Realistic Water Rendering

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Introduction

Correct rendering of water is an aspect of graphics programming that can add tremendous visual appeal to a scene. Water exhibits quite complex physical properties that are difficult, at best, to model mathematically. Earlier games were left with simple textures, stretched over a flat quad representing the surface of the body of water and subsequently made transparent using the alpha channel.

In 2001, Nvidia introduced programmability into the vertex processing pipeline. This was the start of a series of massive enhancements for the real-time graphics community. Today we have fully programmable pixel and vertex shaders with flow control and recently we have seen the addition of the geometry shader.

Waves…or the illusion of waves?

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As this section's title aptly asks, the above method only yields the illusion of waves. Waves are not truly present, as can be witnessed if one carefully studies the edges of the body of water. (Where it meets structures or the boundary of the pool). Here, the illusion is broken and the surface's nature as a regular quadrilateral is revealed.

To truly generate waves, the developer must utilize a height map, so as to change the actual height of the surface of the water, now represented by a vertex grid rather than a quad. This is much heavier to implement and relies on more complex mathematics (differential equations) because the vertical movement of a vertex affects that of its direct neighbours. But the technique can help facilitate interactivity with the user, as effects such as local, expanding ripples where a character enters the body of water become possible.

Reflection and refraction

Reflection and refraction are two very important properties of water. Getting them right is likely the first step toward a representation that seems plausible to the human eye, even without further effects.

Reflection, naturally, is the effect of the world mirroring itself in the surface while refraction is a measure of how light bends when passing through different mediums. These need to be calculated on the fly and, in particular, the relationship between them. A water surface that solely reflects looks metallic – It yields the impression of a pool of mercury rather than water. Similarly, a surface that solely refracts will result in the same effect as looking through a pane of glass.

In our model, it is achieved in a realistic way using the normal map above to help determine the “roughness” of the reflecting surface. (Roughness, here used to describe the extent to which microfacets of the surface deviate from being oriented halfway between the viewer and the incoming light). If we didn’t, the highlight would be a perfectly round reflection of the lightsource rather than portray the uneven surface of the water.

Bump Mapping

Besides the displacement of reflections and refractions mentioned earlier, our solution also makes use of a technique known as bump mapping. Bump mapping is responsible for the appealing specular highlights shown in images to the right. Specularity is an optic effect generated by certain shiny materials such as plastic, glass and, obviously, water. It appears in the area of the material where the reflection of incoming light isn't broken into its red, green or blue components and as such, will always appear white.

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Parallax Mapping

Parallax mapping is an enhancement to bump mapping in that it helps further the appearance of depth in a surface. Bump mapping works well as far as adding realism to the specular highlighting goes, but has a few shortcomings when the material is viewed up close. The illusion of depth through bump mapping is view independent in that it is static – it will look the same at sharp angles whether viewed from the left or right. Parallax mapping is an extension that adds view dependency to the technique.

It utilizes a height map, as shown above, to provide an offset to the texture coordinate, based on height values extracted from the map. The offset so generated replaces the displacement otherwise provided by the bump map and helps eliminate the view independency that hindered the bump mapping technique, because the heights provided and thus the offset will differ as the viewing angle changes.

The height map consists solely of black and white values and as such, valuable space can be saved by encoding it into the alpha channel of the normal map.

The Fresnel Term

The relationship between the two effects is calculated using the so-called “Fresnel term”. A scalar that determines how much of either we need. An approximation to the Fresnel Term is equal to the dot product between the eye-vector and the surface normal of the medium. Thus, if we have a Fresnel term of 0.7, we need 70% refraction and 30% reflection for the surface to appear natural.

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