Procedural cloud shader

Project documentation

Project 2
The goal of this project is to research and implement a procedural, volumetric cloud shader. The following document reveals the process of creating such a shader from both a technical and mathematical perspective, considering different algorithms for techniques like noise generation and raymarching.

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Contents

1 General

1.1 Purpose

During this project, all gathered information and knowledge about the researched algorithms and techniques are written down in this document.

1.2 Revision History

Version	Date	Name	Comment
0.1	March 29, 2020	Matthias Thomann	Initial draft

2 Natural clouds

2.1 Formation

Clouds, as seen in nature, consist of of a visible body of tiny water droplets and frozen crystals. In their natural occurence, clouds are mostly generated from a nearby source of moisture, usually in the form of water vapor. This composition of particles creates the pleasant look of a white-grayish "fluffy" mass, floating in the sky.
Due to certain factors like altitude or water source, different types of cloudscapes can be formed. They vary in shape, convection, density and more. That makes different cloudscapes highly unique in terms of appearance.
For now, those factors are regarded as nature's randomness. However, an approximation of randomness will be covered in subsection 4.1.

2.2 Types of clouds

Cloudscapes are classified in multiple groups, mainly differing depending in their altitude, meaning the distance from the earth's surface to the cloud formation. The following four cloud genera stand out due to their distinctiveness. A realistic simulation of a cloud system would consist of a combination of these types, which is why they are displayed here.

Figure 1: Photographic reference of stratus clouds[1].

Figure 2: Photographic reference of cirrus clouds[2].

Figure 3: Photographic reference of an altocumulus cloud formation[3].

Figure 4: Photographic reference of stratocumulus cloudscape[4].

2.3 Clouds in games

Depicted in Figure 3 and Figure 4 of subsection 2.2 are clouds of the genus *cumulus*, which translated to English means *heap* or *pile*. Their distinctive cotton-like look makes them easy to recognize, which is also why they are often used in games as a reference for "normal" clouds.
In games, the formation as well as the composition of clouds are irrelevant, as they are essentially only used for cinematic ambience or as a medium to enhance the atmosphere. This leaves just the rendering technique to worry about.

2.3.1 Skyboxes

A widespread solution for representing clouds in games is not rendering them separately at all, but instead using a set of polar sky dome images, also known as the skybox. This is a six-sided cube which is rendered around the whole game world. On each inward looking face of the cube, one of the sky dome images is displayed, creating a seemless sky around the inner side of the box.

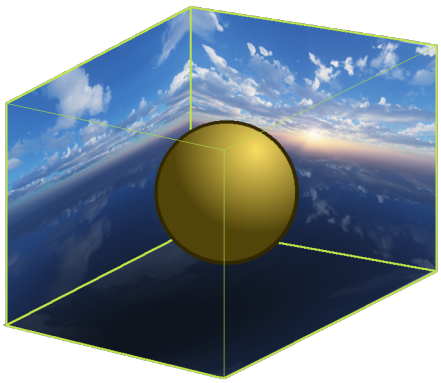

Figure 5: The skybox cube as it used in games.

Figure 6: The polar sky dome images, layed out.

Besides showing the sky, this of course allows clouds to be drawn right into the background. Also, in terms of performance, this is extremely cheap and efficient. On the other hand, it removes the ability for the clouds to move. They also have no volumetric body and no way of interaction with the game world whatsoever.
This method does indeed give the scenery a more cloudy look, but what is missing is the "feel", or in other words the motion, interaction and lifelikeness.

2.3.2 Billboards

Similar to the approach with the skybox, this technique also only uses 2D images of clouds. They are rendered individually and are always facing the camera. This is called billboarding. Now that each cloud is represented by its own game object, thus having a position in world space, a scale and many other properties, it is possible to animate the clouds. For example, by moving the game objects in a circle around the world, the clouds seemingly "pass by".

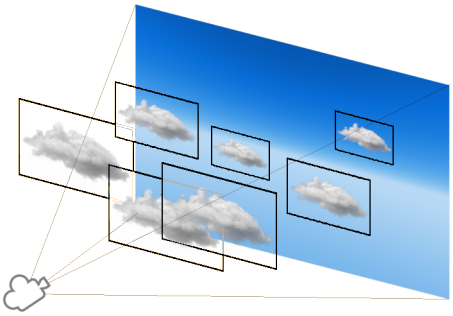

Figure 7: A collection of 2D cloud billboards facing the camera.

Figure 8: The rendered result of the image to the left.

Due to billboarding, the orientation is already given, making the overall time and effort of this technique quite advantageous to others.
The major flaw of using billboards is of course that they are still 2D images, meaning they cannot really change appearance and therefore, do not evolve at all. Still, for many games, this technique suffices in the required diversity of background scenery and the does not exceed the allowed performance share for such a task.

2.3.3 Mesh-based objects

It is imaginable to simply use a polymesh shaped like a cloud and render that like any other game object. By adding a texture, this would make for some decent looking clouds.
However, the level of detail of such a polymesh is directly connected to the amount of vertices and faces that have to be processed every frame. As seen in Figure 9, there are hundreds of polygons required to merely represent the basic shape of a realistic cloud. If a similarly complex mesh is to be used for every cloud, a massive overhead is generated for objects that usually only contribute to the background of a game.

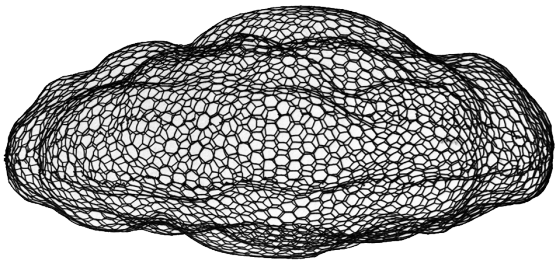

Figure 9: A polymesh in the shape of an altocumulus cloud[5].

Apart from the performance impact, this method offers a volumetric, possibly interactable object just like any other 3D model does. When massively decreasing the polygon count and therefore relinquishing the realistic look, mesh-based objects are a viable solution for some low poly games. Otherwise, it is not reasonalbe to use this method.

2.3.4 Volumetric clouds

Finally, clouds can be rendered via a technique called *volumetric rendering*. The image below shows volumetric cloudscapes as seen in popular AAA titles. The method itself is explained in detail in subsection 3.1.

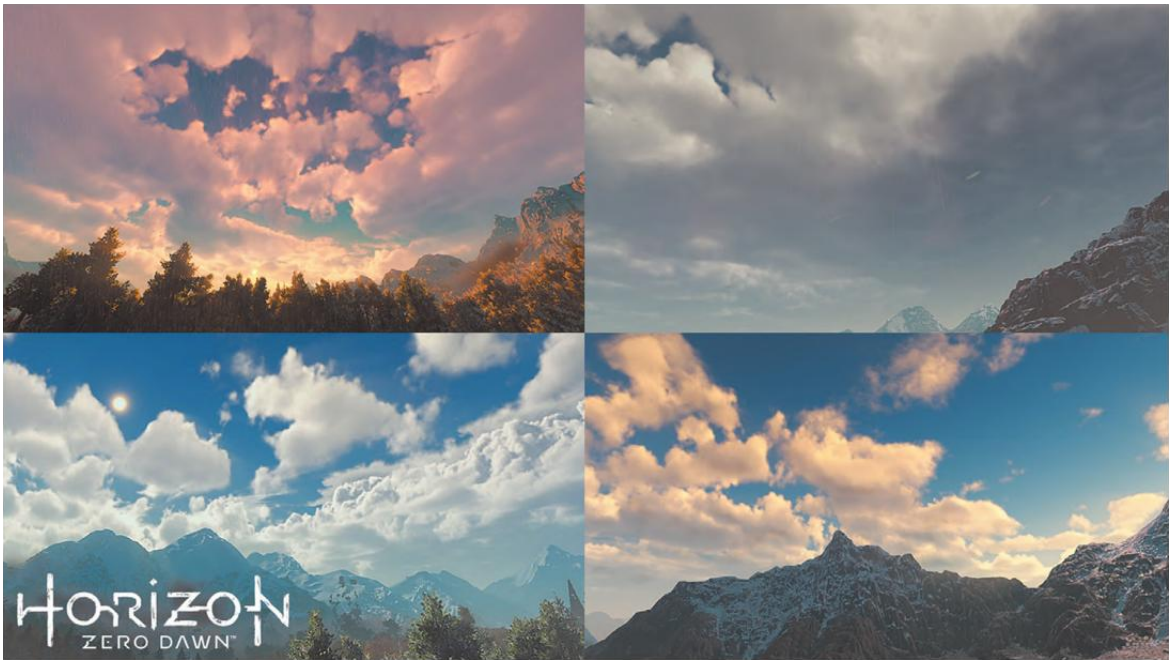

Figure 10: Several volumetric cloudscapes from the game *Horizon: Zero Dawn*, drawn in real time[6].

3 Rendering techniques

3.1 Volumetric rendering

This section is empty.

4 Common Algorithms

4.1 Noise Generation

This section is empty.

Glossary

Billboard A 2D image always facing towards the main camera. 3

Convection Convection describes the transfer of heat from movement of liquid or gas. 2

Low poly A 3D polymesh with a relatively low count of polygons. 4

Polymesh A polymesh is a 3D model composed of polygons or triangles. 4

World space Coordinates defined with respect to a global Cartesian coordinate system. 3

References

[1] *Photographic reference of stratus clouds.* [Online]. Available: `https://en.wikipedia.org/wiki/Stratus_cloud`.

[2] *Photographic reference of cirrus clouds.* [Online]. Available: `https://en.wikipedia.org/wiki/Cirrus_cloud`.

[3] *Photographic reference of an altocumulus cloud formation.* [Online]. Available: `https://en.wikipedia.org/wiki/Altocumulus_cloud`.

[4] *Photographic reference of stratocumulus cloudscape.* [Online]. Available: `https://en.wikipedia.org/wiki/Stratocumulus_cloud`.

[5] *A polymesh of a cloud.* [Online]. Available: `https://www.utilitydesign.co.uk/magis-metal-mesh-clouds`.

[6] *Several volumetric cloudscapes from the game horizon: Zero dawn, drawn in real time.* [Online]. Available: `https://tech4gamers.com/horizon-zero-dawn-gets-new-screenshots/`.