Creating oceans using math

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What to talk about?

- Oceans and why use CG
- Creating ocean using math
- Integrate with Houdini
- Very simple ocean shader
Why use CG?

- Water is a common element
- Hard to capture live
- Very special or extreme situations
- Animated film
- Cheap
- No commercial solution
- Writing your own code = full control
Important elements of an ocean

Surface waves
Important elements of an ocean

Spilling breaker
Important elements of an ocean

Lipspray
Important elements of an ocean

Standing foam
Important elements of an ocean

Procedural foam
Important elements of an ocean

Interaction foam and spray
Important elements of an ocean

- Traveling mist
- Fog/Atmosphere
Previous results

- Titanic (1997)
- Perfect Storm (2000)
- Flags of our fathers (2005)
- Surfs up (2007)
Approach

- Fluids?
- 2D!
- Real-time?
- Scalable
Basics of ocean waves

• Sin-functions?
• Almost infinite amount
• All directions and varying amplitudes
• Made by wind (local or distant)
What we need to model

- What is visible?
- Cheating is OK!
- Audience does not care about fancy simulations
- What looks good is good
- KISS – Simple layers are better (but slower) than complex system
- Quick and Dirty is the key for VFX-programming
- Fancy system design is for people who know what they are doing and what the result should be.
- Do NOT reinvent the wheel
Dispersion relation

- Wave propagation from time and frequency
- Example – White light turns into rainbows
- Key of wave nature and travelling objects
- How energy is transported in any medium

\[ \omega^2(k) = gk \]
Making waves

Wave Spectrum?
Making waves

Wave height from wave staff
Making waves

Spectrum - Periodogram

![Graph showing power spectral density vs frequency](graph.png)
Making waves

Ocean Wave Spectrum

![Graph showing the power spectral density of ocean waves across different frequencies. The graph plots frequency on a log scale on the x-axis and power spectral density on a log scale on the y-axis. The graph shows a peak in the power spectral density at a certain frequency, indicating the most energetic part of the wave spectrum.](image-url)
Making waves

How is this useful?
Let’s make waves!?

\[ P_h(k) = A \frac{\exp\left(\frac{-1}{(kL)^2}\right)}{k^4} \exp(-k^2l^2) \left| \sum \hat{h}(\vec{k}, t) \exp(ik \cdot x) \right|^a \]

\[ k = |\vec{k}| \]

\[ \tilde{h}_0(k) = \frac{1}{\sqrt{2}} (\varepsilon_r + i\varepsilon_i) \sqrt{P_h(k)} \]

\[ \omega^2(k) = gk \]

\[ \tilde{h}(\vec{k}, t) = \tilde{h}_0(\vec{k}) \exp(i\omega(\vec{k})t) + \tilde{h}_0^*(-\vec{k}) \exp(-i\omega(\vec{k})t) \]

\[ h(x, t) = \sum \tilde{h}(\vec{k}, t) \exp(i\vec{k} \cdot x) \]
Making waves

Let’s make waves!

IFFT  Magic?
Making waves

Waves demos
Making waves

Waves demos
Choppy waves
Making waves

Choppy waves
Making waves

Repetition removal
Repetition removal - Math

\[ P_{x\text{warp}} = P_x \times \text{scale} \times f\text{noise}(P_z, 0, P_x) \]

\[ P_{z\text{warp}} = P_z \times \text{scale} \times f\text{noise}(P_x, 0, P_z) \]

\[ \bar{D} = s\text{noise} \frac{(S_1 + S_2)}{2} + (1 - s\text{noise}) \frac{(S_3 + S_4)}{2} \]
Making waves

Repetition removal
Making waves

Repetition removal - Video
Making waves

Realtime preview
Making waves

Realtime preview
Realtime preview – Houdini video
Huge waves
Mastering the waves
Making waves

Foam!
Making waves

Automatic foam

Jacobi and Geo
Making waves

Painted foam
Making waves

Prevent surface/foam sliding
Making waves

Prevent surface/foam sliding - video
Foam

• Foam
  • Difficult
  • Noise, noise, noise…
  • use more noise to remove noise
  • UV-space

• 3 types
  • Bump-foam
  • Top-foam
  • Underfoam
Making waves

Houdini integration

SOP- preview
VOP - rendering
Houdini – Simple Ocean Shader
Houdini – Simple Ocean Shader
Making waves

Results - videos

CG Ocean
What is the power of Houdini?
Houdini – Simple Ocean Shader
Making waves

Work in progress - Awesome demo!

SPH-Solver
• GeForce 275GTX
• Everything done on the gpu (through houdini SOP)
• Collisions using signed distance fields and art directing using force fields

Demo
• 1.8 million particles
• Sim takes less than 9 minutes = less than 9 sec/frame
• 6 collision objects (signed distance fields)
• Use Houdini surface reconstruction = slow and 6 million polygons...... Ouch!