Moana: Crashing Waves

Dong Joo Byun
Walt Disney Animation Studios
Dong.Joo.Byun@disneyanimation.com

Alexey Stomakhin
Walt Disney Animation Studios
alexey.stomakhin@disneyanimation.com

Figure 1: Left: procedural wave generation. Right: fully simulated wave.

ABSTRACT

We used two different solutions for generating crashing waves for more than 40 shots in ***Moana***. Our profile curve based wave deformer was developed and used for art-directed design of shapes, motion, and composition of running and crashing waves. In contrast to previously developed wave deformers, we designed a cross section shape animation by providing a series of profile curves which represented the animation keys. These profile curves could be hand plotted curves or mathematically calculated changing profiles, which means any kind of choreographic touch could be applied for designing the wave shapes. We could design multiple crashing waves for huge scale tsunami scenes and we could art direct the timing and composition of the waves which would fit well with the character animation and camera works.

For scenarios demanding more realism, motion complexity and physical accuracy, we adopted a fully simulated approach. Our APIC-based fluid solver [Jiang et al. 2015] was equipped with control mechanisms allowing us to precisely choreograph the motion of breaking waves to the needs of a specific shot. Though more expensive than procedural approaches, this solution was much more preferable for "hero" shots with close up interaction with boats and characters.

SIGGRAPH '17 Talks, July 30 - August 03, 2017, Los Angeles, CA, USA

ACM ISBN 978-1-4503-5008-2/17/07…$15.00
https://doi.org/10.1145/3084363.3085056

CCS CONCEPTS

• **Computing methodologies → Procedural animation**; **Physical simulation**; **Distributed simulation**; *Simulation by animation*;

KEYWORDS

Procedural animation, simulation

ACM Reference format:
Dong Joo Byun and Alexey Stomakhin. 2017. Moana: Crashing Waves. In *Proceedings of SIGGRAPH '17 Talks, Los Angeles, CA, USA, July 30 - August 03, 2017,* 2 pages.
https://doi.org/10.1145/3084363.3085056

1 INTRODUCTION

There were more than 40 running wave shots in the movie, which provided us with the following two unique challenges. Firstly, the water had to interact with the animated boats and have a specific timing and composition in the camera frame. Secondly, it had to blend seamlessly with the rest of the ocean covering a large area. We used the procedural and simulation solutions for solving these issues.

2 PROCEDURAL WAVES

The procedural solutions for running wave generation provided us with intuitive and art-directable workflows. Artists could interactively design the shape and motion of waves with our procedural wave deformer.

2.1 Wave Deformer

Several different types of wave deformers have been developed for movies over the years. The main contribution of our new system is the ability to design the shape of a wave with a set of *profile curves* that represent the animation cycle of the wave cross-section, see Figure 2. We could have any amount and shape of profile curves. Geometry is deformed by sampling the interpolated section from the profile curves along artistically driven *shape curves* with different time offsets, which allows to create unevenly crashing wave shapes. By providing multiple running shape curves to the tool we could generate multiple running waves, and different wave controls like height, width and emission could be stored in each shape curves and be transferred into the matching waves, when necessary. This deformer let us control the overall shape, motion and the composition of waves exactly as was required by the artistic needs of specific shots.

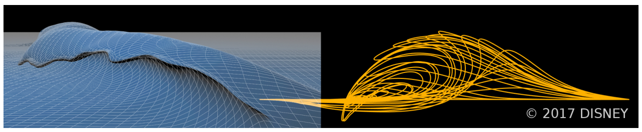

Figure 2: Deformed Wave and Profile Curves

2.2 White-water Generation

We used both traditional simulation and procedural methods of generating white-water on top of deformed waves. The wave deformer stored the peak area of wave geometry and we used it as an emitter for white-water simulation. The wave deformer also calculated the proper initial velocity to drive the simulation. Voronoi patterns were used to enhance the scale of very large running waves, allowing us to cover a wide range of scales. We also performed distributed white-water simulation on multiple cores.

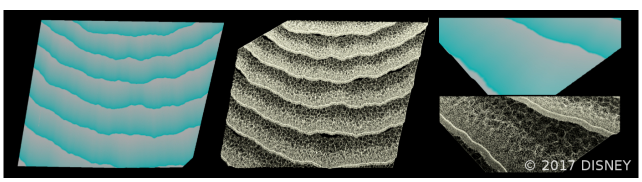

Figure 3: Procedural White-water

2.3 Instancing and Deforming Pre-simulated Crashing Waves

We also had to create extremely large scale of crashing wave trains for tsunami shots. We first designed the overall shape of running waves with the wave deformer and placed 10 different versions of pre-simulated crashing waves on top. The instanced cached particles were deformed to match the shape and not to have gaps between each other and the core wave geometry. Different time offsets were applied for instancing crashing wave particles.

3 SIMULATED WAVES

Typically, movie shots impose requirements on when and how a wave needs to break, leading artists to use procedural rather than simulation tools to create them. Proceduralism, however, can sometimes be limiting of realism and complexity, forcing artists to mask lack of detail with artificial secondary passes, such as white-water simulation discussed above. Thus, we also developed a fully simulated approach to creating controllable breaking waves.

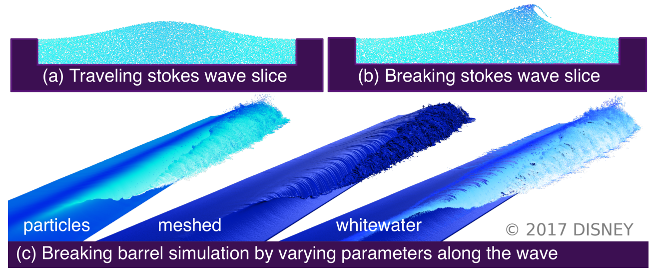

Figure 4: Simulating a breaking wave with FABs [Stomakhin and Selle 2017].

Though more expensive than procedural approaches, this solution was much more preferable for "hero" shots with close up interaction with boats and characters. We start by simulating a traveling swell. We do that by simulating one period of a Stokes wave [Stokes 1847]. Since Stokes waves move with constant velocity, it is beneficial to perform the simulation in the frame of reference of the wave to avoid dealing with a moving window. Figure 4(a) shows a possible setup for the simulation: a period of a Stokes wave, surrounded by a static boundary, imposing the appropriate boundary conditions and emitting and consuming particles accordingly. With this setup, the simulated wave would persist over time without changing its shape. To break the wave it suffices to change the boundary conditions to the ones that would correspond to an non-physically steep wave, see Figure 4(b). By varying the conditions differently along the wave we were able to achieve complex effects such as a surfing tube, breaking from one end, see Figure 4(c). The render is shown in Figure 1 (right).

4 LEVELSET COMPOSITING

Even though we used different solutions for generating running waves, the outputs needed to be blended with the rest of the ocean surface. Our level set compositing pipeline helped us seamlessly combine all of the elements from different resources. Additional height field displacement was added on top to give the waves a more organic look.

5 CONCLUSION

We made many types of crashing waves for the movie with our procedural and simulated solutions. In more art-directed scenarios, we used the procedural deformer, and when realism was called for, we employed the physically accurate simulation solution. If needed, shots could leverage both approaches. In this way, we could produce from the different tools unified effects of crashing waves which blended and harmonized well together.

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