Real-Time Rendering of Ocean Water

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- ***GOAL:***
  - ***Problem statement:***

I would like to attempt the implementation of real-time rendering of a simulation of ocean water/waves with a particular focus on water foam interaction with shorelines.

  - ***Project goals/benefits:***

The results should provide a well-documented open-source repository that can be studied by other students or others with interest in this topic. The project will primarily benefit hobbyist game developers who wish for an easier entry point into a highly popular feature of many games.

- ***CHALLENGE:***
  - ***Why the problem is hard:***

This project will be a challenge since it incorporates aspects of rendering, modeling and animation. The rendering component will of course be the main focus, and could be used as a way to minimize the modeling effort (e.g. bump/normal/displacement mapping). The animation will probably be a very simple looping mechanism. Water rendering also involves many rendering aspects such as reflections, refractions, fresnel reflectance, foaming, etc.

  - ***Other approaches and their limitations:***

Traditionally, water has been rendered as a texture-mapped quad. This doesn't look very realistic and isn't very extensible to many modern use cases. The referenced approaches (included below), vary from using more realistic techniques for rendering planar water to actually perturbing the surface with displacement maps. There also seems to be a limitation of white water effects as waves shear against shorelines. Also, many implementations don't seem to focus on larger amplitude waves.

- ***APPROACH:***
  - ***My approach:***

I can use an iterative approach to building up the project, through consulting my references. I can start by attempting the simpler planar method, with the surface being static (no animation). Once I have achieved a consistent level of realism, I can then introduce a looping animation. I can then test how well the simulation scales and its impact on the rendering time. Furthermore, I can play around with the displacement mapping method. Finally, optimization will come into play at some point yet to be determined, but will involve LOD scaling of the underlying grid structure.

- ***Reasonability of success:***

I believe a reasonably photo-realistic real-time simulation of waves is probable mainly due to the large knowledge base surrounding water rendering in general. Of particular usefulness is that of the included shader code in [Johanson 2004]. If I am ever stuck on implementing one feature a certain way, I have at my disposal a plethora of other attempts and techniques to consult.

- ***METHODOLOGY:***
  - ***Projected timeline:***

The task list is as follows (builds mainly upon what is outlined by [Johanson 2004])…

TASK	**DEADLINE**	**CHALLENGE?**
Setup rendering boilerplate.	Feb 17	
Load in terrain model (with a simple texture) that can be used to simulate islands and ocean depth. Load in skybox (and position sun light). Setup water plane (sea level).	Feb 19	
Implement a LOD discretized grid structure on water plane that can be used for tiling and optimization.	Feb 22	This will have to be adjusted once a better idea of how all components play together.
Implement Perlin Noise based height field generation	Feb 24	
Implement global reflections, phong	Feb 28	

specular sunlight (of varying colour) and fresnel (bump mapping)		
Implement local reflections with terrain islands. Include UI slider for water surface distortion amount.	Mar 2	
Implement refractions	Mar 3	
Implement a simple looping animation	Mar 5	This may turn out not to be very simple due to visual artifacts likely appearing if done incorrectly.
Attempt to scale the water patch to a larger area to see impact on runtime performance	Mar 7	
Implement sea foam, play with exaggerated foam for shearing along shorelines.	Mar 11	This will be challenging to visually replicate without looking fake (too thin? Too thick? Too predictable?)
Improve the UI with better controls over every parameter.	Mar 15	
Optimize	Mar 20	It may prove difficult to balance visual fidelity and the scale of the simulation

- ***Fallback plan:***

I have many options and references. For generating a height field, I can either use noise or FFT. I can vary between bump mapping, normal mapping, and displacement mapping.

- ***METRICS:***

Fortunately, this topic has been researched a ton, and thus I should have ample reference material (images, video, simulations, other applications, etc.) to compare my results to.

My application should meet at least the following criteria:

1. Able to run at >30fps (preferably 60fps) on the Linux graphics lab computers.
2. Provide a simple UI to adjust parameters (such as sun position/angle, surface "bumpiness", animation speed, etc.)
3. Suitably realistic for real-time applications, with an ability to scale up or down the simulation.

- ***SUMMARY:***

This project will serve as a great learning experience for myself in implementing more advanced rendering techniques. Of particular use will be gaining experience in discovering the challenges with optimizing for real-time applications, while maintaining visual fidelity. I will also develop a better ability to work with researched work and hopefully build on their efforts.

- ***REFERENCES:***

Claes Johanson, "Real-time water rendering - Introducing the projected grid concept". Lund University. 2004.
https://fileadmin.cs.lth.se/graphics/theses/projects/projgrid/projgrid-hq.pdf

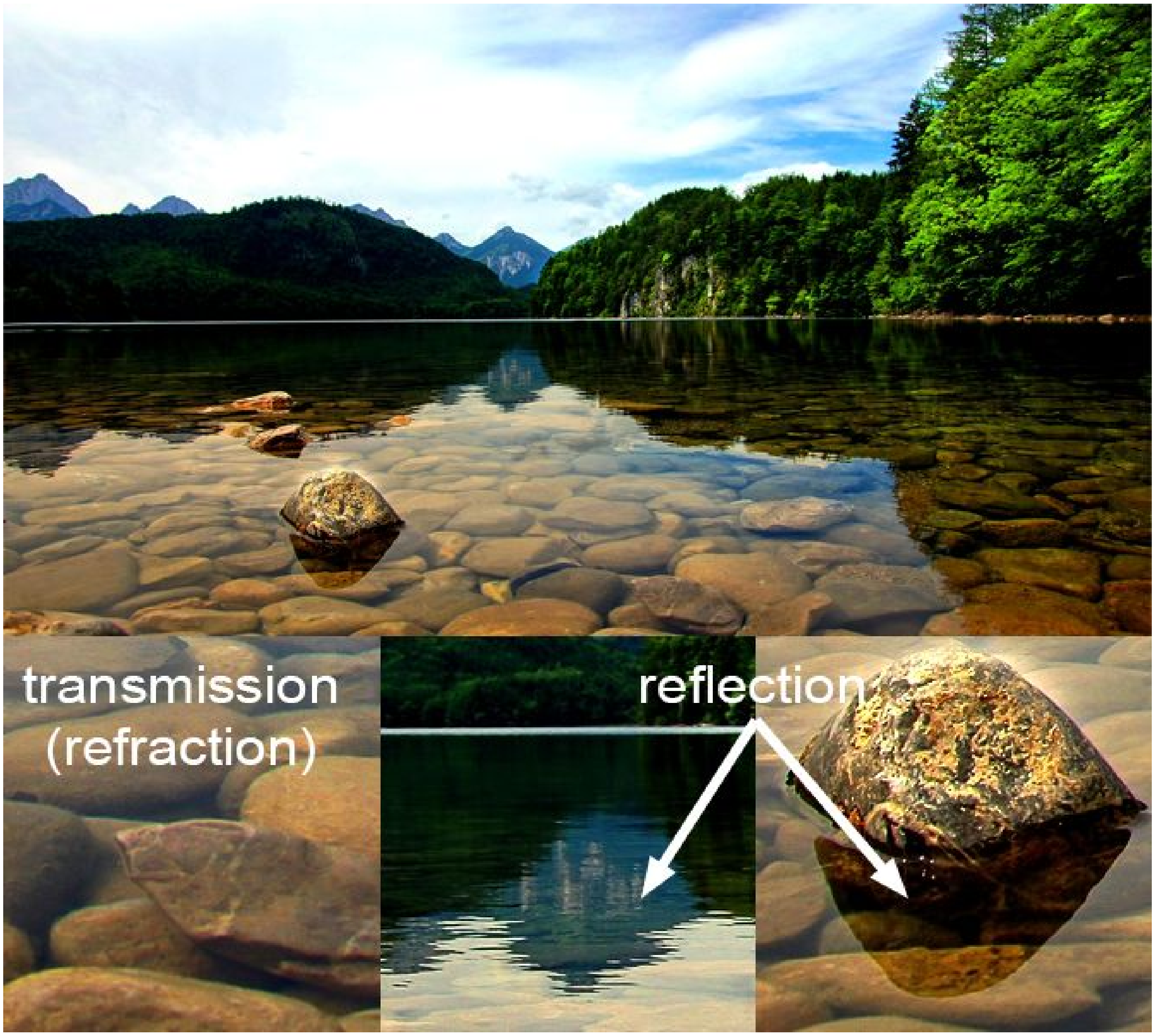
Yaohua Hu, Luiz Velho, Xin Tong, Baining Guo, Harry Shum, "Realistic, Real-Time Rendering of Ocean Waves". Computer Animation & Virtual Worlds 17(1):59-67. 2006.
http://www.xtong.info/rtwave.pdf

Shunli Wang, Fengju Kang, "Automatic Optimization for Large-Scale Real-Time Coastal Water Simulation". Mathematical Problems in Engineering. 2016.
https://www.hindawi.com/journals/mpe/2016/9034649/

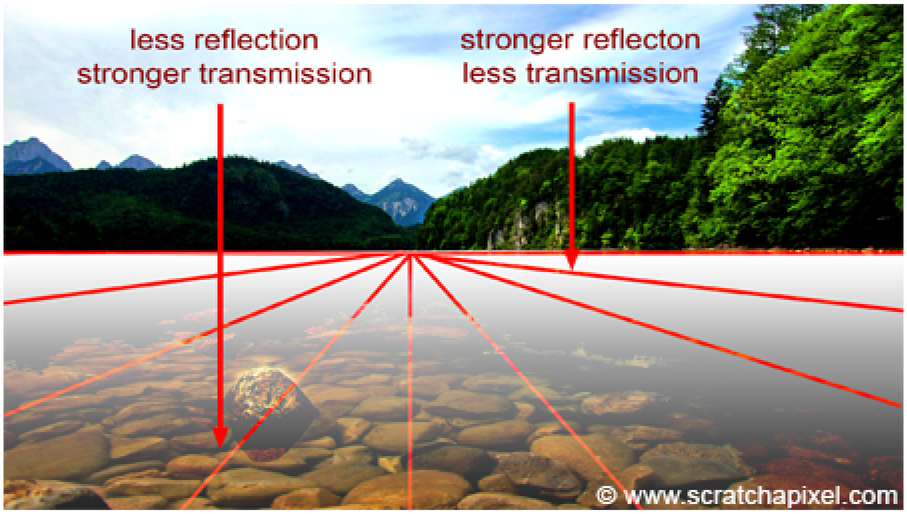
Robert Golias, Lasse Staff Jensen, “Deep Water Animation and Rendering”. GDCE. 2001.

https://www.gamasutra.com/view/feature/3036/deep_water_animation_and_rendering.php?print=1

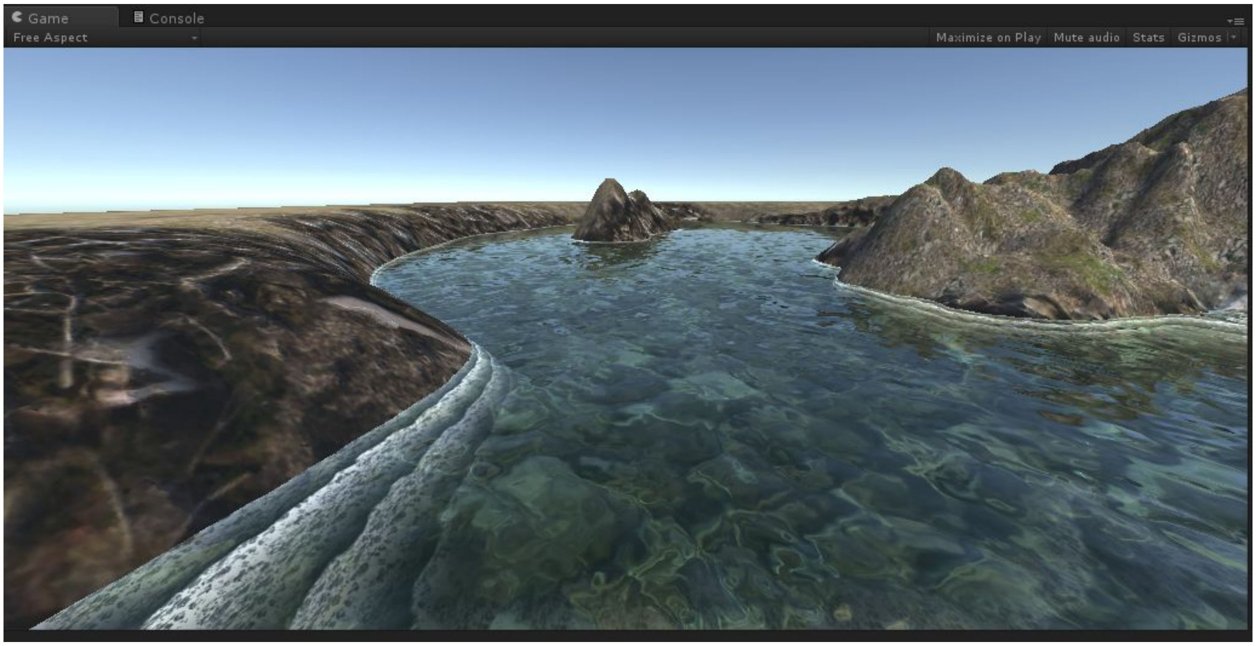
- ***IMAGES:***



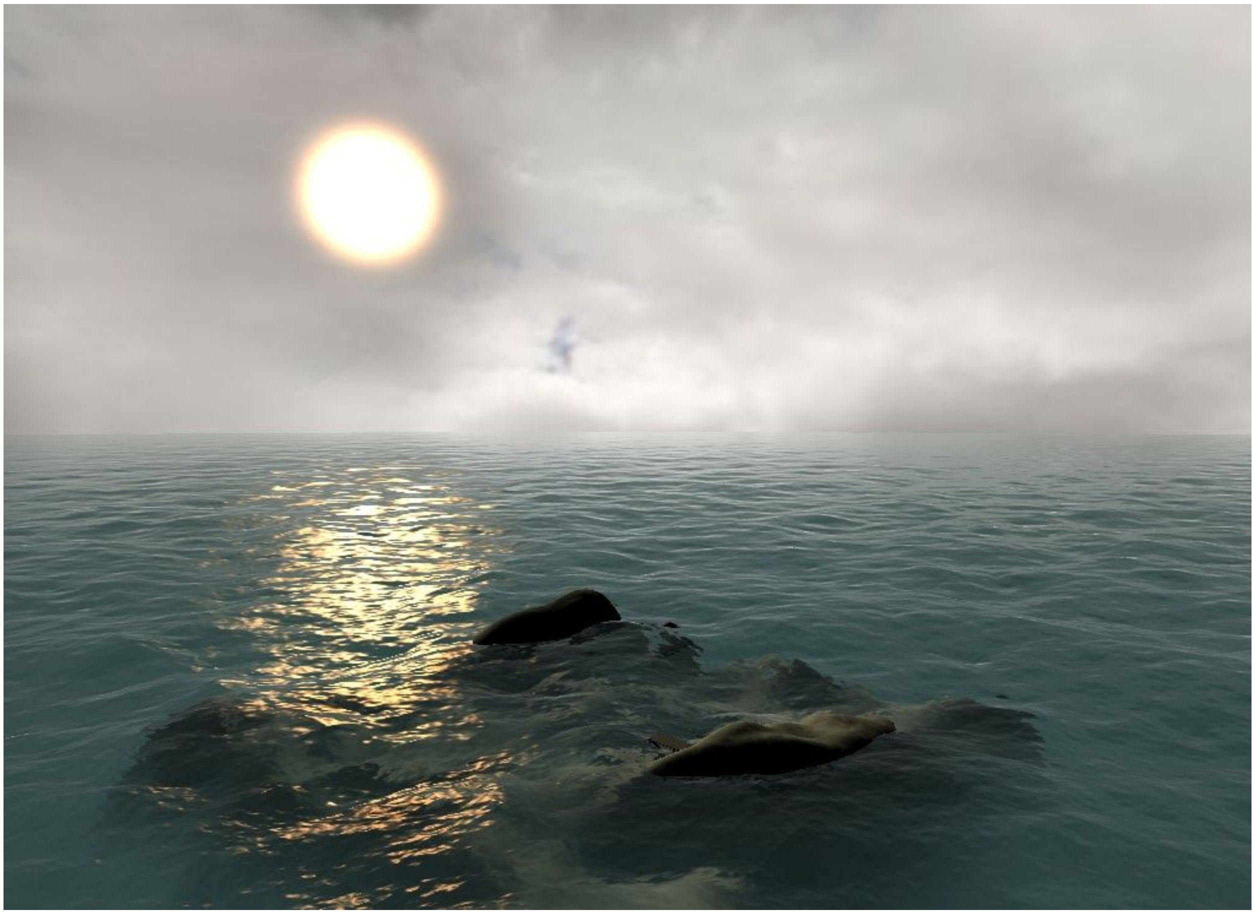
reflection/refraction



Fresnel reflectance



An example of shoreline white water / foam



Sunlight beam and small island features

Foam