Surface Tensions in Liquid Animation

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1 Introduction

This sketch presents a method for the animation of liquid with surface tensions. Surface tensions are indispensable phenomena to be simulated for describing the interfacial dynamics between two fluids. For example, the deformation and the movement of bubbles - the air enclosed by water - are strongly influenced by surface tension forces.

Differently from the techniques developed for the computational fluid dynamics (CFD) applications in which surface tension forces are calculated from the physically accurate geometry of the interfaces between two fluids (for recent techniques and surveys, see [Shin and Juric 2002]), our algorithm estimates them from the minimum simulation data, which supports the easy implementation and the efficient numerical simulation at the cost of the accuracy of physical simulation. Our algorithm can be easily implemented as a part of the numerical Navier-Stokes solver with the standard marker and cell (MAC) grid system [Foster and Fedkiw 2001]. But, unlike [Foster and Fedkiw 2001], our system constructs the polygonal interfaces in the similar way to the fast fluid animation scheme [Kunimatsu et al. 2001]. Rendering with optical effects can be accelerated by means of the vertex shader.

2 Implementation

To simulate two fluids with one system, we define a *material field* on the standard MAC grid system [Foster et al. 2001]. Figure 1(b) shows the material field corresponding to the water-air configuration shown in Figure 1(a). In this material field, 0 means air and 1 means water. The values between 0 and 1 mean the interfaces between two fluids. Although one grid stores only one scalar value for fluids configuration, the material field supplies the sufficient information for numerical simulation and geometry construction.

There are many techniques in CFD studies to calculate the surface tension forces from the geometric curvatures of interfaces. But, since the scientific accuracies are not required in computer animation, intuitively, we can see that the most efficient and easiest way to get the surface tension forces is to calculate them *only* with the material field data within the numerical simulation step before the geometry construction step. Figure 1(c) shows the velocity field generated by surface tension forces. They are calculated based on the fact that surface tension forces have tendencies to minimize the stress of interfacial surfaces. The stress vector between one grid and each adjacent grid is estimated from the material value differences. The determined surface tension forces are inserted as body forces to the numerical Navier-Stokes solving process [Foster et al. 2001]. The interfacial geometry is constructed by the marching cubes algorithm (see Figure 1(d)) for fast animation [Kunimatsu et al. 2001].

Figure 2 shows the rendered images of rising bubbles. The topological changes, movements and deformations of bubbles are animated. The buoyancy forces are simulated with the Navier-Stokes solver by considering the density differences. The shapes of bubbles are influenced by the buoyancy forces and the suface tension forces. At last, the shapes converge to the balancing point of buoyancy and surface tension. Without buoyancy, the shape of a bubble converges to sphere. Since the shapes of small bubbles are dominated by surface tension forces, they can be animated with particle system. Visually pleasing optical effects such as reflection, refraction and diffusion are rendered with conventional vertex shader techniques.

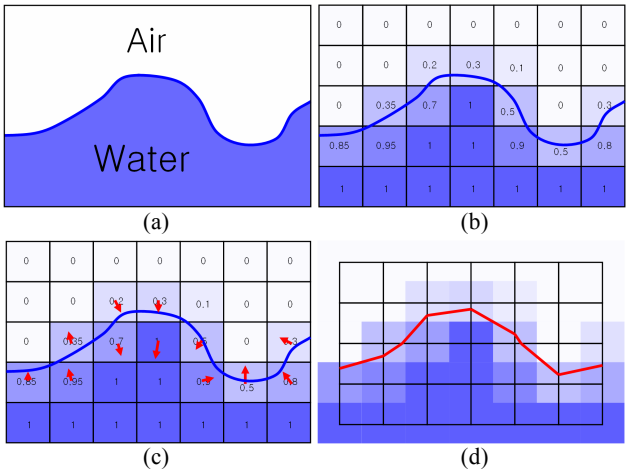

Figure 1: Method Outline

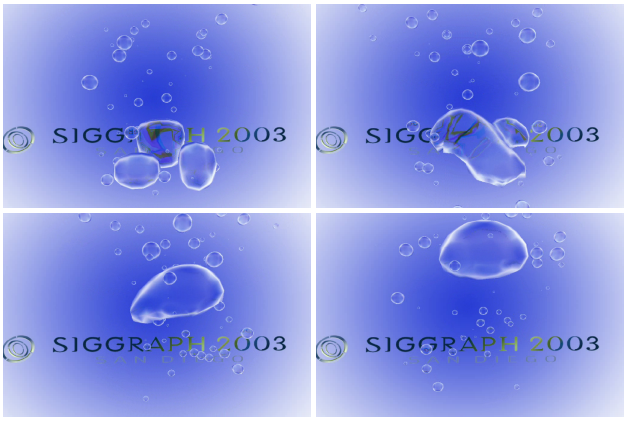

Figure 2: Rising Bubbles

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