

Physics-based Liquid Sound Synthesis



**WILLIAM MOSS, HENGCHIN YEH, JEONG-MO HONG[†]
MING C LIN AND DINESH MANOCHA**

Department of Computer Science
University of North Carolina at Chapel Hill

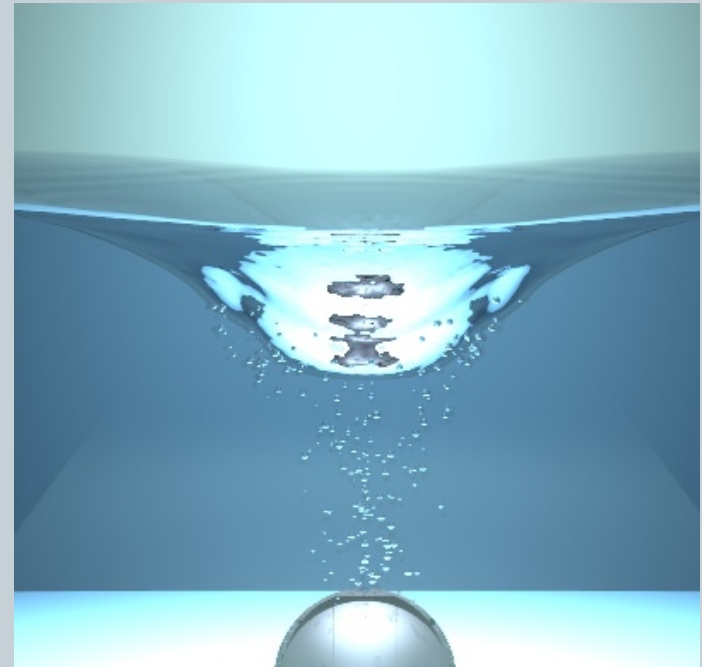
[†]Department of Computer Science & Engineering
Dongguk University

Goals and Motivation



- Automatically generate sound from fluid simulation

- Foley artists are expensive
- Games
- Virtual Reality



Background (Sound)



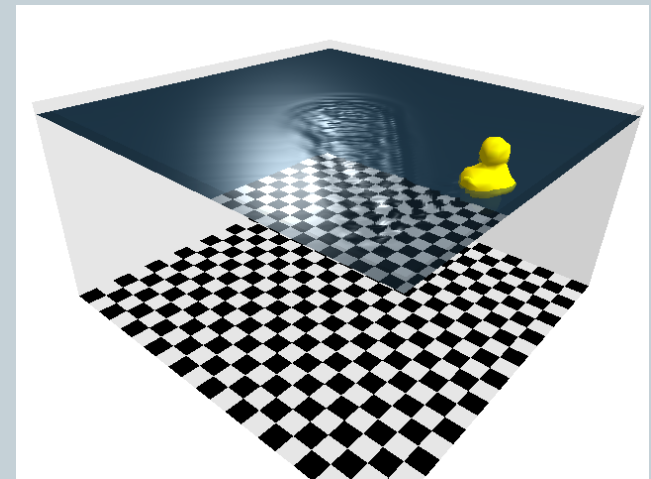
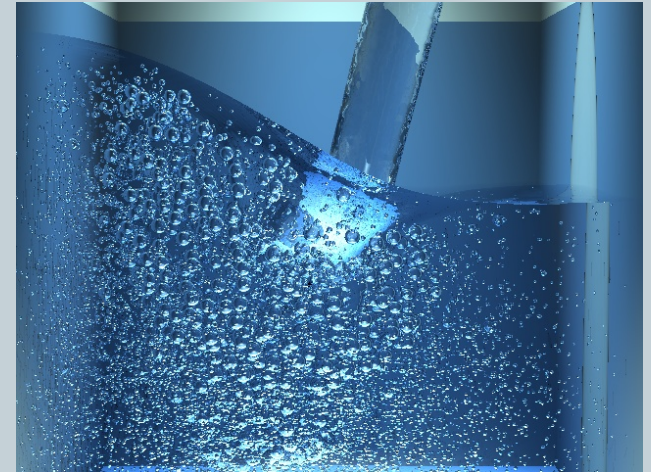
- Large body of physics/engineering research
 - Sound generated by resonating bubbles
- One computer graphics paper [van den Doel, 2005]
 - Spherical bubble model
 - No fluid simulator coupling
 - ✦ Hand tune bubble profile
- Automatically generate sound from fluid simulation
 - Model spherical and non-spherical bubbles
 - Couple to a fluid simulator (or two)
 - Decouple audio and fluid time step

Background (Fluid)



- **Grid-based methods**
 - Accurate to grid resolution
 - ✦ Bubbles can be smaller
 - Slow
 - Can be two-phase

- **Shallow Water Equations**
 - Simulate water surface
 - ✦ No breaking waves
 - Real time
 - One phase → Explicit bubbles



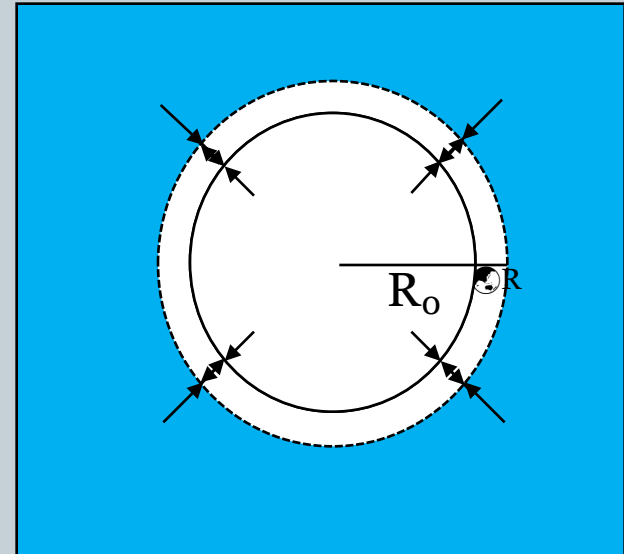
Method (Sound)



- Spherical Bubbles

$$f_0 = \frac{1}{2\pi} \sqrt{\frac{3\gamma p_0}{\rho R_0^2}}$$

$$\tau(t) = A \sin(2\pi f(t)t) e^{-dt}$$



- Non-spherical bubbles

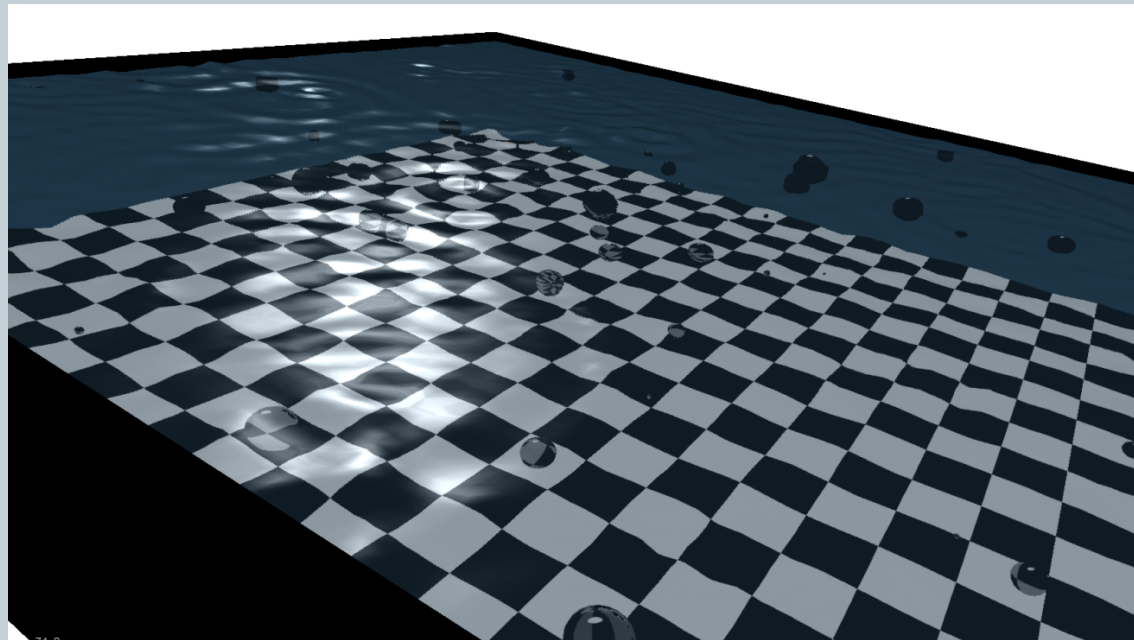
- Decompose into a spherical harmonics

$$f_n^2 \approx \frac{1}{4\pi^2} (n-1)(n+1)(n+2) \frac{\sigma}{\rho R_0^3}$$

Method (Fluid)



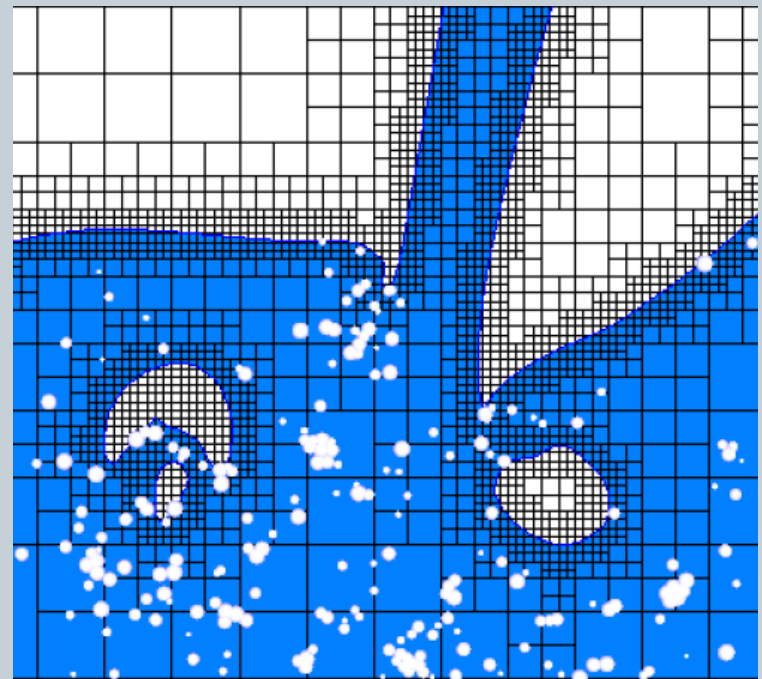
- **Shallow Water Equations**
 - Model bubbles explicitly as sphere
 - Generate sound using spherical bubble formula



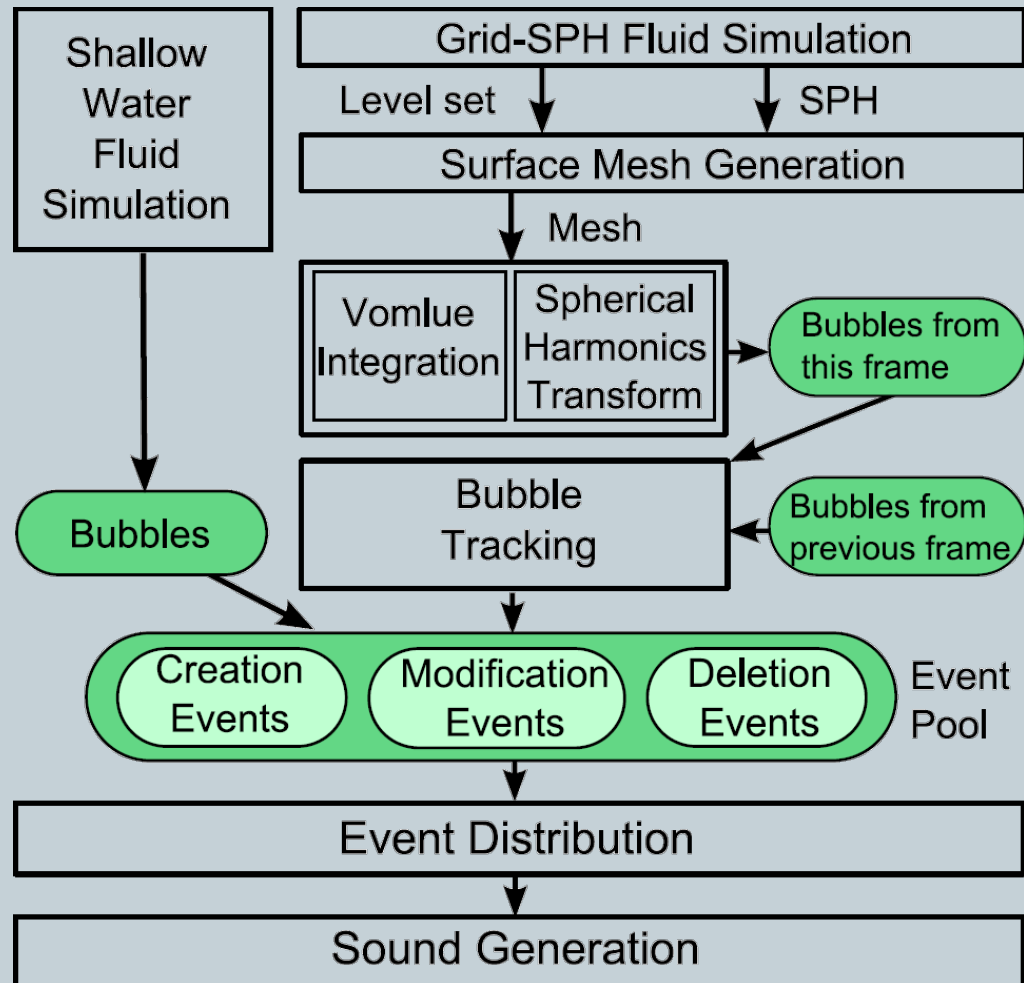
Method (Fluid)



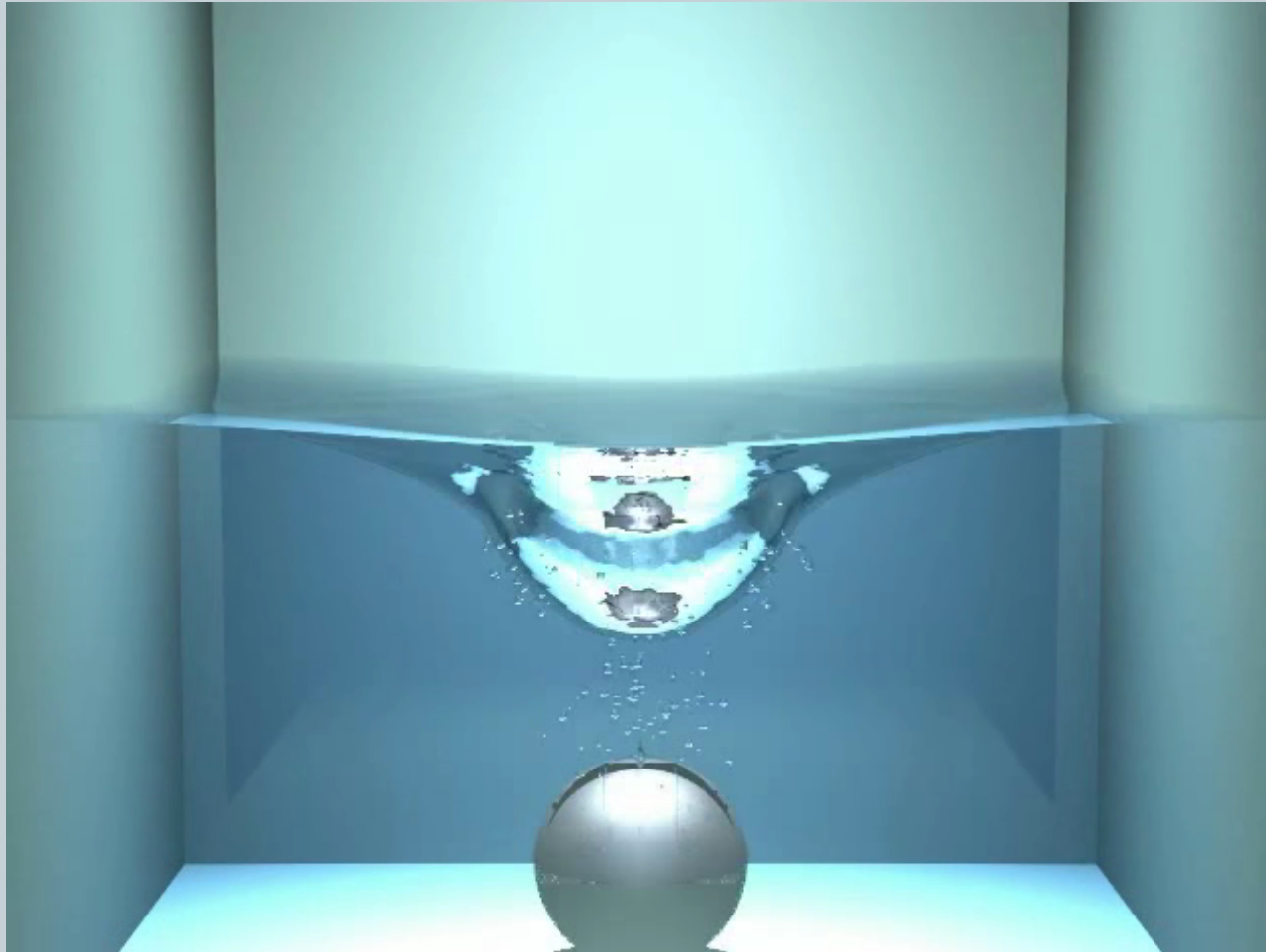
- **Grid-based method**
 - Small bubbles are finer than the grid
 - ✦ Model as small bubbles particles
 - ✦ Model large bubbles on the grid
- **Bubble Particles**
 - Interact with each other
 - ✦ Surface tension, pressure, cohesion
 - Interact with the grid
 - ✦ Get advected by the fluid
 - ✦ Exert forces back on the fluid



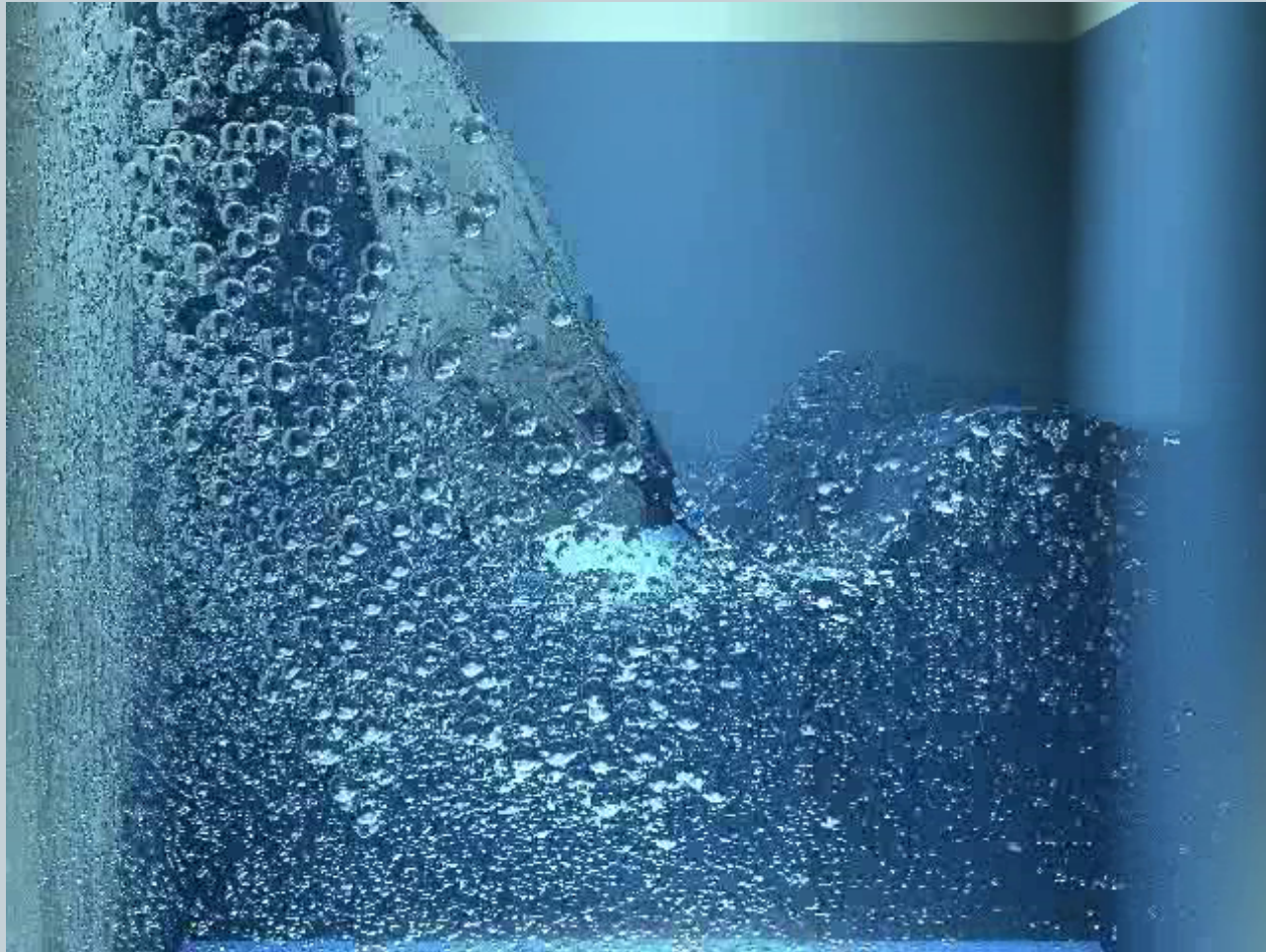
Method (Overview)



Ball Dropping



Pouring Water



Conclusion



- **Physics-based Liquid Sound Synthesis**
 - Model for spherical and non-spherical bubbles
 - ✦ Adaptive
 - Applied it to two types of fluid simulators