Simulating Smoke, Fire and Snowflakes with Particle Systems

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The executable file locates in "release\" directory

Introduction

This is an OpenGL based Computer Graphics program to demonstrate the use of particle systems to simulate log fire, smoke and falling snowflakes. A scene is designed that consists of a house, ground and trees. Inside the house, there is a fireplace with burning flame simulated by a fire particle system. The house has a chimney that emits smoke simulated by a smoke particle system. In the sky, the snowflakes, yet simulated by another particle system, fall down to the ground.

Goals of Project

Construct particle systems using billboards. Create a scene that implements one or more particle systems.

How Goals were Achieved

A number of particles are created at each time step. Particles are created/recycled periodically. This is managed by a linked list. At each time step, the position of a particle is updated according to physical laws or simulated dynamic functions. Each particle is associated with a rotation matrix to make it always face to the camera/viewer. The alpha value (opacity) of quad texture is proportional to probability density function of a standard normal to make the transition smooth. Textured particles are blended to simulate fuzzy objects such as smoke or fire flame. A boundary detection routine is included to prevent snowing within the house. All objects except the particles are rendered with the depth buffer enabled. Note that the depth buffer must be set to read-only before starting the particle systems (in this case the particles can be blended uniformly), otherwise particles could occlude each other during blending.

External Resources

Table and chair are Wavefront OBJ files. Textures.

Possible Further Improvements

Add shadowing effects. Use more realistic dynamics functions to better represent the motions of smoke and fire flame. Create additional particle systems to simulate, for example, grasses on the ground. Use terrain mesh to create a continuously waving ground, etc.

Particle System Implementation

The particle systems are implemented using billboards. Billboards are texture-mapped quads, which always face to the camera/viewer to create an 3D effect. The billboards rotate such that the normal vectors of quads always point to the camera/viewer. The rotation matrix is constructed as follows.

Define:
$C = \text{BillboardPosition} - \text{ViewerPosition}$
$U = (0, 1, 0)$
$X = \text{Normalized}(U \times C)$
$Y = \text{Normalized}(C \times X)$
$Z = \text{Normalized}(C)$

The rotation matrix is then:

$$M = \begin{bmatrix} X_x & Y_x & Z_x & 0 \\ X_y & Y_y & Z_y & 0 \\ X_z & Y_z & Z_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Textures and Screenshots
The following textures have been used in the project

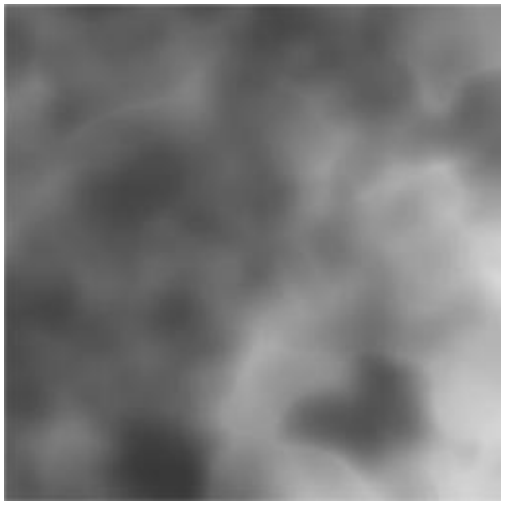
Figure 1. Texture for Smoke


Figure 2. Texture for Fire Flame

Figure 3. The snow, and the smoke out of the chimney

Figure 4. A closer look at the smoke

Figure 5. The fire in the fireplace

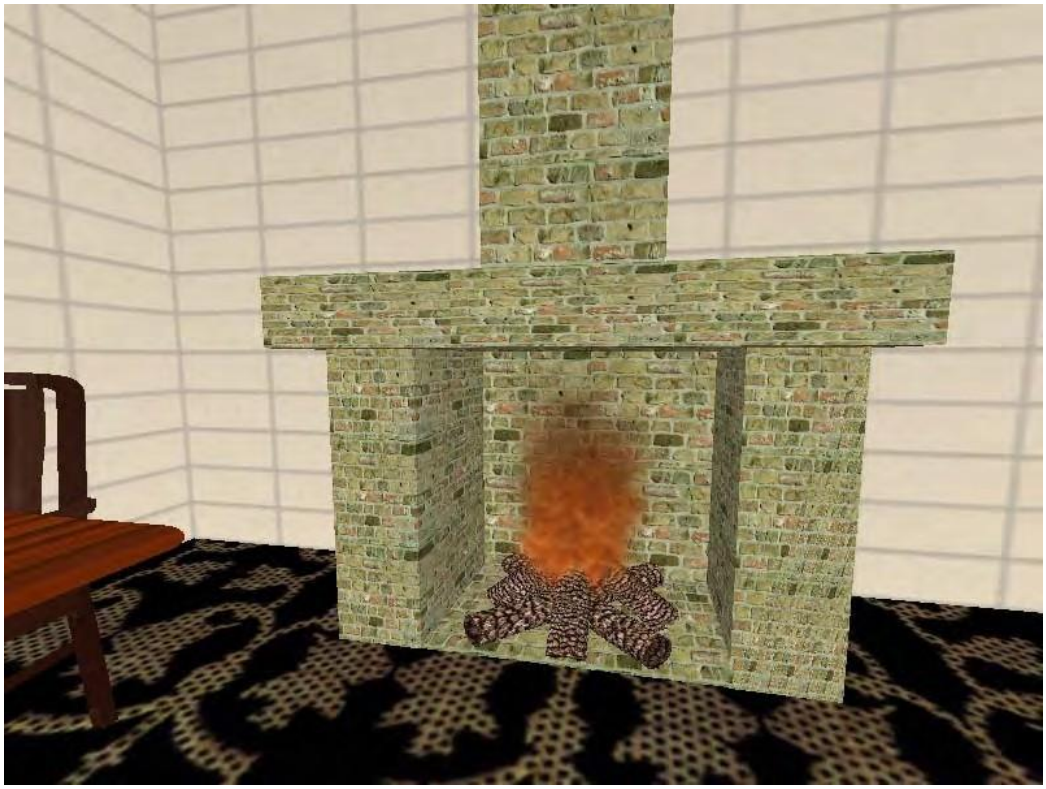

Figure 6. A closer look at the fire