Motion-Based Shape Illustration

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1 Introduction

Motion provides strong visual cues for the perception of shape and depth, as demonstrated by cognitive scientists and visual artists. We present a novel visualization technique that uses particle systems to add supplemental motion cues. Based on a set of rules following perceptual and physical principles, particles flowing over the surface of an object not only bring out, but also attract attention to essential shape information of the object that might not be readily visible with conventional rendering. Replacing still images with animations in this fashion, we show with both surface and volumetric models that the resulting visualizations effectively enhance the perception of three-dimensional shape and structure.

This work is motivated by the observation that the flow of fast moving water over a rock, a dynamic flame from an open fire, or even a flock of birds exhibit motion that gives the perception of shape. Our technique is built on the inspirations we received from kinetic art, the studies done in cognitive science, the ideas of particle systems, and the previous work using texture to convey the shape of overlapping transparent surfaces.

2 Motion Strategies

To generate geometrically meaningful motion, the particles are governed by a set of rules. The overall goal is to create rules resulting in particles that indicate shape by smoothly flowing over an object, with locally consistent directions, and a density distribution that does not let particles "clump" together in regions of little interest.

Since we would like to better illustrate an object's shape, rules are imposed to constrain the motion of particles to be along a surface. The motion of particles along an object's surface can help improve shape perception, over time presenting the viewer with a set of vectors (trajectories) that run parallel to a surface.

The principal curvature directions indicate the direction of minimum and maximum curvature on a surface. We use principal curvature directions to create particles that "follow the shape" of a surface. Particle velocities are adjusted so the particles flow in a direction that favors one of the principal curvature directions chosen by the user.

Since particles moving in opposite directions can provide confusing motion cues, we use a set of rules that move particles in directions consistent with their neighbors. One method we use to give the particles more consistent orientations is to give the particles flock-like behavior. Flocks exhibit motion that are fluid, with each member still exhibiting individual behavior. Thus flocking can be used to add local uniformity to particle motion while still allowing particles to have motion shaped by outside forces like principal curvature direction. The other method for giving particles a consistent orientation is to simply define a "preferred" direction the particles must move, for example having all particle have a preference toward downward motion.

Since the number of particles has a direct influence on rendering time, it is desirable to have a set of rules that efficiently uses a limited budget of particles. By using a set of rules based on magnetic repulsion, more uniform particle densities can be achieved. Particles are modeled as having a magnetic charge of the same sign, and are repelled from their neighbors with a force inversely proportional to the square of the distance of the neighbors.

3 Demonstrations

To demonstrate this motion-based technique, several animation sequences were generated and can be downloaded from http://www.cs.ucdavis.edu/~ma/KinVis. Two frames from a sequence for the visualization of a mouse brain PET volumetric dataset are shown in the left column below. The particles help to illustrate one of the function levels while volume rendering gives their motion context. On the right column, two frames from another sequence which shows the application of rules to better illustrate a surface model of Venus. The particles flow down the Venus model in a manner similar to water. The downward tendency adds consistency to the motion.

The proposed technique can create more perceptually effective visualizations by adding visually rich motion cues. While more work will be required, our current results are encouraging, demonstrating that it is feasible and desirable to capitalize on motion cues for the purpose of enhancing perception of 3D shape and spatial relationships.