Virtual Liquid Manipulation Using General Shape Vessel

Kenji Funahashi
Nagoya Institute of Technology
Center for Information and Media Studies
Nagoya 466-8555 Japan
kenji@center.nitech.ac.jp

Yuji Iwahori
Nagoya Institute of Technology
Center for Information and Media Studies
Nagoya 466-8555 Japan
iwahori@center.nitech.ac.jp

Abstract

This paper describes a method to realize an interactive manipulation of virtual liquid using virtual vessels which are expressed by the general convex shape polyhedron. We have proposed the liquid manipulation model which has some functions to treat the relation between the volume of liquid in a vessel and the height level of liquid surface in it while it is tilted. For a general shape vessel, the look up table to calculate the above functions is implemented. Our system with this proposed model makes it possible to catch the liquid using the virtual vessel, to hold the liquid in it, then to spill the liquid by tilting it. Also the system realizes the manipulation to skim the liquid from another liquid vessel.

1. Introduction

In the field of virtual reality for the recent years, many researches such as [3] have been performed for the interactive manipulation in virtual space. In the conventional researches, the limitation is that users can manipulate only the solid objects under these systems.

While in the computer graphics technology, the scene image of water current have been represented by real-time simulation [1]. However, an interactive manipulation of the virtual liquid is not considered in that and other studies.

In this paper, an interactive model to manipulate virtual liquid using a virtual vessel [2] is described. The main purpose of this model is the realization of the virtual liquid manipulation, while the generation of high quality computer graphics images or simulating the exact behavior of the liquid, are not the main.

Our system with this proposed model makes it possible to catch the liquid using the virtual vessel, to hold the liquid in it, then to spill the liquid by tilting it. Also the system realizes the manipulation to skim the liquid from another liquid vessel.

2. Model for virtual liquid and vessel

2.1. Virtual liquid in virtual space

In this paper, we consider the liquid under the following conditions.
(1) free fall condition (such as flowing water from a faucet).
(2) stay condition (such as holding water in a cup).
The proposed model represents the liquid in the condition (1) as particles. Each particle moves according to the gravity and the inertia. While, the liquid in the condition (2) is represented as volume. The exchange rate between each condition is assumed to be N [particles / volume].

2.2. Model of virtual vessel

A virtual vessel with convex shape is introduced to detect the interference with liquid. Its position is represented by C, which is the center of the sphere with radius r including it. Its direction is represented by θ, ϕ and ψ, while the tilt is represented by θ and ϕ.

The functions of the vessel with the liquid are defined in the following. The over flow point F is represented by the relative vector from the point C. When the volume of the liquid in a vessel is V $(V \geq 0)$, the height level of the liquid surface H is represented by the relative distance from the point C. When the parameter V of the function h is over the maximum volume Vm, H becomes F_y (F_y is defined as the vertical coordinate of F). When the parameter H of the function v is under the vessel, V becomes 0. When H is above the point F, V is taken as $v(\theta, \phi, F_y) = Vm(\theta, \phi)$ (F_y is independent of ψ).

$$F = f(\theta, \phi, \psi). \quad (1)$$

$$H = h(\theta, \phi, V). \quad (2)$$

$$V = v(\theta, \phi, H). \quad (3)$$

For a general shape vessel which is expressed by the general convex shape polyhedron, the look up table to calculate the above functions is implemented.

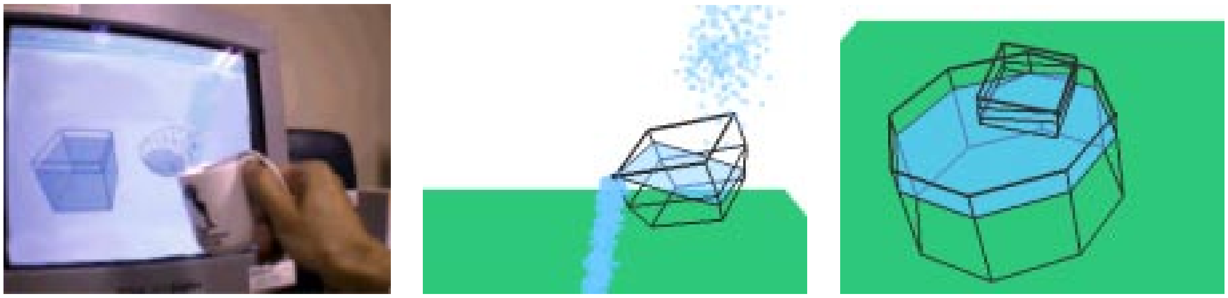

Figure 1. Examples of manipulation on proposed system

3. Interaction model of liquid and vessel

3.1. Liquid in free fall condition and vessel

When the falling liquid (each particle) moves through the mouth of a vessel, the status of the liquid changes from the condition (1) to (2), and the volume of the liquid in it will be increased according to the exchange rate N.

3.2. Liquid in stay condition and vessel

In this section, we describe the interaction model between a vessel and the liquid in another vessel. In the following, let each vessel be designated as *vessel 1* and *vessel 2* respectively, also let the symbol of each vessel be designated as subscript 1 and 2 for the distinction. When the equation (4) holds, vessel 1 and the liquid in vessel 2 are interfered each other.

$$C_{1y} - r_1 < C_{2y} + h_2(\theta_2, \phi_2, V_2), \tag{4}$$

$$C_{2y} + h_2(\theta_2, \phi_2, V_2 + Vm_1) < C_{1y} + F_{1y}, \tag{5}$$

where C_{jy} is the vertical coordinate of the position C_j.

When the equation (5) also holds, the situation is that the part of vessel 1 under the over flow point interferes with the liquid surface of vessel 2. When it does not hold; the situation is that the liquid in vessel 2 flows into vessel 1, the volume of the liquid in each vessel is changed with the appropriate rate by applying the above functions [2].

3.3. Spilling liquid from vessel

When the volume of liquid in a vessel is over the capacity by the above interference or tilting it, the part of the liquid in the vessel, which is expressed using the volume, spills at the over flow point F as particles.

4. Experimental results

Using the model mentioned above, we implemented a system for the virtual liquid manipulation using vessels in C language on a graphics workstation SGI O2. As shown in Fig. 1, the user can catch the falling liquid using the virtual vessel, hold the liquid in it, then spill the liquid. Also it shows that the user can skim the liquid from another vessel.

Through this virtual liquid manipulation system in our laboratory, we get some positive evaluations such that “I feel that I really manipulate the water (liquid) using a cup.” This system can refresh its screen at 24 frames/sec. as the average speed for the representation of around 500 particles.

5. Conclusion

In this paper, we described a method for the virtual liquid manipulation using vessels. The experimental system can catch the falling liquid, skim the liquid from another vessel, hold the liquid and spill it at an interactive refresh rate. Users have an impression close to that in the real world.

The system proposed in this paper is under the stage of the realization of the basic functions, and the following points are remained as the future subjects.

· Vessel expressed by concave polyhedron.

· Condition such as water current.

It is considered that a concave polyhedron vessel should be divided into some neighboring convex polyhedrons, and the current condition is represented as both particles and volume.

References

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