Implementing Wave Particles for Real-time Water Waves with Object Interaction

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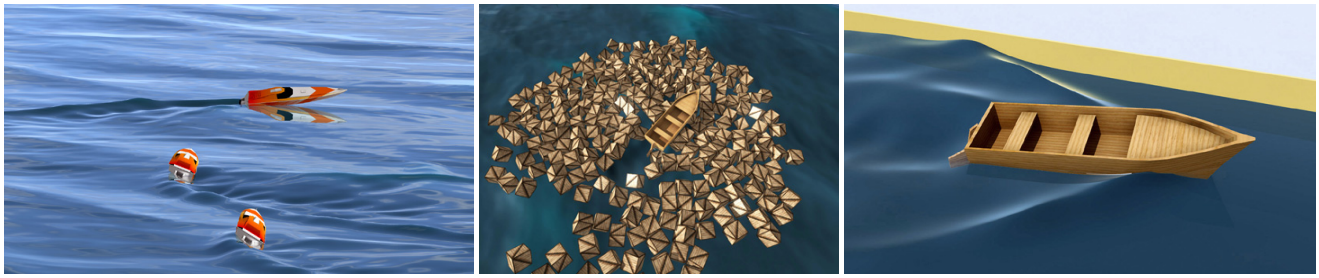


Figure 1: Sample frames captured from our real-time simulation system

We present the implementation details of our real-time simulation system explained in the SIGGRAPH 2007 paper, *Wave Particles*, and shown in the SIGGRAPH 2007 Computer Animation Festival under the same title. Figure 1 shows sample frames captured from our real-time simulation system. The method is based on the new concept of wave particles, which offers a simple, fast, and unconditionally stable approach to surface wave simulation of globally flowless fluids. We also developed a fast object interaction technique that connects our wave simulator to a rigid body simulation system for two-way interactions with the fluid (both object to fluid and fluid to object coupling). In this sketch, we elaborate on the implementation details of our approach and present how to use wave particles to achieve high-performance simulations of fluid surface waves and their interactions with floating objects on a standard PC.

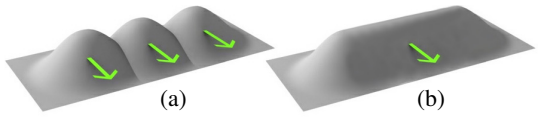


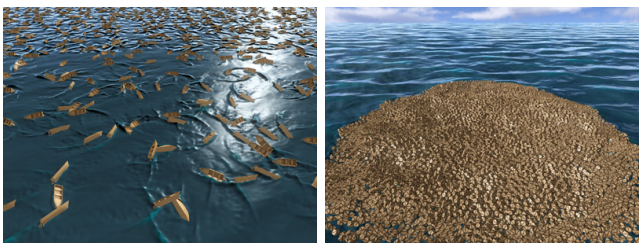
Figure 2: (a) Wave particles, and (b) wavefront they represent

Wave particles essentially form a simple 2D particle system traveling on the water surface. Each wave particle carries a number of properties that define a 3D *local deviation function* to deform the surface around it. Wavefronts on the water surface are formed by placing wave particles side by side as shown in Figure 2. As wavefront expands we introduce new wave particles by *subdividing* the existing wave particles of the wavefront. To simulate reflecting waves from the edges of the container, wave particles bounce back (*reflect*) when they hit a boundary edge. The superposition of all wave particles (i.e. local deviation functions) yields the total surface deformation. We convert wave particles to an extended height field texture, which is directly used for rendering the water surface without the need of a surface construction computation. This decoupling of simulation and surface representation allows simulation of conceptually infinite water surfaces like ocean. Extended height field texture is also used for generating waves resulting from floating object motion, thus eliminating the need for wave particle and object collision detection. For fluid to object coupling, we compute buoyancy force acting on the objects, as well as drag and lift forces on each face of the objects on the GPU.

Wave particles approach is simple and can be implemented in many different ways. However, achieving a high-performance can be complex and nontrivial. In this sketch we present the details of our implementation to provide enough information for achieving the performance level that we present in the paper. We will focus on the following subtopics:

- Building and on-the-fly updating a dynamic time table of wave particle subdivision and reflection events to achieve sub-linear performance in wave particle simulation (this lazy iteration technique allows us to simulate millions of wave particles with minimal cost)
- Generating extended height field from wave particle representation on the GPU
- GPU-based fast wave particle generation technique, which includes finding object silhouette boundaries, fast distributing wave effects of faces to nearest boundaries, and computing wave particle direction and dispersion angle on the boundary
- Fast and stable volume-in-fluid computation on the GPU to find the buoyancy force acting on the object
- Computing drag and lift forces on GPU, and simple optimizations to speed up other steps within this computation,
- Achieving thread-level parallelism to get the most out of the CPUs in multi-core architectures

Wave particles are ready to be used in real-time and interactive applications, as well as fast offline simulations of several thousands of objects and water interaction.



over 1600 boats over 9000 boxes

Figure 3: Massive test scenes for offline simulation.