Lapping Water Effects in *Piper*

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Abstract

The short film *Piper* tells the story of a young sandpiper's first interaction with lapping water. The story is a rhythmic interplay between animated characters and water effects, whether realistic or caricatured. We describe our approach to creating lapping waves, leading edge and surface foam, and thin-surface runoff ripples. We also present a novel approach to varying the interface between wet and moist areas.

Keywords: refraction, flip simulation, displacement mapping

Concepts: •**Computing methodologies → Procedural animation; Physical simulation;**

Figure 1: Water effects for the short film *Piper.* © Disney/Pixar

1 Lapping Waves

The interplay between characters and water in *Piper* called for a controllable lapping wave system with carefully choreographed water, foam and ripple movement. We devised a hybrid solution with both procedural and simulation components. Animation provided proxy wave surfaces to control the speed, composition and timing of lapping waves.

In Effects, we extract various attributes from the proxy wave surfaces and use them to control flip simulations. First, we execute a low-resolution flip simulation to capture the general speed and timing of each animation wave. Then, we source a high-resolution flip simulation from the low-resolution results, retaining velocity and vorticity attributes to act as drivers. After simulation, we process the resulting simulated water surface, adjusting wave thickness to mimic water absorption into the sand. We also blend the water surface with a thin meniscus layer, which is offset slightly from the sand, to model runoff water and wet areas.

The lapping wave system produces a smooth, controllable base wave along with multiple attributes for use in foam and runoff ripple generation.

2 Leading Edge and Surface Foam

To generate foam, we created simple particle simulations in 2D space and built several library elements, including art-directed surface foam patterns and foam patches that could be dressed in the scene and advected with water surface velocity. For leading edge foam, we populated foam particles relative to a simple curve and mapped the curve to the leading edge of each lapping wave.

We use a sculpting method based on particle density to build 3D foam shapes from 2D library elements. By animating density using a predefined popping pattern, we can simulate bubble popping in a consistent way across all library elements.

We use a point cloud to represent foam bubbles and a power law distribution function to vary the bubble sizes. At render-time, a procedural creates bubble geometry from the point cloud, with non-overlapping interfaces between adjacent bubbles.

Shading the foam presented an interesting challenge. From afar, foam has a milky-diffuse look, with specular highlights only apparent in certain lighting conditions. With extreme close-ups, though, individual foam bubbles are visible and we observe intricate reflection and refraction details. We favored the look produced by a thin surface water shader, which produced consistent results for both close-up and wider compositions as well as for different lighting scenarios. The price to pay was the need for millions of small bubbles and a very high number of reflection or refraction bounces to achieve the milky-diffuse look in wider shots.

3 Runoff Ripples

Receding water on a beach result in a thin-surface effect we call runoff ripples. We implemented a procedural ripple pattern generator and a real-time visualizer (in Houdini's 3D viewport) for artists to create and animate highly detailed ripples.

The coverage and presence of runoff ripples are controlled by attributes from the lapping wave system, especially when waves recede. We use image-based displacement mapping to add ripple patterns in runoff areas.

Creating a natural interface between wet and moist areas turned out to be quite challenging. As water pulls back, it is partially absorbed into the sand and the'wet line' separating moist and wet areas slowly recedes and fades away.

Our solution is to vary the index of refraction (IOR) of the meniscus layer from 1.333 (the IOR of water) to 1.0 using IOR maps. Wet areas are assigned IOR values of 1.333, which makes the meniscus layer appear to be a thin water surface, with water-like reflection and refraction effects. Moist areas are assigned IOR values of 1.0, which makes the meniscus layer 'invisible' so that we only see the underlying sand. In-between IOR values create a smooth transition between wet and moist areas.

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