Visual Simulation of Water and Human Motion

Jong-Hyun Kim[1], Jung Lee[2], Chang-Hun Kim[3]

[1,2,3]Korea University, KOREA

Fig. 1. Real-time coupling of water and human motion

Abstract

Recently, an increasing amount of fluid simulation researches in computer graphics are appearing, using human motion data obtained by Kinect. This paper suggests a real-time coupling method of human motion and water simulation by improving a standard sequential update procedure by putting skeleton structured joint velocity into the velocity field of a water simulation. It is possible to earn real-time performance on a large, target driven water simulation scene.

Keyword : Human motion data, Water–human motion coupling, GPU-based fluid simulation

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[1] Jong-Hyun Kim
gogogoscv@korea..ac.kr
Address. Graphics Lab. 407B Woojung Bldg. Korea University, Anam-dong 5(o)-ga, Seongbuk-gu, Seoul, 136-713 Rep. of KOREA
Tel. +82-2-3290-3574

[2] Jung Lee
airjung@gmail.com
Address. Graphics Lab. 407B Woojung Bldg. Korea University, Anam-dong 5(o)-ga, Seongbuk-gu, Seoul, 136-713 Rep. of KOREA
Tel. +82-2-3290-3574

[3] Chang-Hun Kim
chkim@korea.ac.kr
Address. Graphics Lab. 407B Woojung Bldg. Korea University, Anam-dong 5(o)-ga, Seongbuk-gu, Seoul, 136-713 Rep. of KOREA
Tel. +82-32-860-7452

1. Introduction

Video scenes increasingly include virtual avatar characters that are manipulated by motion capture. To facilitate these manipulations, very expensive capture devices are required to extract human motion data and labor-intensive post-processing needs to be performed to refine the captured motion data. For example, Park and Hodgins proposed a data-driven modeling method to capture high-resolution motions that deform the skin and muscles [1]. Hong et al. also proposed a data-driven segmentation method to solve the twisted artifacts that occur in joints with complex topology, such as the shoulder joint [2]. However, these methods focused on capturing human motion in an accurate manner; therefore, their computational costs are too great to allow their application in interactive applications.

In addition, many real-time motion capture applications have been proposed. Lange et al. developed a Kinect-based game for rehabilitation [3] and Tseng et al. proposed a Kinect-based rehabilitation system for virtual scenes [4]. These methods aimed to facilitate rehabilitation in the home or other places without appropriate facilities.

Martinovikj and Ackovska proposed a gesture-based presentation control system that analyzed human motions, instead of using a mouse and a keyboard [5]. This method analyzed hand gestures, but only two gestures were considered: swipe-left and swipe-right. Tam and Li proposed a gesture recognition system using quick response (QR) codes and mobile devices [6]. In addition, visual simulation techniques that allow interaction with human motion data have been developed. In particular, Kwatra et al. aimed to represent the swimming motions of an articulated body by addressing water-body coupling issues [7].

We propose a novel structure to couple water and a human motion. In particular, the main contributions of this study are as follows.

- We suggest a real-time target driven water simulation using captured human motion data
- We suggest a method for coupling human motion and a large scene while using a large amount of particles

2. Related Works

In the spherical approximation method, surfaces are approximated by particles to accelerate the processing of interactions with rigid bodies. The particle representation is generated in a preprocessing step using a distance field [8,9,10,11]. One criticism of spherical approximation has been that it is very slow, because an enormous number of spheres are required. The inner sphere tree method addresses this problem by adaptively approximating a shape using large spheres for the bulk of the object and small spheres on its surfaces [12,13,14,15]. However, reconstructing this tree for deformable bodies would take too long.

Fedkiw introduced the ghost particle method to determine collisions between fluids and solids more accurately [16]. Recently, Schechter and Bridson introduced a solid boundary condition method which allows for cohesion [17]. However, the ghost particle method is computationally expensive to use with complicated solids.

Ihmsen et al. solved the problem of particles stacking near the surface of a solid in narrow valleys by using predictive corrective incompressible SPH, which repeatedly corrects the positions and velocities of particles [18]. Qin et al. also tried to solve the stacking problem by improving the repulsive boundary condition [19]. Akinci et al. proposed a pressure-based scheme to couple simulations of a fluid and a rigid body [20]. This method employs boundary particles to represent rigid objects, and effectively avoids the problem of particle deficits at spatial and temporal discontinuities between heterogeneous materials. However, this method relies heavily on the pre-sampling of objects, and it is difficult to generalize to deforming solids. Akinci et al. addressed this problem by generating boundary particles quickly and compactly on the surface of a deformable body, leading to a notable improvement in performance [21]. However, many boundary particles are still required, and the method can fail if particles move too quickly as a result of the tunneling problem.

3. Coupling Simulation

3.1 Target Driven Water Simulation with Human Motion

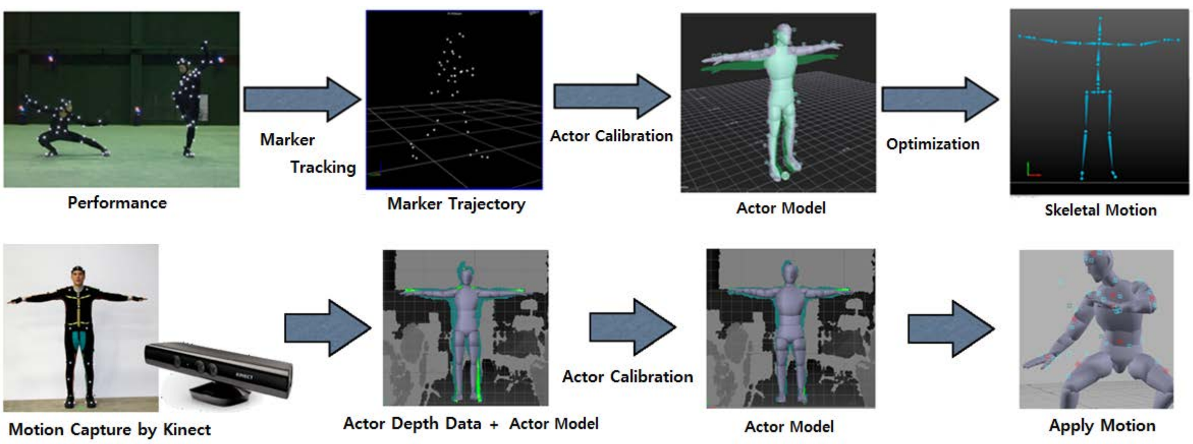

Fig. 2. Obtaining human data by motion capture(a) and Kinect(b)

In this chapter, we explain about the application of human data on a target driven method. Target driven method is a method to control fluid to form a specific geometry during a fluid simulation. A popular example of it is frequent in movies, such as fire or water shaping into a form of a man or a beast. Human data describes a motion of a user. Human data can be captured by using a motion capture method or Kinect. (Fig. 2)

General motion capture methods employ placing of special markers over a target user, tracking the markers. By placing the markers to specified locations, the methods can obtain highly detailed human data, including human facial expressions. However, the methods require specialized equipment and suits. Therefore, motion capture methods are generally not for general applications but for some specialized applications which requires detailed human data, such as movies.

Kinect obtains motion data by using its depth camera. It has an advantage of low price which can be easily purchased by public, and relatively easier to use. However, it lacks the accuracy compared to the motion capture method. It is more suited for applications where the target does not require high accuracy, such as gaming.

The obtained human data goes through a process to map its data to an avatar in a virtual environment. After the process, the captured motions are applied to the avatar, and will be modified for a further application.

A target driven method can be implemented using a signed distance field (SDF). SDF spatially devices the simulation space into a grid, then describe objects or positions by a signed distance from a nearest grid cell. Generally, a negative sign means the cell is positioned inside of an object while a positive sign means its outside. (Fig. 3)

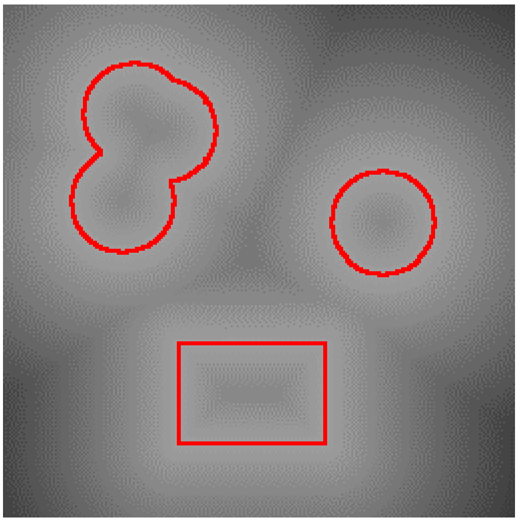

Fig. 3. An SDF snapshot. Red outlines are objects. The image gets brighter as its closer the objects.

There is a need to convert a SDF to a vector field prior to the target driven simulation. The direction of the vector will be a direction from a cell to an object's surface, while the magnitude of the vector will be proportional to the distance between the surface and the object. By mapping this vector field to the simulation space and applying external force over the field, we can drive fluid into a target shape. (Fig. 4)

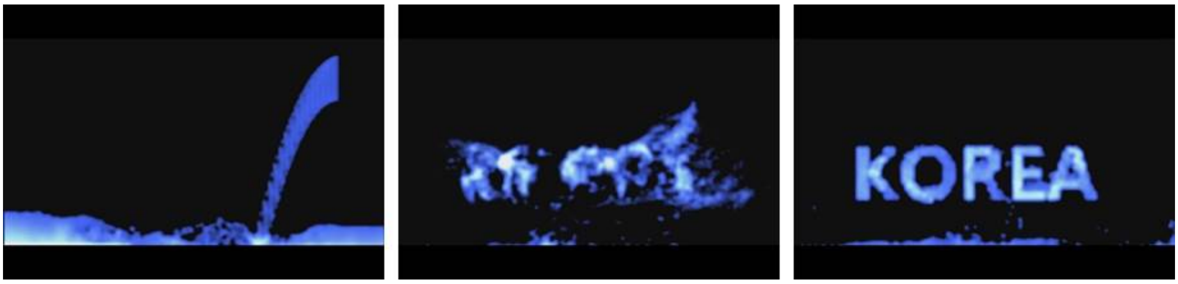

Fig. 4. Target driven implementation using external force by a vector field

The motion of avatar from human data can be applied to the target driven simulation to construct a interactive target driven application. The coupling of the avatar and fluid uses a general fluid coupling method. To make it real-time, it is recommended to implement it over a GPU. It is also worth noting that its more easier and efficient to obtain human data by Kinect, instead of using motion capture methods.

3.2 Coupling of Water and Human Motion

Fig. 5. User input from Kinect

Detailed position information is required to connect a user input and a fluid simulation. However, Kinect supports only handful of information from the major joints, which is not enough to be applied to a fluid simulation. (Fig. 5) To compensate it, we employ point sampling based on joint information to improve the interaction of the fluid simulation, by using up-sampled information using spheres for major joints and cylinders for edges.

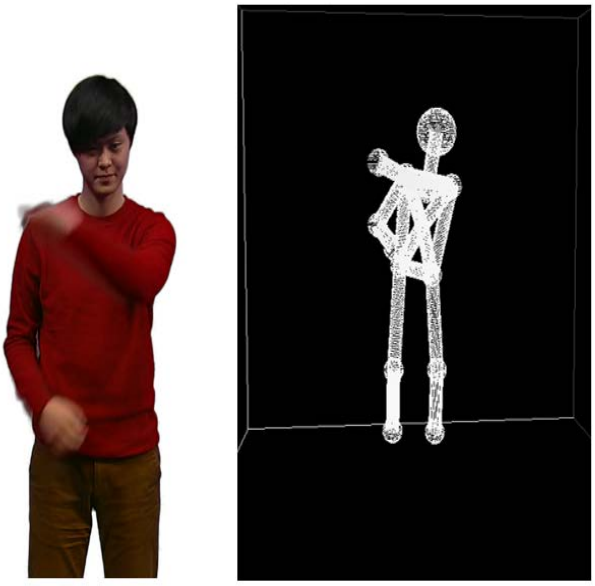

Fig. 6. a) User input, b) Mapped human data

There are several ways to interact with fluid using the sampling data. Traditionally, SDF can be used to produce collision detection and interaction. However it requires long computational time and the SDF has to be updated for every time-step. It also requires large amount of time and memory to reconstruct data connection to generate a mesh.

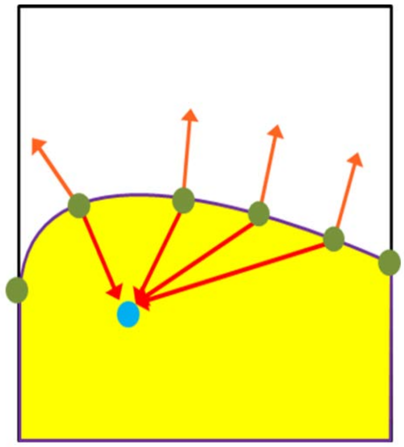

Fig. 7. Particle side check using normal vectors

The previously described up-sampling method uses spheres and cylinders where can be used to obtain normal vectors easily. The normal vectors can be used to quickly approximate whether a particle is positioned inside or outside. (Fig. 7.).

$$S = (\mathbf{x}_{NearestPoint} - \mathbf{x}_{Particle}) \cdot \mathbf{n}_{NearestPoint} \qquad \text{(Eq. 1)}$$

$$S \geq 0 : \mathbf{x}_{Particle} \text{ is Outside}$$

$$S < 0 : \mathbf{x}_{Particle} \text{ is Inside}$$

Collision detection can be performed by looking at the sign of the dot product between a relative position of a sampling point and its nearest normal vector (Eq. 1). If the particle is positioned inside, a user interaction can be easily done by applying external force of a direction of the normal vector (Fig. 8).

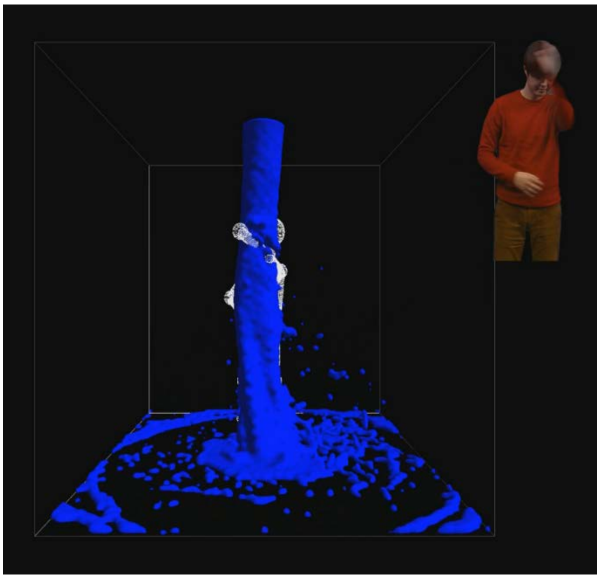

Fig. 8. User and Fluid Interaction

3. Experimental Results

In this section, we demonstrate the versatility of our coupling method between water simulation and human data. Our experiments show plausible target driven water simulation and water-human interactions for real-time applications.

Fig. 9. Real-time rendered target driven water simulation.

To show that our approach can handle real-time target driven simulation, we tested our algorithm by dropping a liquid into a ground and simulating to a target shape (Fig. 9). For this scenario our algorithm is stable with a large time step and can achieve real-time performance. Also note that how the particles form the target shape. The particles retain their property as fluid even when moving toward the target shape.

Fig. 10. Real-time interaction between water simulation and human motion.

Our second experiment shows that it is possible to interact water simulation and human motion at interactive rate (Fig. 10). There were up 128k fluid particles in the scene. The human data and fluid particle can be coupled in a realistic way using sampling point of skeleton extracted by Kinect. The point of this scenario is to show that our method can achieve plausible results with large time steps, even in the 3D simulations.

We use position based fluids method [22] for computing SPH pressures and clamp the density constraint to be non-negative. Furthermore, we apply the model of versatile surface tension method [23] to handle cohesion and surface tension effects. For neighbor finding we use the compact hashing technique. We implemented our algorithm in CUDA and ran our simulation NVIDIA GTX 770. Table 1 summarize the performance of our algorithm in a selection of scenarios.

Scene	particles	steps/frame	iters/step	time/step	Rendering time
Case 1	15K	2	10	5*ms*	200*fps*
Case 2	128K	4	3	20*ms*	50*fps*

Table 1. Performance results for two examples.

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