

Advances in Scientific Visualization

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Abstract

This paper discusses scientific visualization of scalar and vector fields, particularly relating to clouds and climate modeling. One cloud rendering method applies a 3-D texture to cloudiness contour surfaces, to simulate a view from outer space. The texture is advected by the wind flow, so that it follows the cloud motion. Another technique simulates multiple scattering of incident light from the sun and sky. This paper also presents a simulation of the microscopic cross-bridge motion which powers muscle contraction. It was rendered by ray-tracing contour surfaces of summed gaussian ellipsoids approximating the actin and myosin protein shapes.

Key Words: scientific visualization, scalar fields, vector fields, flow visualization, muscle, cross-bridge, contour surface.

Climate Visualization

Climate simulations calculate several 3D scalar variables like temperature, humidity, and cloudiness at millions of spatial/temporal sample points. In order to make sense of this massive amount of data, it is useful to produce time-varying computer animated renderings. At Lawrence Livermore National Laboratory, we have concentrated on visualizing cloudiness, a scalar quantity, in conjunction with wind velocity, a vector quantity [1]. As we discuss the rendering techniques for scalar fields below, we will write in terms of cloudiness, but they are equally applicable to any other 3D data. However, our flow visualization techniques are more appropriate to velocity fields than to other vector fields, since they use motion along the flow direction.

We used global climate data output by the Cray 2 for every hour in a 10 day simulation for the beginning of January, using an algorithm from the European Center for Medium Range Weather Forecasting. The data is given on a curvilinear 320x160x19 longitude/latitude/altitude grid. This grid is not in simple spherical coordinates, because the lowest altitude level bends to follow the height of the terrain, and the higher levels also bend to accommodate.

The grid spacing is larger than one degree on a side, so the model cannot represent individual clouds. Instead, the cloudiness variable represents the fraction of the sky that is covered by clouds at the level of the altitude coordinate. Cloudiness is a scalar field, so standard volume rendering techniques can be used. These include contour surfaces, as in figure 1, and direct volume rendering, as in figure 2.

Contour surfaces are built from polygons, and can take advantage of polygon rendering hardware. For figure 1, we divided the hexahedral volume cells defined by 8 sample vertices up into 5 tetrahedra, and interpolated the cloudiness function linearly across each tetrahedron. If a contour surface of the linearly interpolated function intersects a tetrahedron, it does so in a planar triangle or quadrilateral.

To produce figure 2, we used a different interpolation scheme across the cell bounded by the 8 sample points. We interpolated the cloudiness linearly along the projections of the edges, and then linearly across horizontal scan lines to get the value at each pixel center on the projection of each boundary face. Each viewing ray intersects the cell in a segment between two boundary face pixel center positions, so we can linearly interpolate these values across the segment. Such a scheme defines a piecewise trilinear interpolation over any convex polyhedral cell [3]. The shapes of the pieces depend on the cell orientation and projection direction, so the interpolation is not invariant under rotation. (A similar problem occurs with the piecewise bilinear interpolation used with Gouraud shading.) However, this method allows the faces to be scan converted coherently, which increases efficiency, as does treating the cell as a whole instead of dividing it up into tetrahedra.

Advances In Scientific Visualization

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