Volumetric Modeling with Implicit Functions
(A Cloud is Born)

David S. Ebert
Computer Science and Electrical Engineering Department
University of Maryland Baltimore County
1000 Hilltop Circle
Baltimore, MD 21250
Phone: (410)455-3541, email: ebert@cs.umbc.edu

April 14, 1997

.

30-word Summary

This sketch describes a new, flexible, natural, intuitive, volumetric modeling and animation technique that combines implicit functions with turbulence-based procedural techniques. A cloud is modeled to demonstrate its advantages.

Volumetric modeling is vital for realistic simulation of many natural phenomena, including water, clouds, gases, and fire. There are two general classes of techniques to simulate these natural phenoma: physically-based simulation and non-physically-based solutions. This sketch describes a new procedural technique for modeling and animating volumetric objects, which combines implicit function modeling, procedural turbulence simulations, and volume rendering to produce a powerful, easy to use, realistic volumetric modeling system for natural phenomena. The use of implicit functions (blobs, metaballs) as a modeling primitive allows the user to take advantage of smooth blending of primitives, sketetal modeling elements [3], and more natural animation control.

Volumetric procedural modeling (VPM) has previously been used to model gases, fur, water, and fire [1]. Procedural techniques have many advantages, including data amplification and parametric control [2]. However, the definition of overall volumetric shape through procedures can be a difficult task, especially for non-programmers.

By combining implicit functions with VPMs, a natural, flexible, powerful animation and modeling system can be built. The advantages of both techniques can be harnessed to enhance the design and animation of volumetric objects.

An Example Procedural Volumetric Implicit Function

This new technique can be used to create realistic volumetric clouds that can be rendered with low-albedo and high-albedo physically-based illumination and atmospheric attenuation. Figure 1 shows a cumulus cloud created by positioning 9 implicit spheres with varying radii and blending amounts to define the overall shape of the cloud.

The turbulence-based [4] volumetric procedures add natural detail and allow control of the density and edge sharpness of the cloud. User-defined parameters control the blending of the implicit function density and the turbulence-based procedural density, the overall denseness of the cloud, and the sharpness of the density fall-off. The algorithm below describes the general cloud procedure:

```
cloud(pnt)
   perturb point using noise and turblence
   density1 = implicit_function(perturbed_point)
   density2 = turbulence(pnt)
   blend = blend% * density1 + (1 - blend%) * density2
   returned density = power(blend*max_density, exponent)
end cloud
```

Cloud formation and evolution can be simulated by adding time as a parameter.

Conclusion

This sketch shows that implicit functions can be combined with procedural models to model and animate complex volumetric objects and phenomena. The addition of implicit functions provides natural blending of primitives, use of skeletal models, and ease of modeling and animation. More examples of this technique and resulting animations can be found at :

`http://www.cs.umbc.edu/˜ebert/cloud`

References

[1] David Ebert, Ken Musgrave, Darwyn Peachey, Ken Perlin, and Steve Worley. *Texturing and Modeling: A Procedural Approach*. Academic Press, October 1994. ISBN 0-12-228760-6.

[2] David S. Ebert. Advanced modeling techniques for computer graphics. In *CRC Handbook of Computer Science and Engineering*, chapter 56. CRC, 1997.

[3] Andrew Guy and Brian Wyvil. Controlled blending for implicit surfaces. In *Implicit Surfaces ’95*, April 1995.

[4] Ken Perlin. An image synthesizer. In B. A. Barsky, editor, *Computer Graphics (SIGGRAPH ’85 Proceedings)*, volume 19, pages 287–296, July 1985.

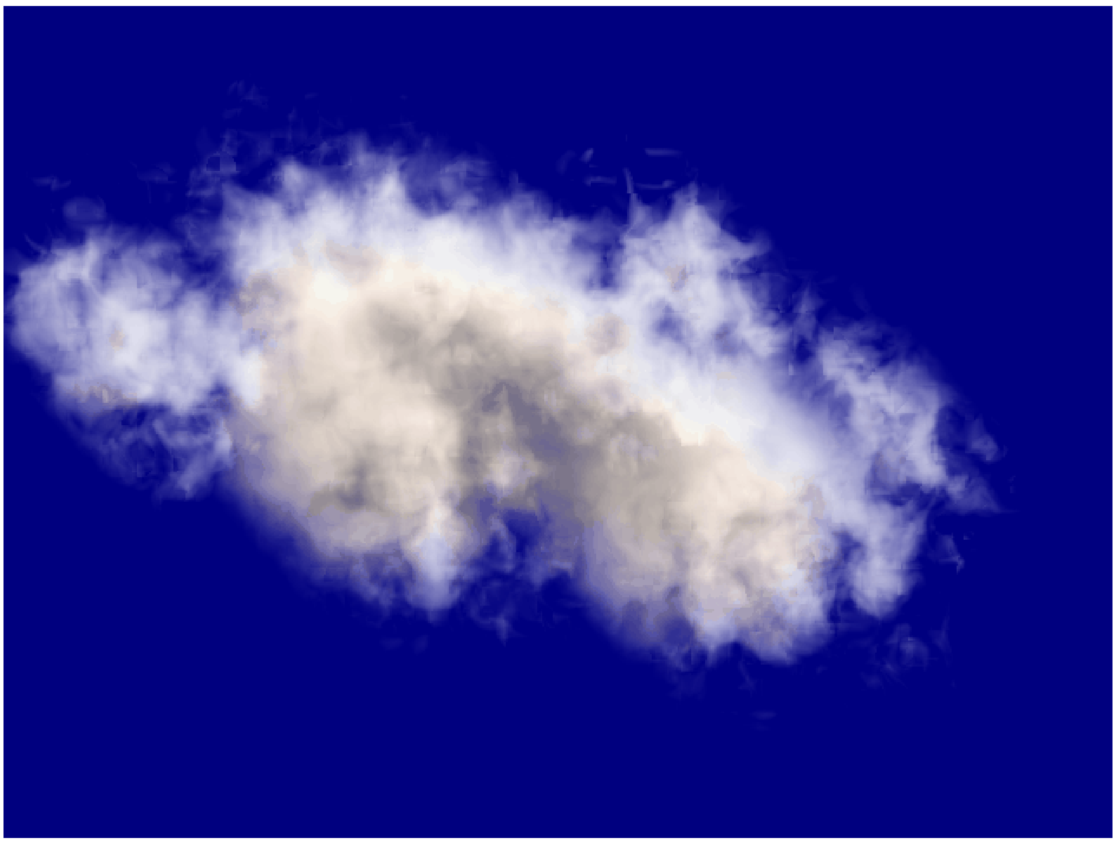

Figure 1: Volumetric Implict Turbulent Cloud