THE REPRESENTATION OF WATER

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Abstract

Water is the commonest of everyday substances and its many forms have provided subjects for artists for as long as art has existed. But in computer graphics, there seem to have been few attempts to make pictures of water. The reason for this is simple. Realistic pictures of water are very hard to produce. We examine some of the reasons for this difficulty and report on some of our own experiments.

Background

Water is all around us and plays a part in many natural scenes. But it rarely appears in computer graphics images. The last four years has seen an enormous increase in interest in modelling natural phenomena. Fournier [1982] and others have produced realistic terrains using approximations to fractal surfaces building on the ideas of Mandelbrot [1983]. Reeves [1983] has modelled fire and Gardner [1985] has made impressive clouds. Although Reeves suggests that his particle systems can be used to model water, his paper gives no example. Perlin [1985] has published a picture, *Ocean Sunset,* showing a representation of a seascape and this is probably the best representation to date. However, it shows only one appearance of water and it is not clear how the method should be generalised. Water reflections appear in *Road to Point Reyes* [Cook 1983] but they are very simple, as is the pool with ripples in *Erehwon* [Weliky 1985]. Nelson Max [1981] made some pictures of a pair of islands in the sunset and his discussion deals with some of the problems mentioned below. It is, unfortunately, difficult to assess Max's ideas from the pictures themselves as he was hampered by using a display with only 256 colours.

Water is difficult to represent for several reasons. Most of the water we see is in motion. Its shape depends on this motion and the motion is very complicated. A full, hydrodynamic simulation can, in principle, provide us with a complete description of the shape of any mass of water, but the computational requirements would be huge.

Even when we know the shape of a mass of water, it is still difficult to render because of its optical properties. Most of the light falling on it is refracted or reflected, but even light which passes through the water gets scattered in a more or less complex fashion. And the appearance is further complicated by the fact that any surface below the water is illuminated indirectly by rays focused and scattered by refraction at the surface. Water in lakes, ponds and puddles presents the simplest surface, a plane disturbed by combinations of waves. The wave shapes are affected by varying depth and boundary. Water flowing in streams and rivers is far more complicated. We have initiated a research project aimed at studying all aspects of the appearance of water. In particular we are experimenting with the technique of *soft* objects [Wyvill 1986] to provide a general model for the more complicated cases: streams, waterfalls and fountains.

In this paper, we have confined ourselves to the study of pools of water with waves. We have not yet attempted animation, and we have avoided actual physical simulation. Our main purpose is to discover which features matter most when presenting a realistic picture of water with waves. Another way of looking at it is to ask which features can be omitted without making the picture *unconvincing*. Our standard of assessment is thus rather subjective. Still photographs of moving water often look very different from the original because we never observe waves over an area at the same moment. Ideally we should be trying to compare our artificial pictures with photographs of water in similar circumstances. This we have not done.