Efficient Sound Synthesis for Natural Scenes

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Abstract

This paper presents a novel framework to generate the sound of outdoor natural scenes, such as waterfall, ocean, etc. Our method firstly simulates liquid with a grid-based method. Then combined with the movement of liquid, we generate seed-particles which represent bubbles, foams or splashes. Next, we assign each seed-particles a radius with a new radius distribution model. By calculating the bubbles' pressure wave we generate the sound. Experiments demonstrated that our novel framework can efficiently synthesize the sounds for natural scenes.

Keywords: sound synthesis, seed-particles, bubble, radius distribution model.

Index Terms: H.5.5 [Information Interfaces and presentation (e.g., HCI)]: Sound and Music Computing—Modeling; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Animation

1 Introduction

Liquid simulation, as an important part of computer graphics, have received great success until now. And in recent years, there are a few methods on synthesizing liquid sounds. These methods focused on a realistic bubble simulation, and then synthesized the sound by extracting the bubble meshes. For liquid in a container, they had a good result. However, due to the high complexity of their algorithm, they are inapplicable to generate the sound of liquid for natural scenes. So we present a novel framework to generate sound for large scale outdoor scenes. Instead of extracting the bubbles' meshes from fluid simulation, we propose seed-particles to represent bubbles, which can greatly reduce the algorithm complexity. And after a using of a radius distribution model, we can synthesize the sound. And the distribution model is an approximation of bubble distributions in natural.

2 Related Work

The researches shows that the bubbles' formation and resonance generates most of the liquid sound [1]. Van den Doel [2] proposed a statistical method to generate bubble sounds, but they didn't apply it to a specific scene. Zheng et al. [3] presented a harmonic-based synthesis method to synthesize fluid sound, and their examples need a laboriously hand-tuned. Moss et al. [4] generalized the sound creation mechanisms to non-spherical bubbles. Both of these two methods used a single-phase liquid simulator. Later, Langlois et al. [5] presented a method for synthesizing physics-based bubble sounds directly from two-phase incompressible simulations of bubbly water flows. All these methods simulated liquids in a container, and with the improvement of sound results, the complexity of the method was improved obviously

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3 Method

The sound generated by bubble formation and oscillation is one of the most important sources for ocean noise [6]. Different from the simulation of liquids in a container, when we create a large scale outdoor scene in computer, the bubbles' shape and mergence cannot be simulated. That is to say, the previous method which synthesized the liquid sound through an extraction of bubbles' meshes are inapplicable. Actually, in large scenes, variations in bubbles' shape radiate very little sound directly [7], and the distortions from a spherical shape influence the bubble' sound slightly [8]. Based on the above observation, we present a novel framework to generate sound of natural scenes without an accurately simulation of bubbles' state, and all bubbles are assumed as spherical. Figure 1 shows the different workflow between previous methods and ours.

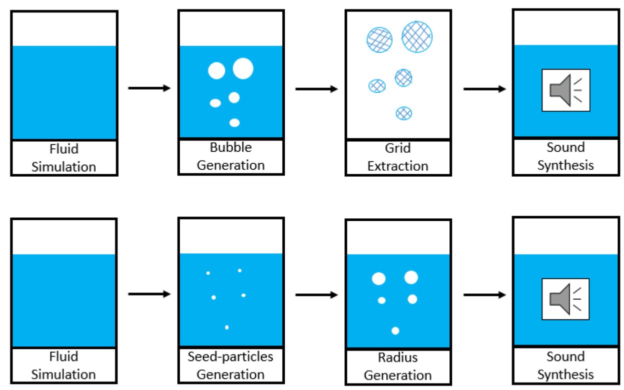

Figure 1: Comparison of the workflow between our method (bottom row) and the state-of-the-art (top row).

In this paper, the method how natural scenes can be simulated is not addressed. What we do is when we can simulate the scenes, how we can generate the sound of them. Based on this, we divide our method into three parts: 1.The extraction of particles' characteristics during the simulation; 2.Radius generation in per frame; 3.Sound synthesis.

Characteristics extraction: Whatever method we take to simulate the natural scenes, in order to enhance the authenticity of them, we will add some auxiliary particles. For example, during a simulation of ocean, many particles which represent bubbles, foams or splashes would be created. And in our method, we name these particles as seed-particles. When the state of the liquid varies, some of the characteristics of the particles will also change. Now in our method, we use the number of these particles in per frame to show the different states of the liquid.

Radius generation: For sound synthesis, each particles should have a radius. Although other properties are also demanded during computation, we take them as constants. In surface wave breaking entraining process, the bubble size distribution can be expressed as $N \sim r^n$, where N denotes the bubble population, and r the bubble radius [6]. And the bubble size distribution is essentially the same in fresh and salt water [9]. On the basis of this theory, we present our radius generation method.

Assume that in one frame, there are totally M particles. And the radius ranges from r_{min} to r_{max}. we use $d(r)$ denotes the number of particles with a radius r. We calculate it as follows:

$$d(r) = M * r^{-n} / \sum_{i=r_{min}}^{r_{max}} i^{-n} \quad (1)$$

where r_{min} , r_{max}, and n are adjusted according to the final sound. A larger value of r_{min} or r_{max} may lead to a lower sound. And when r_{max}/r_{min} >=100, there would be a better result. Generally, a n between 1 to 5 could be chosen. And about 50 radii we chosen to discrete radius range.

Sound synthesis: For a bubble in water surface of breaking waves, its oscillation typically decay within O(10) ms [10]. So in our experiments, we give each particle a random life L less than 44100/*fnum* in audio generation time step, where *fnum* denotes the number of frames in one second. And we modify each particle's radius in below way to add some randomness in the results, so that the result can be more close to the natural situation:

$$\mathrm{r} = \mathrm{r} * (0.5 + \mathrm{L/fnum}) \quad (2)$$

Then we calculate each particle's pressure wave with following equation[4]:

$$p(t) = \epsilon r_0 \sin(2\pi f(t)t)\, e^{-\beta_0 t} \quad \epsilon \in [0.01, 0.1] \quad (3)$$

where $f(t) = f_0(1 + \varepsilon\beta_0 t)$ is the resonant frequency of a bubble, which is affected by the original resonant frequency f_0 and changes with time. And $\beta_0 = \pi f_0 \delta_{tot}$ is the rate of decay. δ_{tot} is a term related to damping. We divided it into two parts: thermal damping δ_{th} and radiative damping δ_{rad}:

$$\delta_{th} = \sqrt{\frac{9(\gamma-1)^2}{4G_{th}} f_0} \qquad \delta_{rad} = \sqrt{\frac{3\gamma p_0}{\rho c^2}} \quad (4)$$

where γ is the heat capacity ratio of gas and ρ is the density of fluids, c is the speed of sound. G_{th} is the thermal damping constant, we calculate it in the following way:

$$G_{th} = \frac{3\gamma p_0}{4\pi\rho D_g} \quad (5)$$

where D_g is the gas' thermal diffusivity, p_0 is the hydrostatic pressure of the liquid. The final result is a sum of all bubbles' sound.

4 RESULT

We simulated the scenes in a computer with a core of 3.60GHz Intel(R) Core(TM) and a graphics card of NVIDIA GeForce GTX 960. Two results are shown in Figure 2, namely "waterfall" and "ocean". It can be seen from the sound curves that the sounds are greatly matched with the fluid animation. The accompanied demo demonstrate the visual animations and the computed sounds of the above two natural scenes.

In our two results, we cost 4 seconds to synthesize the sound of "waterfall" and the video time is about 4 seconds. In scene "ocean", we spent about 8 seconds to synthesize an 8 seconds sound. In paper [5], their sound synthesis process was divided into several parts, and, finally, they need several hours to generate the results by using more than 8 cores which we used. That is the reason why we think it is difficult to be used to generate natural scenes sound.

5 CONCLUSION

We presented an efficient sound synthesis framework for large-scale outdoor fluid scenes. Different from classical methods, we propose seed-particles to represent bubbles; with a radius distribution model, our method can efficiently evaluate the bubble sound. By integrating the bubble sounds, the scene sound is finally computed. In comparison to the state-of-the-art methods, our new work flow can greatly reduce the algorithm complexity.

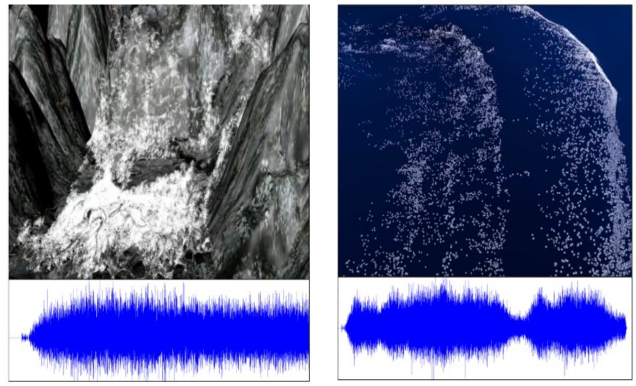

Figure 2: Scene "waterfall" (left), "ocean" (right) and their sound curves

Our bubble radius distribution model may fail for some special cases such as fluid-solid coupling. This is because that under the above situations the bubble distribution may not obey the power law. In the future, we would explore other bubble radius distribution models with wider applicability. We would also incorporate sound propagation into our method to improve the sound fidelity.

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