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An overview of real-time 3d cloud rendering

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Abstract

Clouds are complex objects with undefined and varying shapes and structures. They have fractal surfaces of various density and transparency levels. Physical properties of cloud such as shape, colour and area of expanse and height of occurrence determine the type of the cloud. Rendering a real-time 3D cloud object on a two dimensional screen is considered to be a tedious task, while having a good scope of research in the field of Computer graphics. The rendering needs high speed graphics hardware which gives greater performance and optimal accuracy. while listing some crucial physical properties of a cloud which directly or indirectly affect the appearance of the cloud, this communication gives a short note on a three step 3D cloud rendering process, *i.e.*, cloud modeling, multiple scattering and cloud rendering.

***Keywords**: Cloud rendering, Real-time, Multiple scattering, Cloud modeling, Ellipsoids.*

Introduction

Clouds are amorphous gaseous entity having varieties of shapes and densities. There are four basic types of clouds namely: *Cirrus, Stratus, Cumulus* and *Cumulonimbus*. *Brahmanda Purana* (Volume II, Chapter 9) gives some information on hydrological cycle. It says that the seven color rays of the Sun extract water from all sources, by heating them (II, 9.138-139). Thereafter, the clouds of different shapes and colors are formed. Then they rain with high intensity and great noise. (II, 9.167-168) (Vanadeep, 2012).

Clouds have always been a child's objects of imagination, amusement and pleasure. Clouds and their appearances are often compared with human moods from our olden days. They are one of the most important objects in portraying outdoor scenarios, resembling various ambiences of nature.

From the perspective of computer graphics, Clouds are complex fractal objects. Real-time rendering of clouds on a screen to accuracy is considered to be one of the most tedious tasks in the modeling and animation industry as clouds are amorphous in nature with irregular and constantly changing shapes, densities and colors et cetera.

Some of the current application programming interfaces or renderers used today to render clouds are OpenGL and Direct3D. While OpenGL is an open source and can be implemented in various platforms, Direct3D targets only Microsoft Windows operating system.

This communication gives a short note on physical properties of the cloud which may help in real-time 3D cloud rendering process to give more realistic and visually enhanced outputs. Thereafter, three basic steps of cloud rendering that are used today are explained precisely.

Physical properties of the cloud

Before rendering a realistic 3D cloud, it is always wise to contact a meteorologist to have a better idea of how an appearance of a cloud is directly affected visually, geometrically and computationally by its physical properties and its prevalent ambience. Some of the important

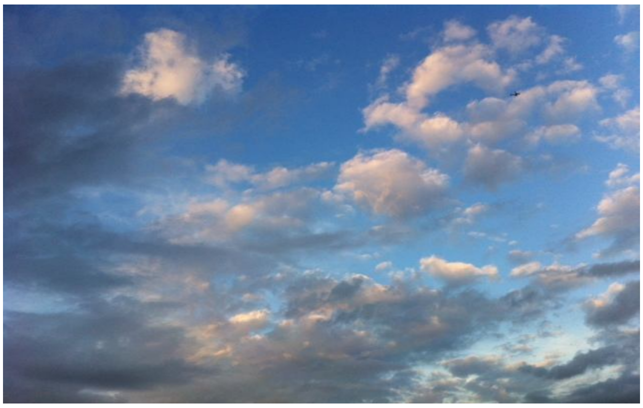

Fig. 1 Physical properties play pivotal role in cloud rendering

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physical factors to consider while judging the appearance of a cloud are-

1. Color of the cloud
2. Extent or expanse of the cloud and its direction *i.e.*, Vertical or Horizontal
3. Nature of the cloud based on level of transparency- determining whether the cloud is transparent, translucent or opaque.
4. Height of occurrence of the cloud
5. Shape of the cloud
6. Cloud density. Transparency of a cloud depends on its density. Denser the clouds are, lesser is their transparency.
7. Wind direction and velocity: ‘Wind is called the architect of a cloud’ as it directly affects shape and movement of the cloud.
8. Direction of the Sun: when the sun is at 90^o (noon), a cloud appears either white or black due to less scattering of light rays. However, when the Sun is at an inclination, i.e., during morning or in the evening, colourful clouds appear with yellow, orange and red shades due to greater scattering of light rays. (In the VIBGYOR, yellow, orange and red possess greater wavelengths).
9. Reflection and Refraction of a light ray passing through water droplets: Light passing through opaque clouds results in the formation of a silver lining and sometimes a phenomenon of cloud iridescence can also be seen.
10. Lastly, the overall ambience.

Real time 3d cloud rendering

3D Rendering is a process of generating a three dimensional image on a two dimensional screen. It is the final step in the graphics pipelining process of computer graphics. A cloud can be rendered two dimensionally or three dimensionally. But while projecting a real time scenario, 2D rendering poses visual artifacts. A step-wise procedure is followed in order to a render a cloud three dimensionally.

1. Cloud Modeling
2. Modeling the scattering of light
3. Cloud Rendering

1. Cloud modeling

Fig. 2: Rendered clouds in a flight simulator

The first step in the process of rendering a cloud is Cloud Modeling. Clouds possess complex structures both macroscopically and microscopically. Modeling helps to design complex fractal surfaces of a cloud and also to estimate and apply suitable density distribution based on the cloud type. There are two basic ways of cloud modeling techniques used today namely,

a. Procedural based cloud modeling technique
b. Simulation based cloud modeling technique

Procedural based cloud modeling technique: Procedural techniques are based on mathematical functions like Fourier synthesis (Nishita *et.al.*, 1999). Cloud shape is designed by various methods like fractal structure generation using noise octaves (Perlin Noise Method), production of multiple ellipsoidal geometrical objects by varying colours and transparencies *et cetera*. Later, all the generated noise octaves or ellipsoids are merged together to produce volumetric cloud structures, having density values depending upon required cloud type. So in this modeling technique, first a high level cloud structure is formulated and then obtained model is reduced to particles to which all the other parameters like colour, transparency, size and expanse are applied procedurally. As they are mathematical modeling techniques, they estimate modeling parameters very easily. These are more efficient techniques which produce better results in lesser times.

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Simulation based cloud modeling technique: Simulation modeling is based on physical phenomena of a cloud using equations describing buoyant forces, diffusion, pressure, fluid movements *et cetera* (Mark Jason Harris, 2003). This technique uses approximations of physical processes within the cloud, producing realistic structures and movement of gaseous phenomena. The user implements all the parameters by a trial and error method. Computational simulation of the fluid dynamics is this kind of simulation modeling used today which can generate some good quality real time image structures. On the other side, fine tuning of the image takes more time and effort which may lead to undesirable artifacts due to physical approximations considered. So, these physics-based techniques usually limit the animation, by laws of physics (Joshua *et al.*, 2003).

Modelling the scattering of light

Cloud particles are either illuminated by direct sun light or sky light caused due to atmospheric scattering. Scattering is caused due to the interaction of charged particles in the sun's radiation with various chemical ions and free radicals in the atmosphere. Light rays of shorter wavelengths are subjected to greater scattering. Cloud properties like visibility, color and brightness depend on factors like position of the sun, viewing angle, intensity of sun light, ambience of the scenario *et cetera*. In addition, scattering of light and illumination effects play a major role in modeling a cloud to make it look more realistic and eye-catching.

There are two types of Scattering Models-

1. *Single Scattering Model:* Simulates scattering in a single direction while moving along a single viewing light ray medium, varying brightness levels.
2. *Multiple Scattering Model:* Scattering is done in all directions. Here in this scattering model, the cloud particles are added to a chain and are sorted based on their distance from a light source and a view point. Later, they are sent for rendition accordingly. Therefore, this allows faster rendering process and yields to an accurate modeling, though complicated and expensive (Nishita *et al*, 1996).

Cloud rendering

Three dimensional cloud rendering needs high speed and high quality renderer to get realistic cloud objects. Multiple rendering parameters affect the display of a cloud or cloud motion in multiple ways. Some of them are sharpness, torque, density, slicing planes, opacity *et cetera*. One can choose; depending upon their needs and cost criteria from three general rendering approaches.

1. *Algorithms based on physical principles:* Ray Tracing algorithm is one of these kinds of rendering. It computes light ray passing through the cloud pixels in an image plane. The resultant images are visually far realistic; but have lower rendition speeds, which are not greatly suitable for current graphics rendering hardware.
2. *Volume rendering:* This technique is implemented by merging multiple 3D slices of textures which can be implemented in few steps-

- Create plane slicing through a volume of an ellipsoidal texture.
- All These planes are organized parallel to each other and they all stand perpendicular to a light vector. So vertices taken on all planes for a single light ray remain collinear.
- CPU calculates implicit functions at each vertex. The value obtained is used to calculate opacity of vertex.
- Iterate through all vertices to get a shadow buffer, used to get a vertex color. Some transformation matrices (represent a series of translation, scaling and rotation) generated by CPU are implemented on vertices, to generate shadows. Now each vertex gets its opacity, color and world coordinates.
- These vertices are sent to the vertex processor along with the values of their properties. The rasterizer interpolates these vertices into pixel fragments which are then sent to a fragment processor.

- Fragment processor gets the fragments from the vertex processor and performs operations like applying colours, textures and depth to the input pixel fragments. These processed pixel fragments (final pixels) are then sent to the frame buffer.
- Then the rendering is done from the frame buffer. Volume rendering consumes high memory spaces if multiple clouds are to be rendered.

3. *3D textured mapped Primitives*: These methods are used by well known computer graphics professionals like Gardner and others. In Gardner's approach, the transparency texture is created by adding 3D sine waves which have increasing frequencies and decreasing amplitude with random offsets (Pantelis Elinas *et al.*, 2000), while varying transparency levels and colors. Transparency is considered in such a way that the texture is drawn opaque at the center of the ellipsoidal textures and the transparency values increase as the renderer moves to the edges of the texture. All these generated textures are mapped or composited together to form a textured cloud. This process can be modified by using Perlin noise octaves method, where textures are created by linear interpolation of random number generator results.

Conclusion

Cloud rendering is used in real-time flight simulations, flight training, military training, and 3D animation motion pictures. To have visually appealing cloud structures, it is always useful to know the physical characteristics of a cloud before proceeding further with the rendition process. While doing so, one has to also consider rendering costs and complexities involved. The same cloud rendering techniques can be applied to any fractal phenomena like haze, hallows and fog. Cloud rendering in 3D real-time environment, though complex, is an exciting area of research and development which have greater scope of implementation in the field of computer graphics in the near future.

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