

泡と雪のシーンのため効率的な物理モデル

Efficient Physical Modeling of Bubble and Snow Scenes

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概要

衝突処理や簡単な論理演算子において、球と球殻は簡単な形であるため幾何プリミティブとしてよく使用されている。我々は、二つ以上の泡が接触するときのシミュレーション手法を提案し、可能な形状変形について議論する。

現在の泡の可視化において、任意のクラスタに対して共通する面の計算には一般的な方法を使用しないという問題がある。我々は泡クラスタで共通する面の形状を生成するために CSG(constructive surface geometry)に基づくアルゴリズムを提案する。また、3D シーンの雪のモデルに球は有用である。提案モデルは二つの粒子法を使用する。一つ目はワールド空間の雪の流れと衝突をシミュレートし、雪がある場所をテクスチャー空間にマークするためである。二つ目はマークした場所にブロビーの表面を形成し、雪を積もらせるためである。

Abstract

The spheres and spherical shells are often used as geometry primitives due to their simplicity in collision handling and simple boolean set theoretic operations.

We present some simulative techniques when two and more bubbles meet and discuss the possible geometry arrangements. The problem in current bubble visualizations is that they do not use a general method for calculation of common surfaces for arbitrary cluster. We demonstrate the algorithm based on constructive surface geometry (CSG) to find the geometry of common surfaces in bubble clusters. The other scene where the spheres are useful is the modeling of snow scene for a given 3D input scene. The proposed modeling tool uses two particle systems, the first one to simulate the flow of snow in the space and mark the snow places in the texture space after particle collision; the second one to accumulate the snow on the marked places by forming the mesh surface from accumulated blobs.

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Abstract

The spheres and spherical shells are often used as geometry primitives due to their simplicity in collision handling and simple boolean set theoretic operations. We present some simulative techniques when two and more bubbles meet and discuss the possible geometry arrangements. The problem in current bubble visualizations is that they do not use a general method for calculation of common surfaces for arbitrary cluster. We demonstrate the algorithm based on constructive surface geometry (CSG) to find the geometry of common surfaces in bubble clusters. The other scene were the spheres are useful is the modeling of snow scene for a given 3D input scene. The proposed modeling tool uses two particle systems, the first one to simulate the flow of snow in the space and mark the snow places in the texture space after particle collision; the second one to accumulate the snow on the marked places by forming the mesh surface from accumulated blobs.

Keywords: geometry of soap bubbles, common surfaces, snow modeling

1 Introduction

Soap bubbles are fragile and beautiful natural phenomena. They are prominent in everyday life, can be found in many places in real world such as carbonated beverages, on the ground of waterfalls, and while washing up. The geometry of bubble clusters is as clean and elegant as anything in nature, which makes them particularly suited to computer graphics. On the other hand the snow countryside is very fascinating, one can observe the fantastic snow shapes due to the wind and temperature. Snow surface are shiny and sparkling.

2 Spheres in Bubble Clusters and Snow

While ordinary people are fascinated by the beauty of the iridescent soap bubbles, mathematician's interest is mainly due to the minimizing property of soap films. There are contracting forces which try to minimize the surface, so in relation to its volume, soap bubbles have the smallest surface area. For that reason the gas inside the bubbles is compressed

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and prevents the bubbles from collapsing entirely. There are several works that dealt with geometry of soap bubble clusters. Analytical approach modeling clusters was presented by Andrew Glassner's work [Glassner 2000]. Ďurikovič et al. [Ďurikovič 2001] dealt with a complete computer simulation of soap bubble clusters from a dynamic perspective. It was the first physically based simulation of soap bubbles in graphic's community. Light interaction on the bubble cluster and interference effects observed on thin surfaces have been simulated in Iwasaki [Iwasaki et al. 2004].

In the next part we propose a simple script implemented in the 3DS Max to simplify the generation and rendering of snow scene. The snow modeling has been researched by Nishita et al. [Nishita et al. 2001] in his pioneering work. Fearin [Fearing 2000] in his work focused on physical based modeling of the proces of snow falling. We will generate just the final scene where the snow is accumulated by a simplified physical model. The technique should be simple to ran fast and be implemented by a few script commands.

3 Optimum Cluster Arrangement

The major part of each bubble in a cluster configuration consists of spherical shells of soap film separated by a spherical cap of soap film. If the bubbles are of different size, the smaller bubble, which always has a higher internal pressure, will intrude into the larger bubble. The junctions, where the films meet are called Plateau borders. According to the Law of Plateau, the films always meet in groups of three and form angles of 120° . Fig. 1 shows the configuration of two bubbles with radii r_A and r_B and internal pressures P_A and P_B resulting from Plateau's laws.

A *common surface* is the spherical shell with radius r_c formed between two bubbles A to B . In the case that bubble radii are equal the common surface is planar. The common surface is a spherical shell with radius r_c

$$\frac{1}{r_c} = \frac{1}{r_b} - \frac{1}{r_a}, \quad (1)$$

where r_a and r_b are radii of the two bubbles that join up. Distance between bubble centers A to B can be derived from the cosine rule as

$$AB^2 = r_a^2 + r_b^2 - r_a r_b. \quad (2)$$

An equivalent equation can be derived for the distance AC

$$AC^2 = r_a^2 + r_c^2 + r_a r_c. \quad (3)$$

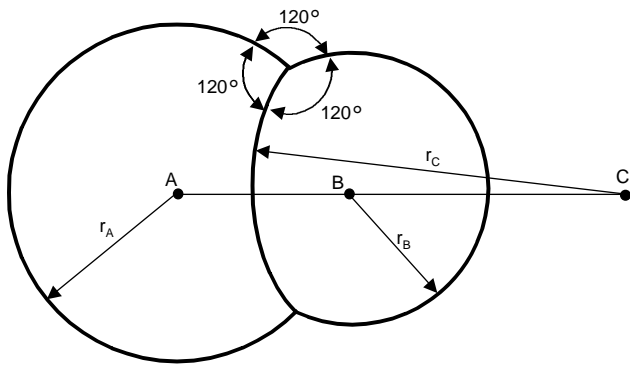


Figure 1: Curvatures of double bubble shells.

One outstanding problem involving bubbles is the determination of the bubble arrangement with the smallest surface areas enclosing and separating n given volumes in space.

The common surfaces are spherical shells cut from calculated positions and radii of the curvature spheres shown as green spheres in Figure 1. The common surface gets a bit complicated in the case of triple-bubble but it is a hassle for large clusters. Previously, we have used the dynamic meshes involving attractive and repulsive forces to calculate the common surface but it is not reliable because simulation takes long time and the event in the reality happens in a moment. We extend the ideas from double-bubble case to N -bubble case by handling the cluster as multiple double-bubbles and use a fast and simple algorithm using the CSG operations on the spheres as described in the next section.

3.1 Proposed common surface calculation

In our proposed method we first use dynamic calculation [Đuriković 2001] to find the geometry arrangement of soap bubbles. The positions and radii of all spherical bubbles are therefore known for us, but we need to calculate positions and radii of the curvature spheres that cut them up. In case of two intersecting bubbles with exactly the same radius we need to find also the equation of a plane that creates the border. At the end we perform CSG operations on each two intersecting spheres. The results will be very realistic.

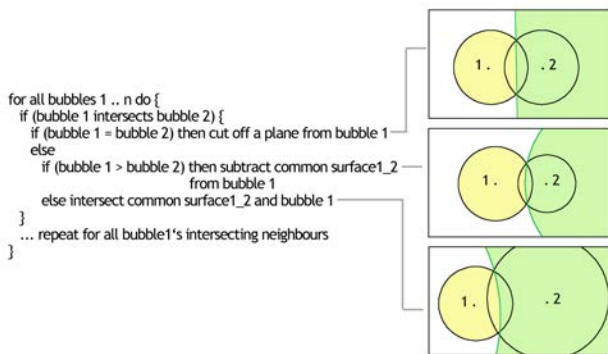


Figure 2: Pseudocode of our proposed method.

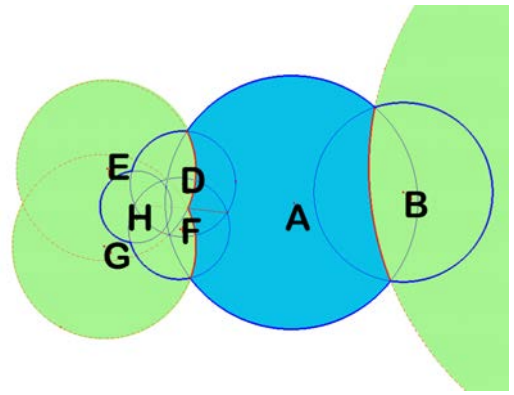


Figure 3: CSG operations on bubble A.

The basic idea is to pick one bubble and for all its intersecting neighbours determine if this neighbouring bubble is smaller, equal or bigger than the picked one. If it is smaller we create subtraction *common surface sphere*, that creates the border between two bubbles, from the main bubble. If it is reversely and the neighbouring bubble is bigger we perform an intersection the main bubble with the *common surface sphere* performed. The last alternative, when both bubbles are equal, the border is flat plane that goes through the intersection points. We can make either subtraction or intersection between main bubble and plane in this situation. After that we will pick as a main bubble another sphere from sorted list of bubbles according to radii and repeat the process. For better understanding there is a pseudocode in Figure 2.

There is a rule that small bubble always intrudes into the larger one, because has a higher pressure. So it is clear that we need to subtract the bubble that forms on common wall from the larger bubble in each intersecting pair of bubbles. Figure 3 presents bubble cluster of 5 bubbles. Bubble A is the biggest bubble and has common intersection with bubbles B, D, F and H. We get the desired borders after cutting off all *common surface spheres* (green circles) from bubble A resulting in the blue area.

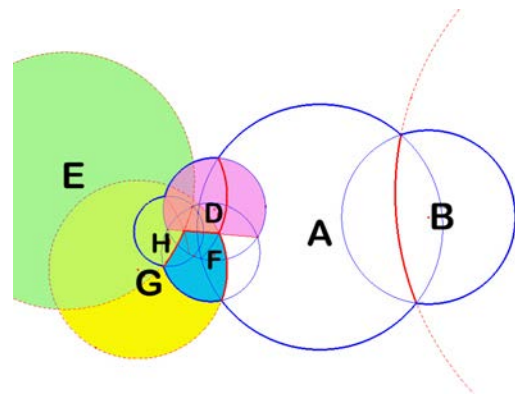


Figure 4: CSG operations on bubble F. Subtraction is represented by green color, intersection by yellow color and purple symbolized the subtraction of same sized bubble.

Then we take the next sphere from sorted list by radius. It is bubble F, in our example on Figure 4. If selected sphere is

in bubble pair with bigger bubble A we take the intersection with the *common surface sphere* that forms on common wall shown as yellow circle. If bubble F is largest in bubble pair we always subtract the *common surface sphere* from it (green circle). If the two bubbles are equal shown in purple color the border is a flat plane. If two bubbles have no intersection we never do the CSG operations on these two bubbles.

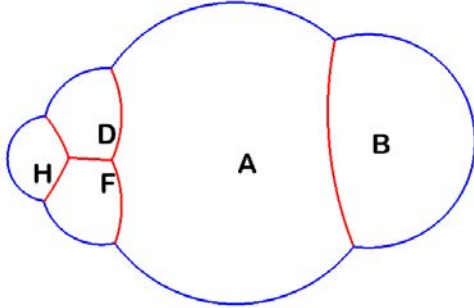


Figure 5: Complete bubble cluster. Red lines show the common surfaces.

4 Examples of Common Surfaces

After having information about bubble centers and radii, we compute the necessary information about centers and radii of common surface spheres. Finally, the CSG operations are used to cut out the common surface within the cluster. A POV-Ray script that calculated the radii and makes all CSG operations and returns us required common surfaces have been implemented. We present here several bubble clusters rendered by POV-Ray using our proposed method. In Figure 6, we have used different color and emphasize the common surface from outside shells.

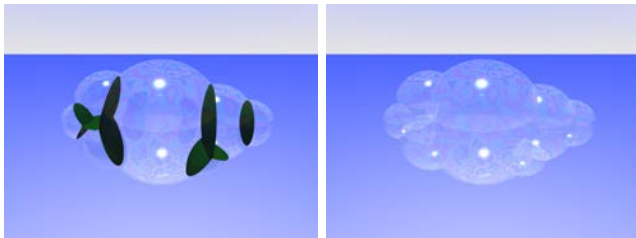


Figure 6: Bubble cluster with 7 bubbles. Left: Common surfaces are green for better visibility. Right: Common surfaces have natural bubble texture.

5 Spheres in Snow Modeling

The system consists of several basic parts. First is the particle systems, that localizes the places on the object surface where the snow should occur. We call this particle system `PF_Locate_Snow`. We store the position and snow amount information into a texture. The texture is then used in the second particle system that generates small metaballs to create the snow surface on the objects surface. The second

particle system is noted as `PF_Create_Snow`. All particles model use already implemented particle flow system in the Autodesk 3ds Max we have set the proper parameters of particles, their velocity, turbulence and determined the actions after the particle collision with the object surface. Because the scrip is much slower then the compiled code we had to simplify the mesh model for faster collision handling. The number of particles in the scene had to be managed by deleting the particles leaving the scene. After storing the information into the texture we can also delete the particle from simulation loop.

The final particle flow model uses flow of metaballs. There is no need for large amount of particles because all particles are attracted by marked places in the texture. The metaball surface is then rendered by using sub surface scattering and noise bump mapping texture to enhance the sparkling effect using the V-ray rendering implemented in the the commercial software.

6 Examples of Snow Scene

Here we show some examples of snowy objects rendered using the techniques described in this paper.

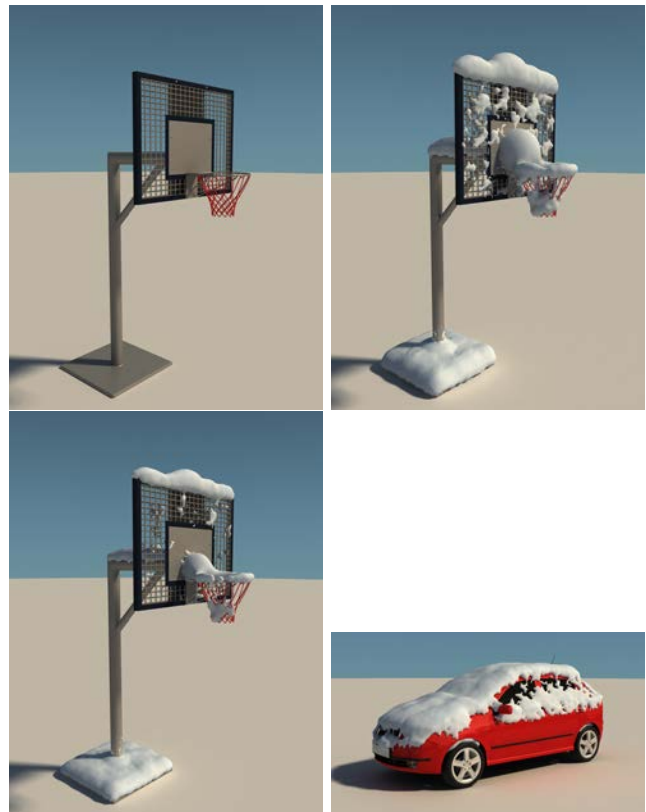


Figure 7: Snow scenes. Top left: Input mesh model. Top right: Rendered scene covered by snow. Bottom left: Changing the amount of falling snow. Bottom right: Car model covered by snow.

7 Conclusion

We have shown that the spheres can be efficiently used to model the common surfaces in bubble clusters by clever order of SCG operations. We have also demonstrated use of particle spheres in the 3DS Max script to find the snowy places in the scene and to create the covering snow mesh.

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