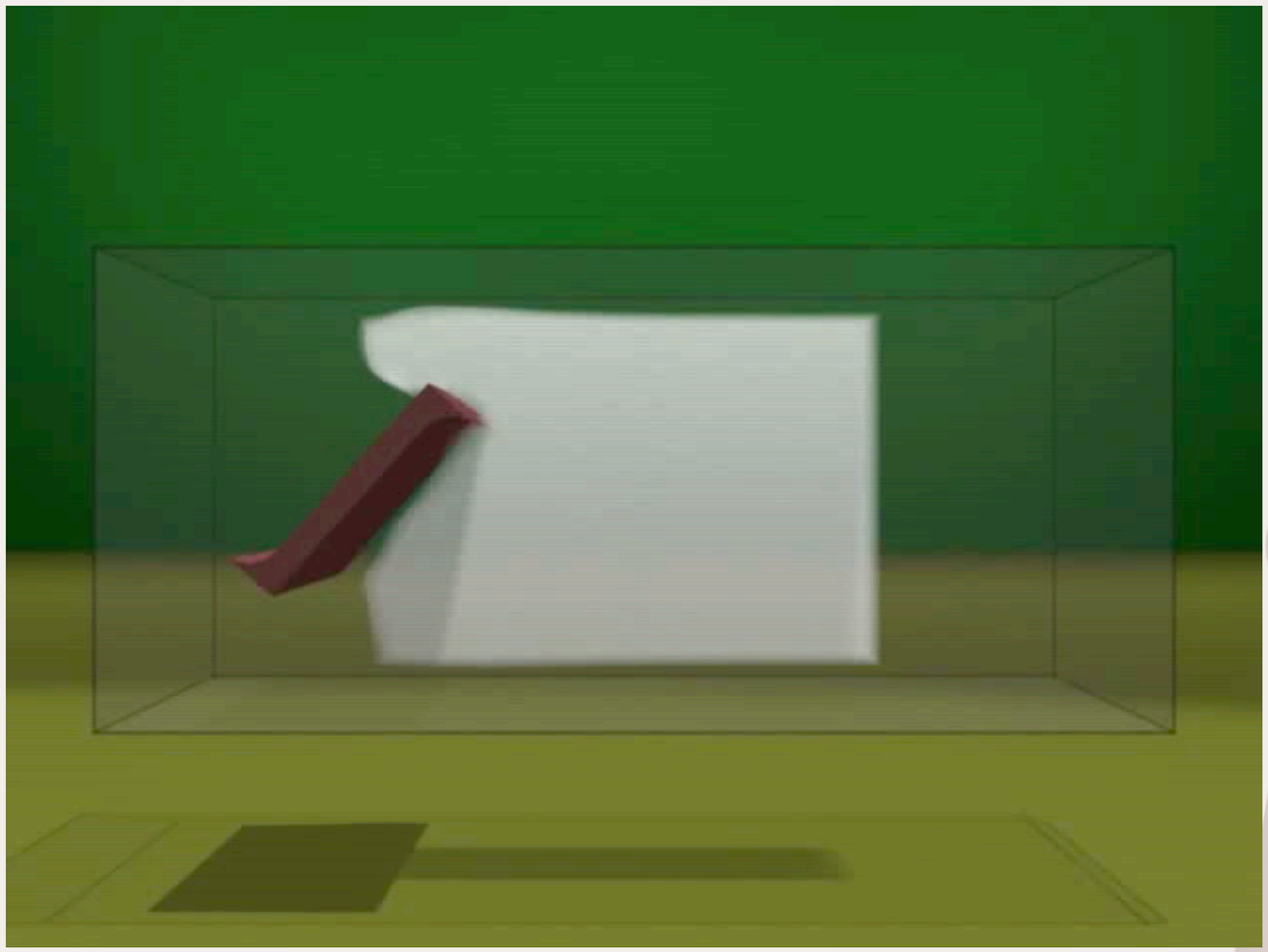
Example



source: Losasso, Gibou, and Fedkiw [2004]

Question

- What about non-rectilinear boundaries?
  - Tetrahedral meshes.



source: Feldman O'Brien and Klingner [2005]

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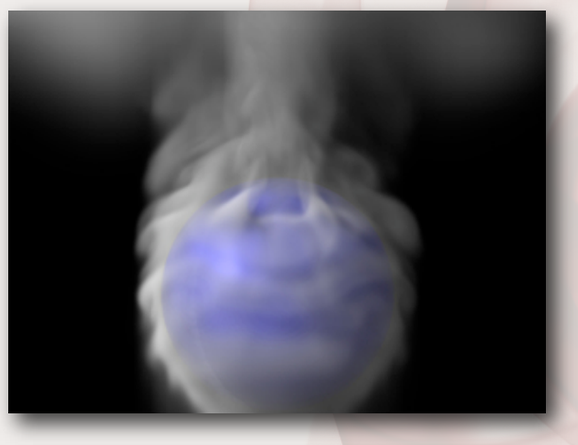

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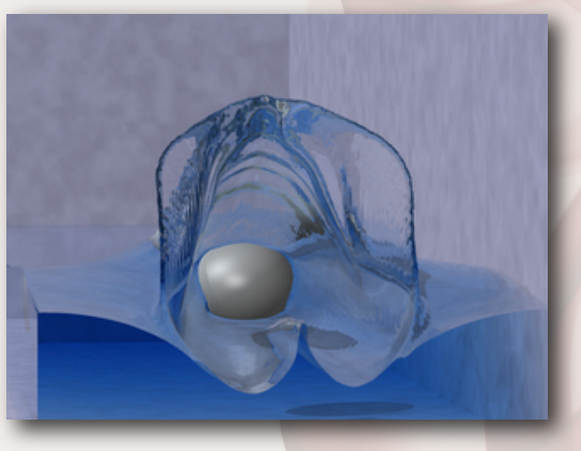
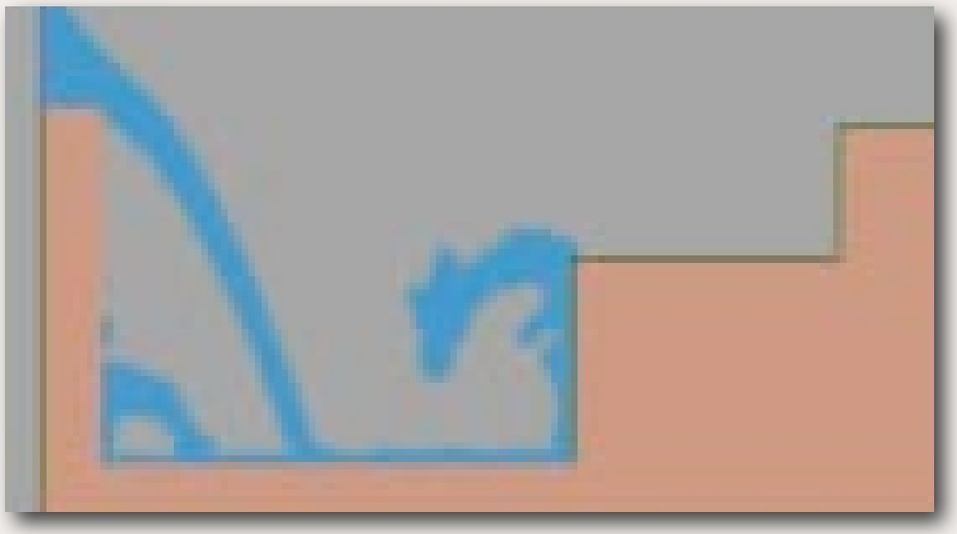


Free Surfaces

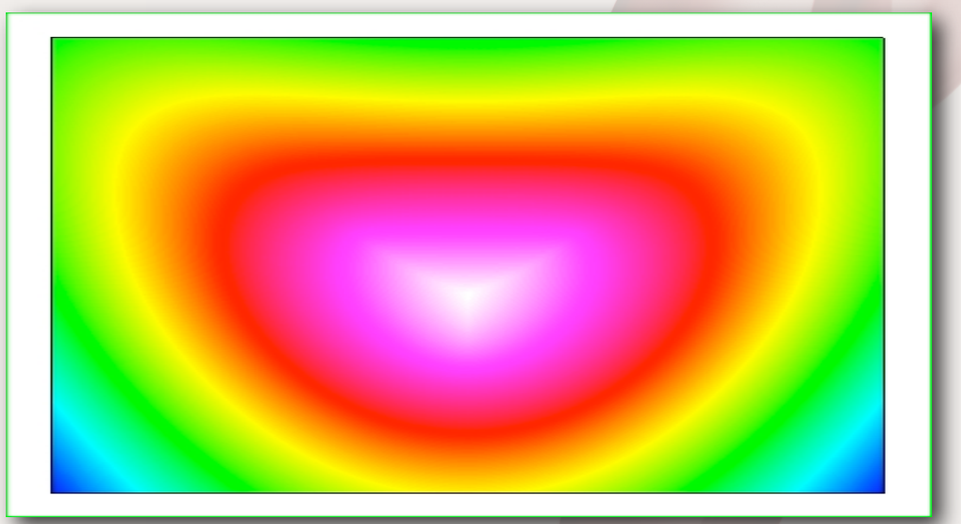
- **Surface between two fluids.**

source: http://plus.maths.org/issue22/news/skimming/

Volume of Fluids

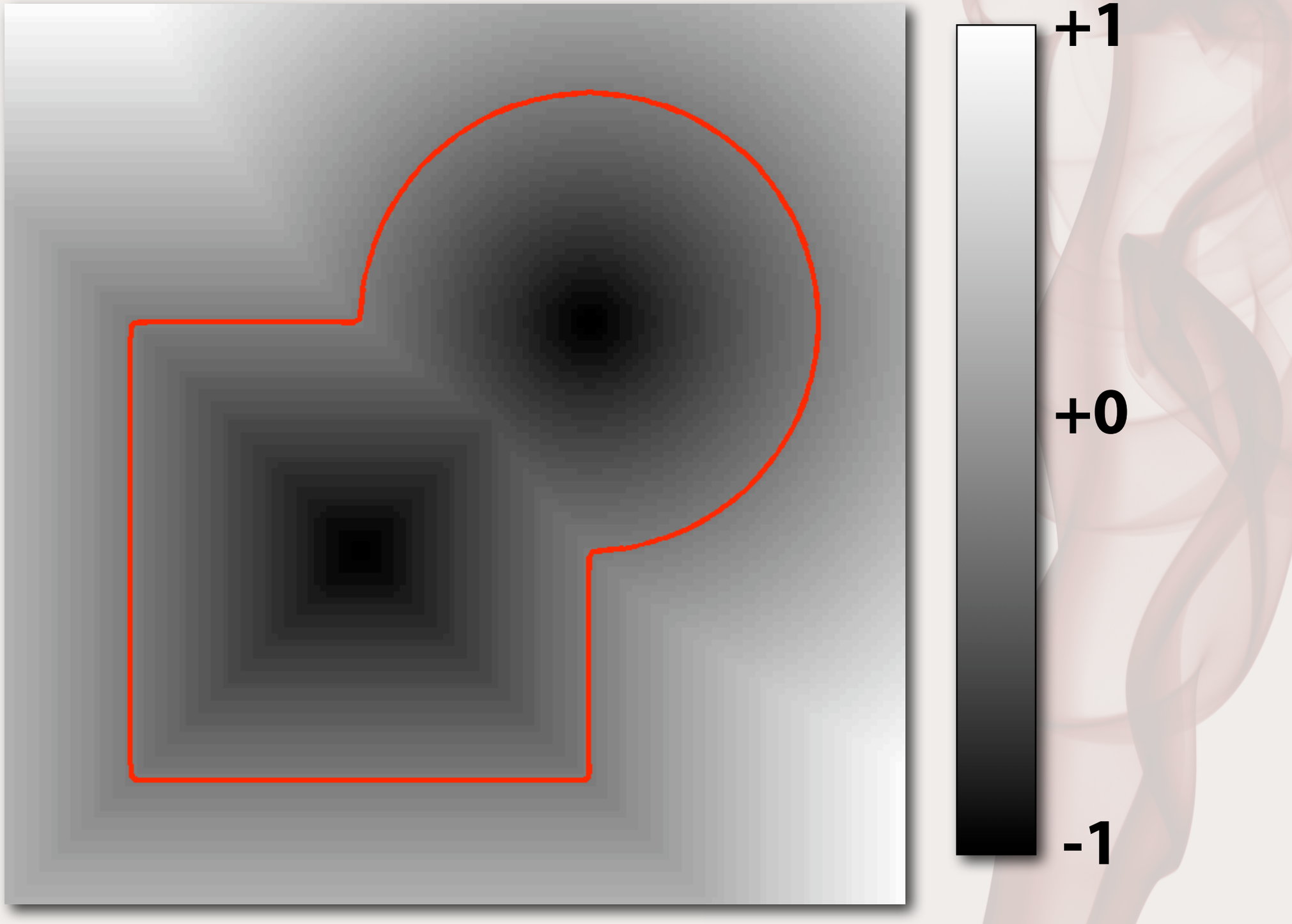


Signed Distance Function



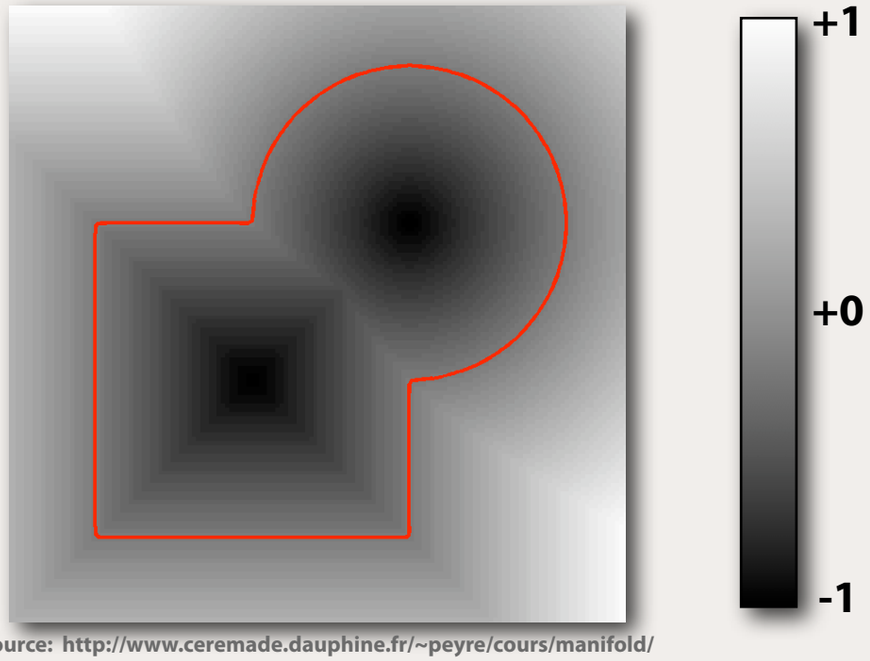
source: http://www.csc.fi/english/pages/elmer/examples/fallingdrop/

Signed Distance Function



source: http://www.ceremade.dauphine.fr/~peyre/cours/manifold/

Signed Distance Function



source: http://www.ceremade.dauphine.fr/~peyre/cours/manifold/

- Easy to know where water is.
- Good surface reconstruction: marching cubes algorithm.
- Advection OK!
- Must be redistanced:

$$\phi\big|_{\partial M} = 0 \quad ||\nabla\phi|| = 1$$

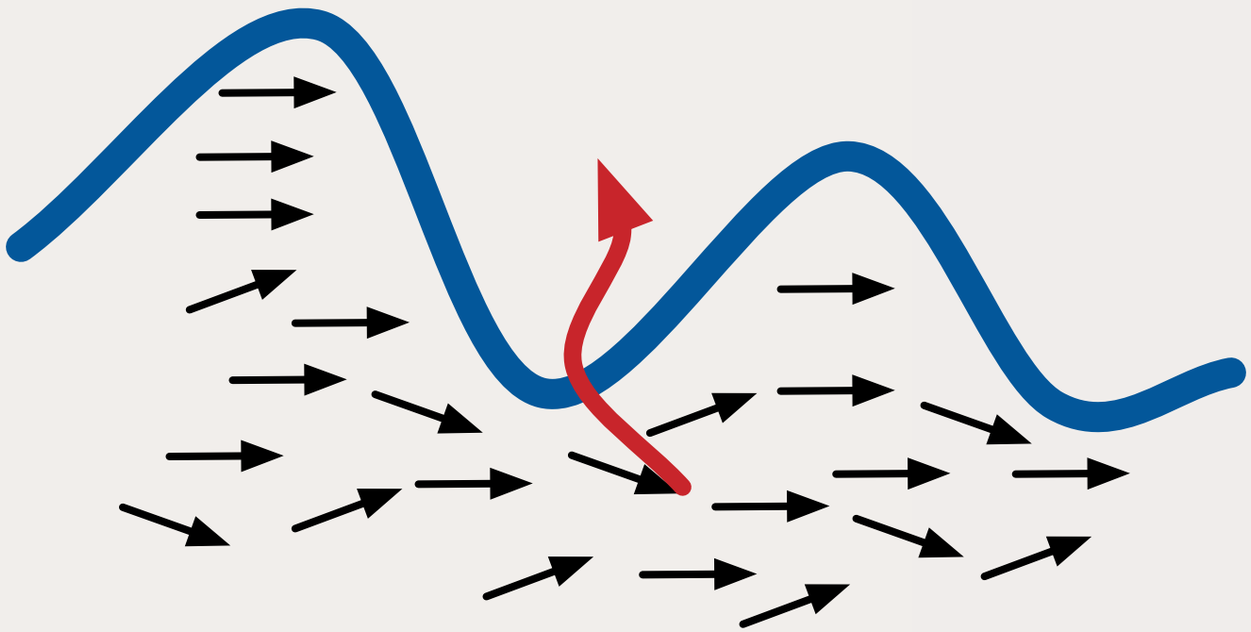
Signed Distance Questions

- How can we perform intersection?
- How can we perform union?

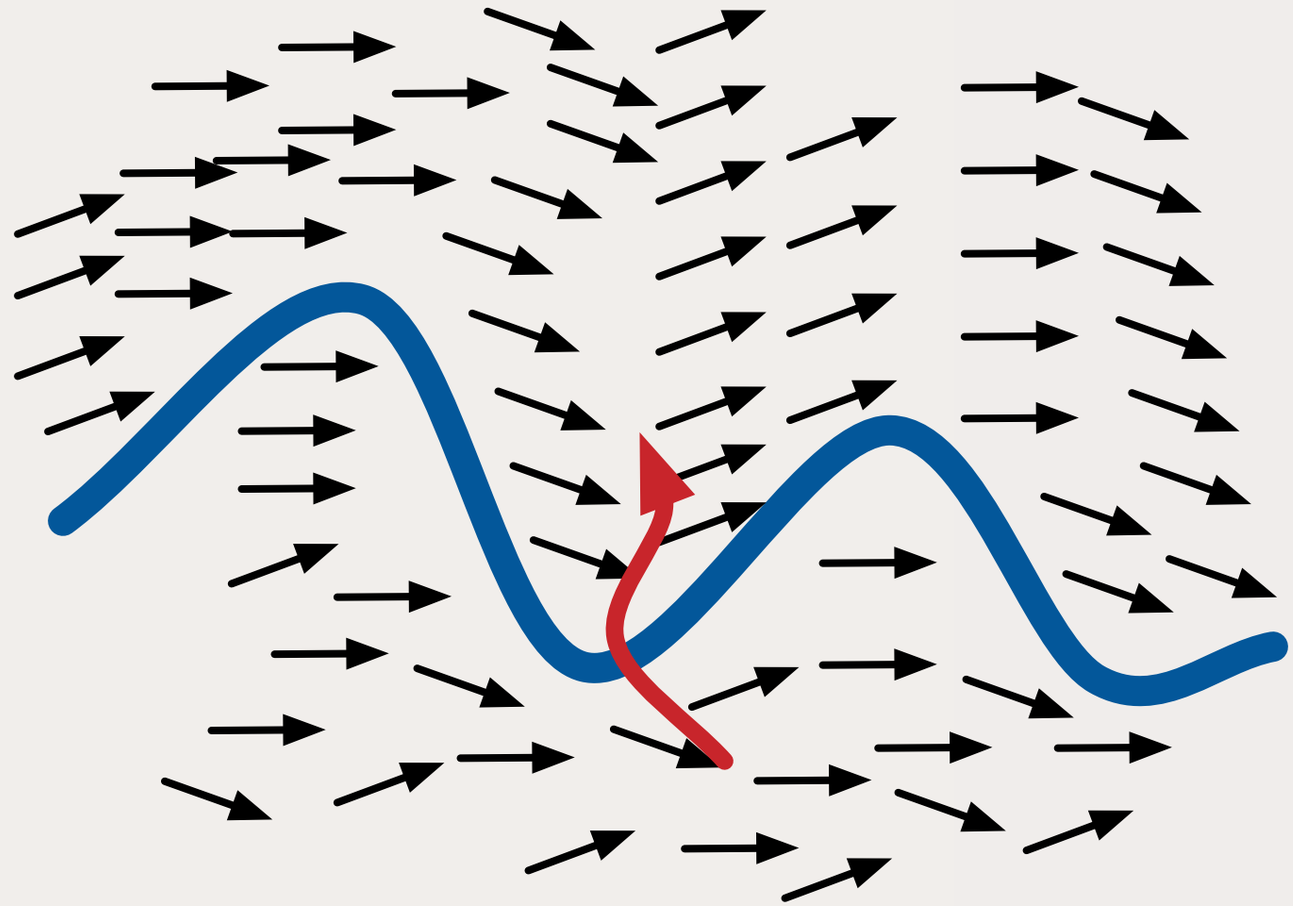
Liquid Simulation Issues

- How do we change the advection step?
- How do we change the projection step?

Path Clipping



Velocity Extension



D. Adalsteinsson and J. A. Sethian. *The Fast Construction of Extension Velocities in Level Set Methods*. Journal of Computational Physics [1999]

Pressure

	1	
1	-4	1
	1	

$$\nabla \mathbf{u}_{0,0} = p_{0,-1} + p_{0,1} + p_{-1,0} + p_{1,0} + 4p_{0,0}$$

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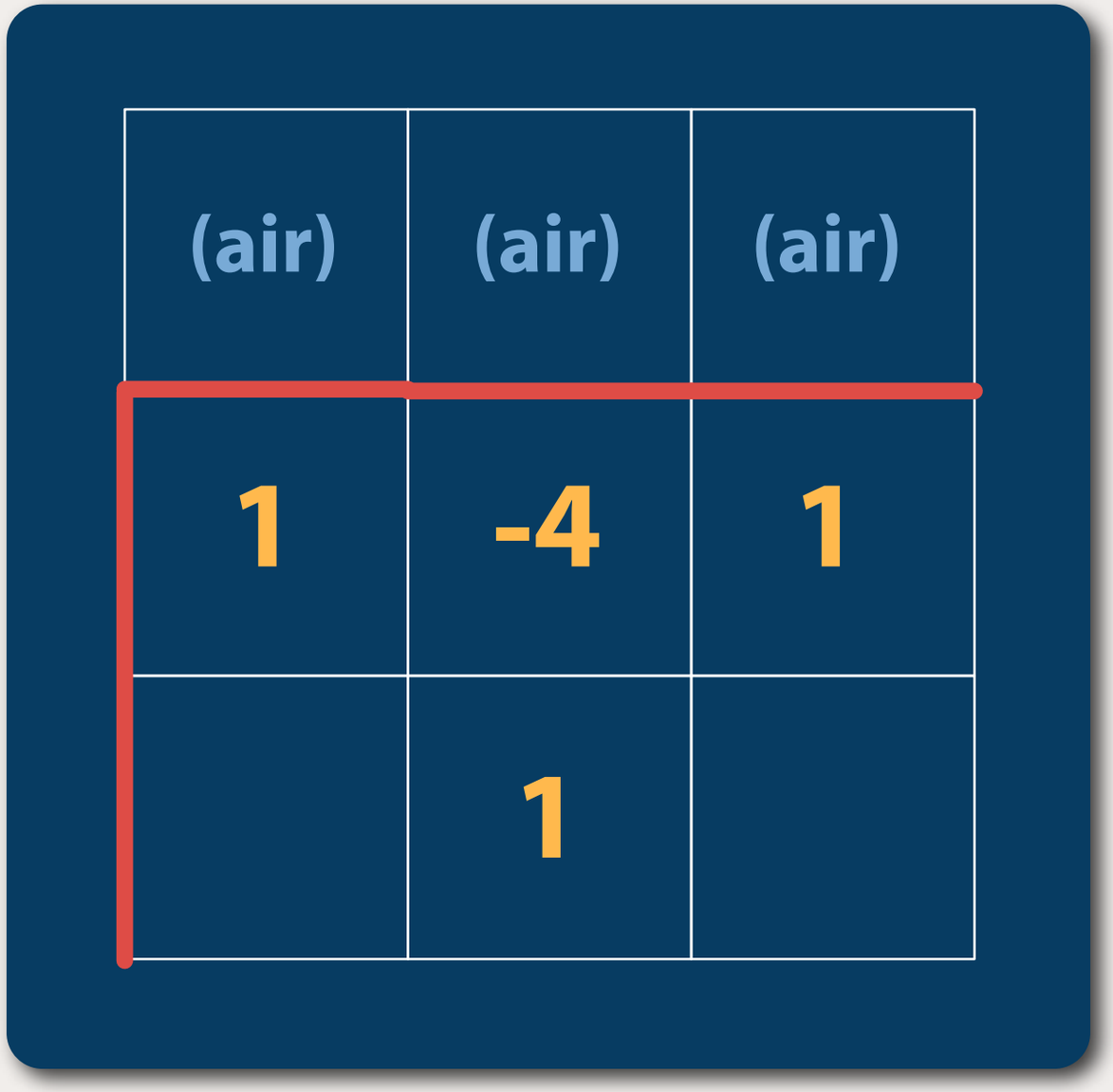

$$\nabla \mathbf{u}_{0,0} = p_{0,-1} + p_{0,1} + p_{1,0} - 4p_{0,0}$$

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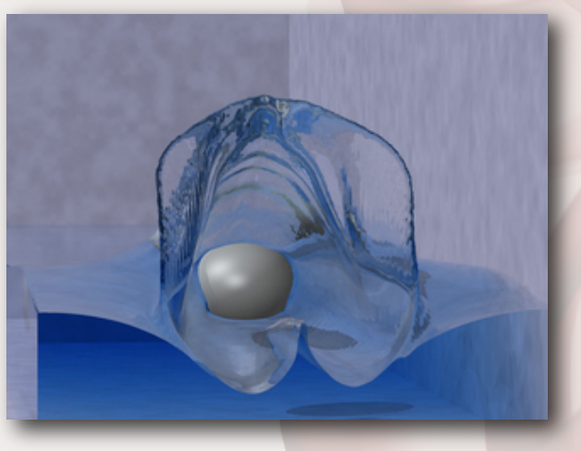

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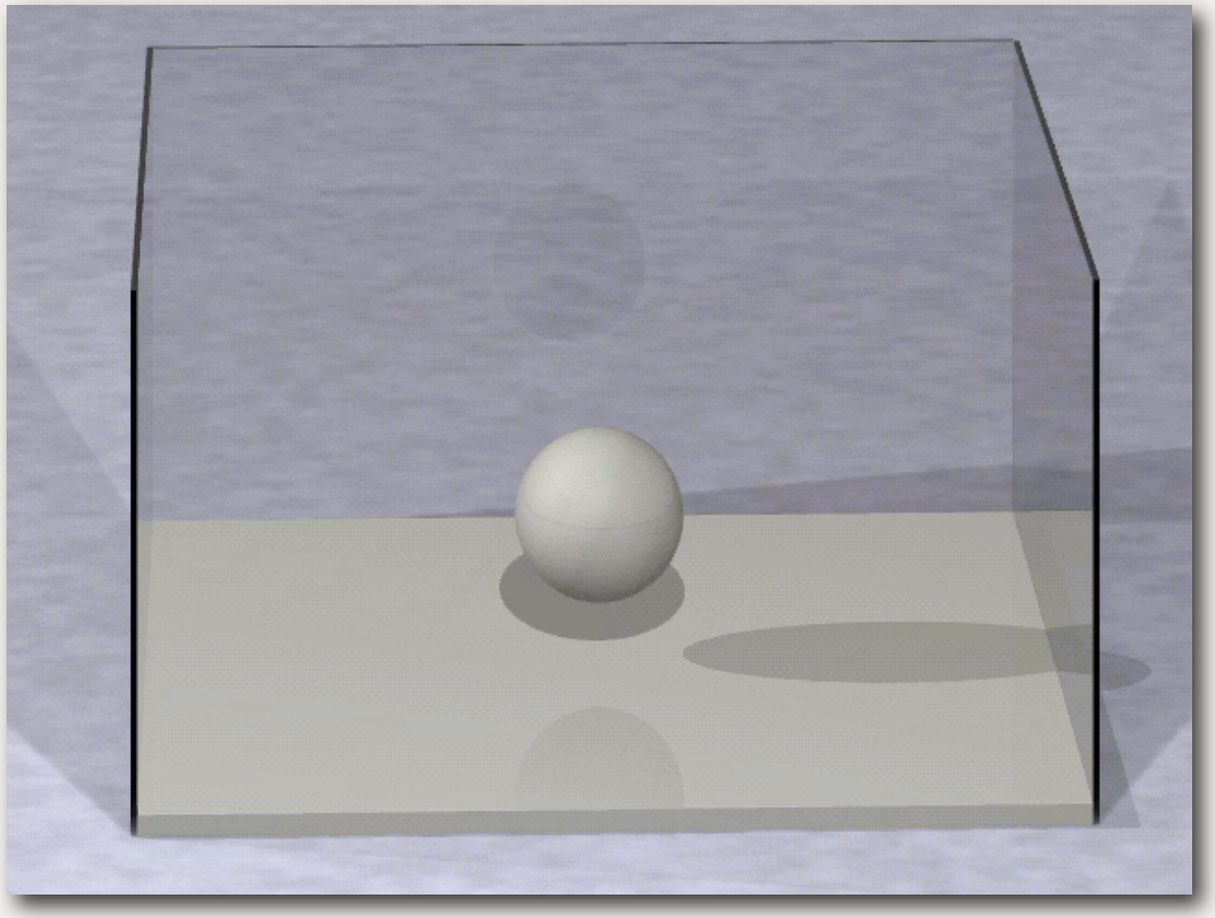
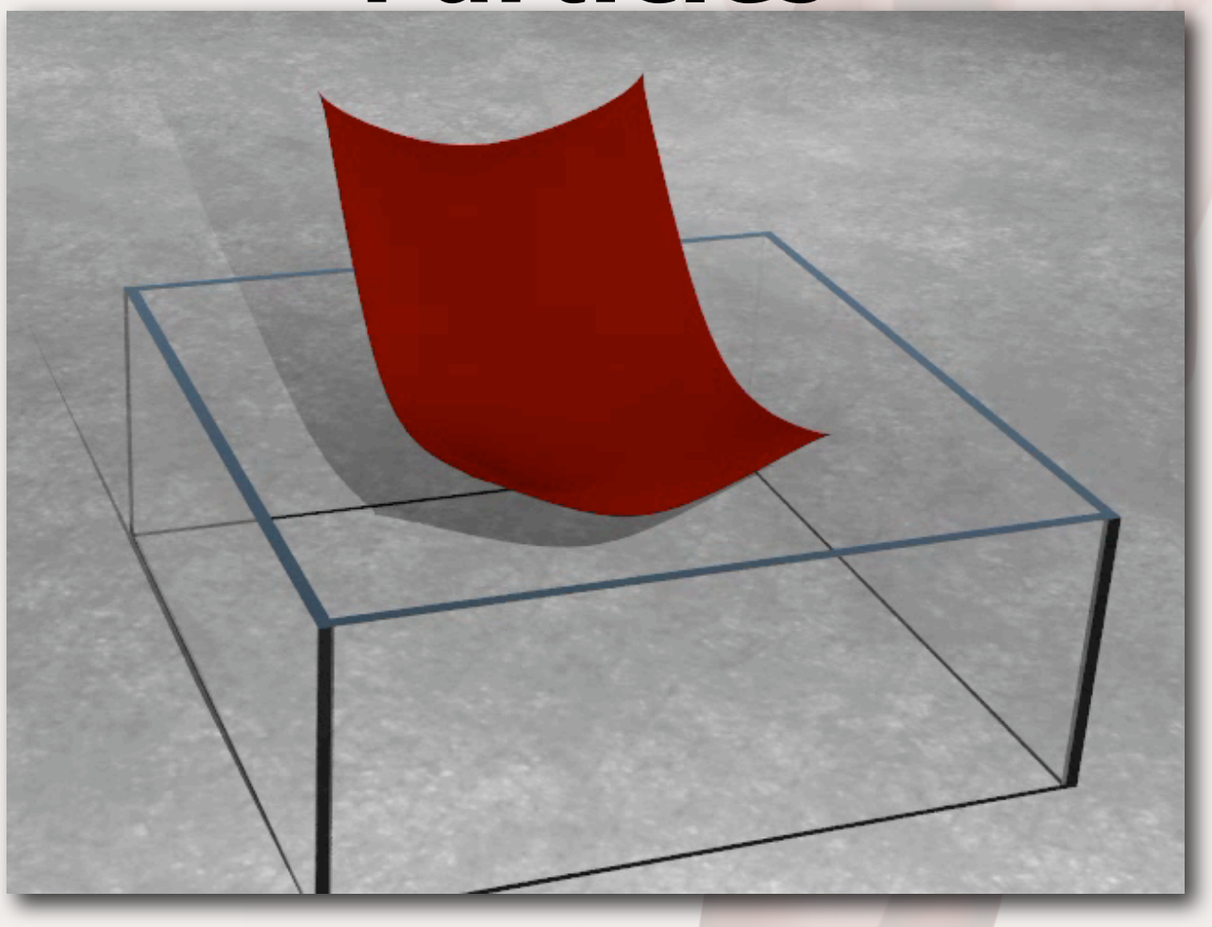
Resolving Small Features

Quad Trees



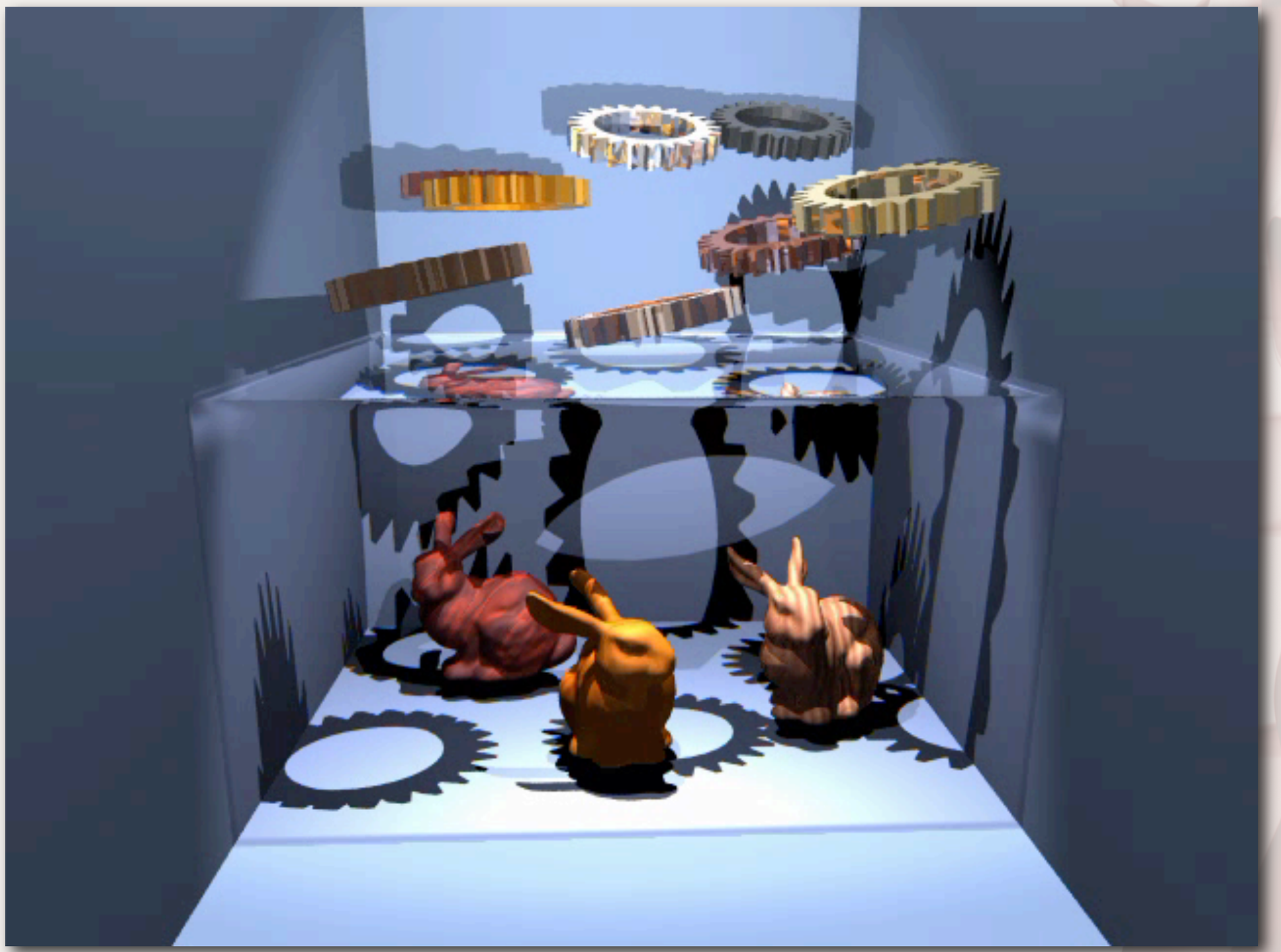
source: Losasso, Gibou, and Fedkiw [2004]

Particles



source: Guendelman et. al. [2005]

Coupling



source: Carlson, Mucha, and Turk [2004]

Real-time

source: Treuille, Lewis, and Popović [2004]

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Closing Statements

- Next Wednesday's class.
- Question:
  - How can we preserve volume?