Simulation, Simulation, Simulation

Integration of multiple simulation techniques to create realistic water motion in order to maintain highest level of flexibility

Markus Kurtz
markusk@rhythm.com

Jerry Tessendorf
jerryt@rhythm.com

Rhythm and Hues Studios

Introduction:
Over the last couple of years, Rhythm and Hues Studios developed various fluid simulations techniques, which can be combined in a flexible process to maximize the ability to manipulate and art direct each step. This workflow was successfully developed and applied on recent feature work such as “Superman Returns” and “Happy Feet”.

Ambient wave simulation:
In order to create realistic interaction of characters or objects in water, we first define the ambient ocean waves as the base. This approach synthesizes a patch of ocean waves from a Fast Fourier Transform (FFT) prescription, with user-controllable size and resolution, and which can be tiled seamlessly over a larger domain. The patch contains many octaves of sinusoidal waves that all add up at each point to produce the synthesized height. The mixture of sinusoidal amplitudes and phases comes from statistical, empirically based models of the ocean. What makes these sinusoids look like waves and not just a bunch of sine waves is the large collection of sinusoids that are used, the relative amplitudes of the sinusoids, and their animation using the dispersion relation. The output of this process is a series of displacement maps, which are applied to the water surface at render time. This stage of the process does not yet account for any interaction with characters or obstacles in the water.

Fluid simulation:
The next layer, if necessary, is a computational fluid dynamics solver (CFD), which solves for local big waves and splashes. The inputs to this simulation are the computation bounding box, the body of water and the animated characters converted to velocity fields. The output of that stage can be an animated surface geometry, velocity fields or displacement maps. In the case of combining multiple simulations, the output are displacement maps which get combined with the ambient wave output at render time. In those areas where ambient ocean waves interact with CFD waves the displacement maps are masked appropriately according to the magnitude of the ambient waves and the relative influence of the fluid simulation to generate realistic looking surface behavior.

Interactive wave simulations (iWave):
CFD solver are good for the larger motion of fluids, but are not efficient when it comes to the fine surface detail. iWave is used as the third level in the simulation process to achieve a high level of detail of small interference wave patterns. Animated characters or still standing objects of any shape can be present on the water surface and generate waves. Waves that approach an object reflect off of it realistically. Because the entire iWave algorithm is based on 2D image manipulation, this step is very fast and flexible. Similarly, the output of this process can be a displaced geometry, or displacement maps which will be combined with the previous steps in the displacement shader at render time.

Fig 1: Rendered image of ambient ocean waves

Fig 2: Rendered images of iWave simulations

Particle simulations:
The final step of that process is the creation of water drips, splashes and whitewater as a result of the simulated waves. Each step outputs surface velocity data which can drive the rate and initial velocity of particles emitted from the surface. Particles which fall back into the water surface are being fed back into the iWave simulation step to generate additional and more realistic interference patterns on the surface.

References:
J. Tessendorf, “Simulating Ocean Surfaces”, Course Notes, Siggraph 2004