Envelopment Surface Rendering of Falling Water for Particle and Volume Based Virtual Liquid Manipulation Model

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1 Introduction

This paper describes a method to render envelopment surface of falling water in an interactive manipulation model of virtual liquid that we have proposed for virtual reality system. In the CG field, although researchers have developed the method to simulate the behavior of fluid with particle method e.g. SPH method [1], it needs enormous computation time and usually needs parallel processing to realize real-time processing. Therefore, we have already proposed an interactive manipulation model of virtual liquid like water which focus on user impression and real-time processing rather than exact behavior simulation [2]. The model can make user feel realistic sensation from the water behavior occurred by user's manipulation. However, free fall condition water is just simulated with particles and rendered as a particle simply. Although metaball and marching cubes method [3] are famous to render surface calculated with particle system, these method are not appropriate for interactive manipulation system because of much calculation time and many times of data scan. In this paper, we propose an efficient and effective rendering method of free fall condition water. To reduce data scanning frequency and searching pattern, it is classified into simple patterns to create process of envelopment surface from particles in the method. Then envelopment surface is rendered in real-time without parallel processing.

2 Particle and Volume Based Model

Our proposed model represents the water as following two conditions to simplify calculation; the stay condition which exists in a container and the free fall condition which flows from/to container. The stay condition water is treated with the volume value, and the free fall condition one is treated as a simple particle system that particles do not interfere each other. Using this model, total calculation time is reduced drastically, and an interactive water manipulation is realized in real-time. We have improved the stay condition water, that is, we developed the method to express wave, vortex and diffusion of color as surface effects of water [4]. The improved model can make user feel more realistic sensation. However, free fall condition water, or each particle is rendered as a simple square polygon, and every polygon is directed to the viewpoint.

3 Envelopment Surface Model

The new model renders envelopment surface for free fall condition water that was rendered as a particle simply (Fig. 1). Although each process to make the surface is described and illustrated as two dimension in the following explanation, it is actually rendered in three dimensional space. At first, the 3D space is divided into grid (Fig. 2(a), (b)). Then the following steps are processed every drawing frame.

Step 1: Set the grid value where any particle exists to "1" (Fig. 2(c)). The calculation amount of this process is proportional to the number of particles that exist in virtual space.

Step 2: Scan and draw each grid as one of the predefined patterns (Fig. 3) according to the 8-neighbor of it (Fig. 2(d)). The calculation amount is proportional to the grid size.

The grid is often big size, but the number of times the grid is scanned is just one per a frame in our model.

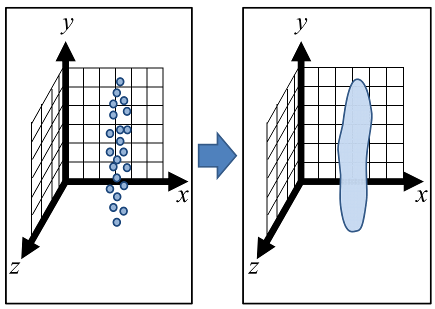

Fig. 1: Rendering outline

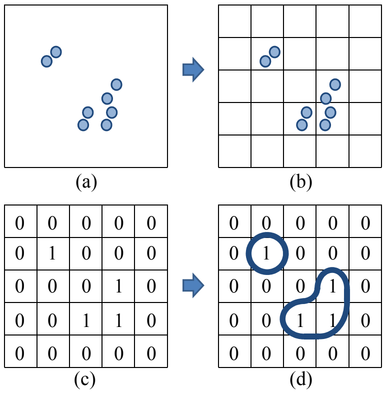

Fig. 2: Rendering procedure

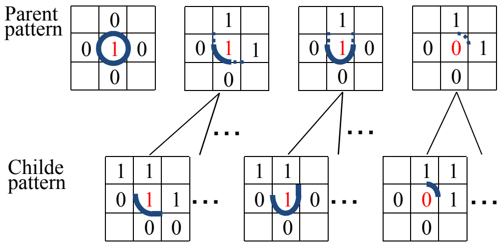

Fig. 3: Examples of 12 predefined parent patterns, each pattern has 0–7 child patterns in 2D

4 Experiment

Using the model mentioned above, we implemented a virtual liquid manipulation system (Fig. 4). User can move a container with POLHEMUS 3SPACE ISOTRAK II. We compared this new model that renders envelopment surface (Fig. 5(left)) with previous model that renders particles directly (Fig. 5(right)). The envelopment surface is rendered and covers particles which decide the behavior of free fall liquid, so user feel more realistic sensation at depth and spatial effect. The processing speed is 29 fps with about 1500 number of particles where the grid size is 120 × 120 × 60. It means interactive manipulation is realized in real-time.

5 Conclusion

In this paper, we proposed an efficient and effective rendering model of free fall water with envelopment surface. It can make more realistic sensation. As a future work, we should improve visual effects of envelopment surface, e.g. at shading process, and rendering speed not only for experimental system but for application system. We are now promoting to apply this virtual water manipulation model to new e-learning system based on VR technique e.g. virtual experience system of chemical laboratory. Realistic sensation felt from the liquid manipulation and real-time processing on low-priced PC are important than the exact behavior of water for the system like described above.

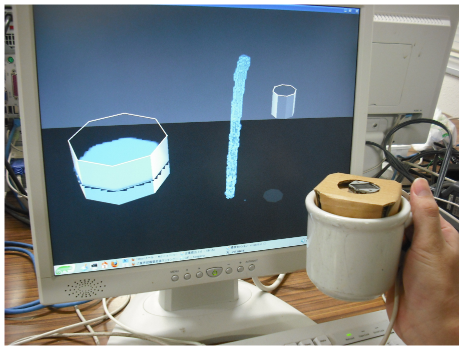

Fig. 4: Appearance of experimental system

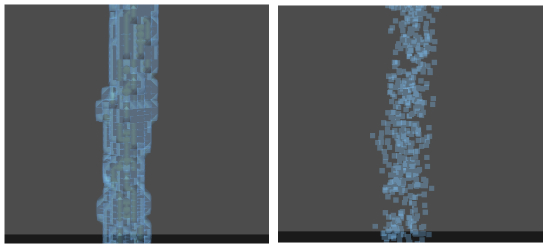

Fig. 5: Envelopment surface and particles

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