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Fast 3D Collision Detection Algorithm using 2D Intersection Area

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***Abstract*—**There are many researches to detect collision between real object and virtual object in 3D space. In general, these techniques are need to huge computing power. So, many research and study are constructed by using cloud computing, network computing, and distribute computing. As a reason of these, this paper proposed a novel fast 3D collision detection algorithm between real and virtual object using 2D intersection area. Proposed algorithm uses 4 multiple cameras and coarse-and-fine method to improve accuracy and speed performance of collision detection. In the coarse step, this system examines the intersection area between real and virtual object silhouettes from all camera views. The result of this step is the index of virtual sensors which has a possibility of collision in 3D space. To decide collision accurately, at the fine step, this system examines the collision detection in 3D space by using the visual hull algorithm. Performance of the algorithm is verified by comparing with existing algorithm. We believe proposed algorithm help many other research, study and application fields such as HCI, augmented reality, intelligent space, and so on.

***Keywords*—**Collision Detection, Computer Vision, Human Computer Interaction, Visual Hull

I. Introduction

MANY collision detection algorithms have been proposed in recent years within the fields of Computer Graphics, Computer Vision, Computational Geometry, and Robotics. Augmented reality and virtual reality which is two fields of computer vision have much interest in this collision detection algorithm [6]. Existing ways examine the collision between modeled virtual 3D objects, but collision detection between real and virtual objects is considered in recent years. Proposed researches are efficient to detect collision, but there are some weak points. One of the researches make real object to 3D model using the multiple cameras and visual hull algorithm. This procedure need huge CPU power, so almost their systems are network computing, distributed computing, or cloud computing. These systems are very expensive to popularize. Another use the single computer system, but that can handle a few or small virtual object. It means low practicality to use. To solve these problems, this paper propose a novel fast 3D collision detection algorithm between real object and virtual object using 2D intersection area that can run in low cost single computer system with many virtual objects. Proposed algorithm is used 1 PC system, 4 cameras and visual hull algorithm. To improve the performance and accuracy of collision detection, it employs coarse-and-fine method, for each step it offers a clue which can improve the throughput. In the coarse step, the system distinguishes virtual object 2 groups; one has possibility of collision and another have no possibility. By separating the process of collision detection, it can reduce needless computing for collision detection in 3D space. In the fine step, the system decides the 3D collision in the 3D space by using visual hull algorithm. Existing ways need virtual object made by real object using visual hull, but proposed algorithm don't need all model of real object. Proposed method decides the collision while generating of voxel by using visual hull algorithm, but existing ways decide the collision after generation.

The remainder of this paper is organized as follows. In the next section, the definition of collision will be described. After next section, meaning of the collision and approach will be shown. Section 5 will describe an experiment and result of collision detection. Conclusion will be describe at the last part of the paper, in Section 6.

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II. DEFINITION of Collision

The meaning of the 'collision' has to be reviewed in this paper. If collision is caused in 3D space, there is no any gap between collided objects at the collision point. Our approach is from this simple knowledge. Existing many ways don't consider this simple point. Hence, they calculate all virtual objects to decide the collision with real objects. However, our approach uses this simple point before the examination of collision detection. The meaning of 'collision' can be redefined as an adherence between 2 objects. That mean, there are no gap or space between objects for all points of view. If real and virtual object have collided, their silhouette images are connected and they have intersection area. Proposed algorithm uses this in the coarse step of the algorithm.

III. Silhouette volume Intersection and Visual hull

Silhouette volume intersection is the most popular idea for

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computing 3D volume of the object [2, 3, 4, 5]. This idea is based on each 2D silhouette of the object which is captured by multiple cameras. The concept of this idea is shown well in the Figure 1.

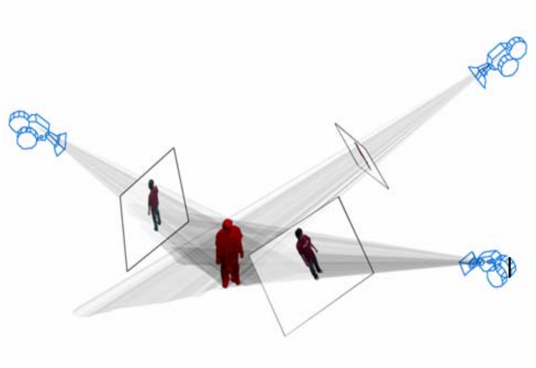

Fig. 1 Silhouette Volume Intersection and Visual hull

By intersecting the cones for all silhouettes, an approximation of the object volume is obtained. This 3D volume is called "Visual hull" [1]. The visual hull is consisted of voxel data group. The voxel means a volume element, representing a value on a regular grid in 3D space.

In the proposed system, the visual hull algorithm is used to decide the collision between virtual and real object in 3D space. The amount and existence of the voxel data are key information which to decide the collision. By employing the visual hull algorithm, system can examine the collision detection accurately. Existing many researches don't consideration of the actual 3D shape of the real objects. Therefore, existing system often cause wrong result. However, it also has weak point that it needs huge CPU power. Hence, it causes latency or high cost of the system

IV. Collision Detection Algorithm

Proposed algorithm employs coarse-and-fine method to improve existing ways. At the coarse step, examine the collision in 2D space by using images of virtual and real object silhouette. If collision is happened, there are intersection areas on the silhouette images between virtual and real object.

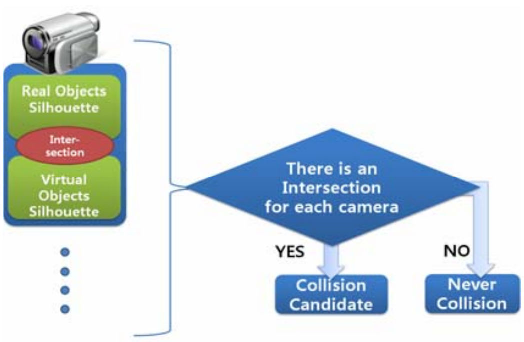

Fig. 2 Coarse step flow

Figure 2 shows coarse step flows. Coarse step is processed for each virtual object with real object. The result of coarse step is candidate virtual object which has possibility of collision as shown in Figure 3.

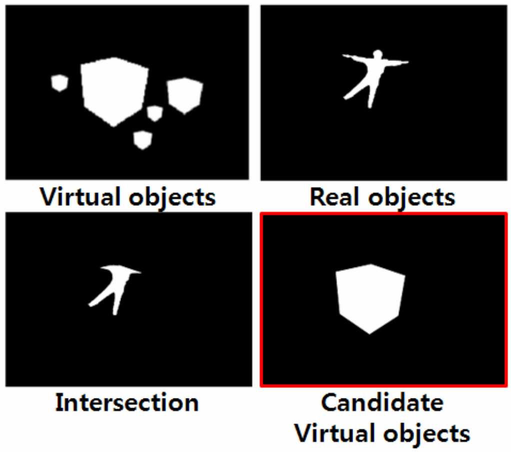

Fig. 3 Silhouette Volume Intersection

This result only means a possibility of collision, not a final collision. It means system needs to examine the collision in 3D space to decide final collision at the next step. In the coarse step, it distinguishes virtual objects into 2 groups by possibility of collision. This distinction help improve the performance of the algorithm, because virtual objects which have no possibility of collision mean it don't need to perform collision examination in 3D space.

To decide collision completely, it examine the collision detection in 3D space at the fine step. The examination is done by using the visual hull method for the candidate virtual objects. Figure 4 shows a fine step flows.

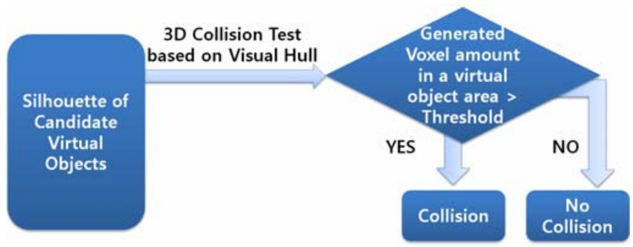

Fig. 4 Fine step flow

The result of visual hull algorithm is a group of 3D voxel data. If amount of voxel data is over the threshold, system decides a collision finally.

Figure 5 illustrates all flow of the collision detection algorithm and result for each step. Fine step also help to improve the performance of algorithm. Existing algorithms can decide the collision in 3D space after all voxel data generation of real object. However, proposed algorithm can decide the collision in generating procedure. If collision is decided in generating, do not need to generate all voxel data about real object for the remainder area.

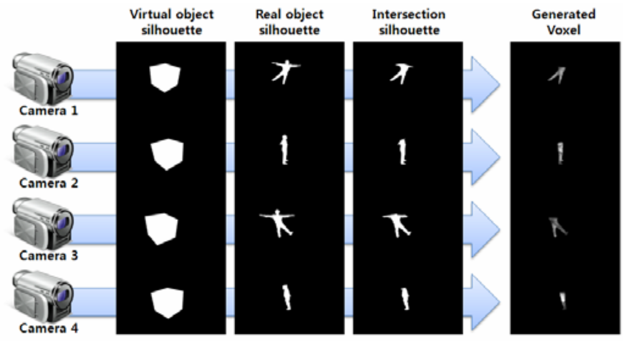

Fig. 5 Result for each step in collision detection

V. Experiments and Result

In the experiments of the collision detection between virtual and real object, proposed system used 4 IEEE1394 cameras placed at the ceiling for capturing multi-view image data of a real object. The size of input image is 640 × 480 pixels and speed of capturing is 30 fps. Figure 6 illustrates experiments environment. Experiments environment is contained in a space 3m × 3m × 2.2m.

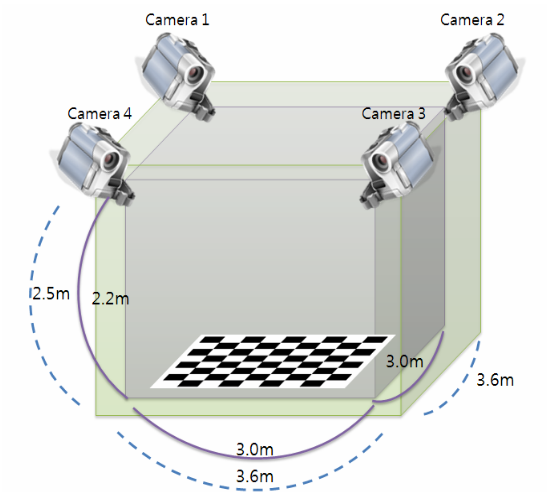

Fig. 6 The camera settings

In addition, 1 PC has Pentium D (2.0 GHz) installed and IEEE-1394 capture board which has 800 MB/s bandwidth. The system performance is measured by checking the total throughput of the system including the image capturing process by changing the number of virtual objects.

Figure 7 shows one of the experiment environments. Left top image is experiment space (studio), right top image is virtual object set in the space, left bottom image is collision detection result between real and virtual objects for all virtual objects, and right bottom image is collision detection result between real and virtual objects for only collided virtual object.

Fig. 7 Experiment

Table 1 shows the throughput of proposed method to detect collision between virtual and real object and Table 2 shows the throughput of existing method which has no coarse step.

TABLE I
THROUGHPUT OF PROPOSED METHOD

Virtual objects (Amount)	Throughput (fps)	
	Virtual objects size (10 x 10 cm)	Virtual objects size (20 x 20 cm)
25	22.21	22.08
50	21.78	21.51
75	21.14	21.00
100	20.69	20.48

TABLE II
THROUGHPUT OF EXISTING METHOD

Virtual objects (Amount)	Throughput (fps)	
	Virtual objects size (10 x 10 cm)	Virtual objects size (20 x 20 cm)
25	11.64	9.24
50	10.12	6.73
75	8.76	4.18
100	6.01	1.70

Figure 8 shows a result of experiment. Where vertical axis is performance (fps), horizontal axis is amount of collision, each line on the graph is amount of virtual objects.

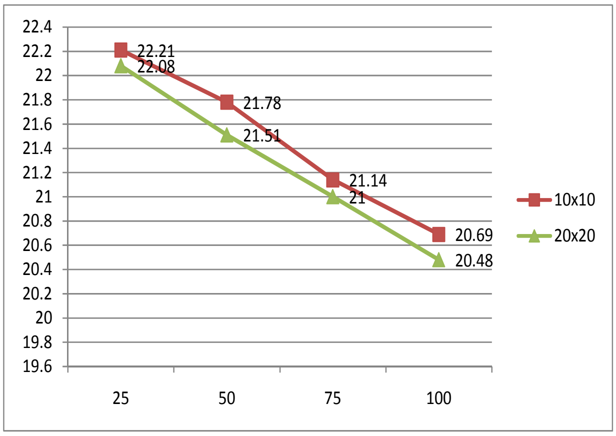

Fig. 8 Experiment result graph

As shown in Figure 8, proposed algorithm show high performance better than existing ways. Existing method depend on the number of virtual object and collision deeply. However, proposed algorithm shows low dependency.

VI. Conclusion

A novel fast 3D collision detection algorithm using 2D intersection area for between virtual and real object is proposed in this paper. The algorithm performance is evaluated by comparing with existing algorithm and the result shows this novel algorithm is fast than existing ways and efficient.

Proposed algorithm can be used for many other researches, study and application field such as 3D reconstruction, Gesture recognition, Augmented Reality, Intelligent space and so on.

Currently this algorithm is applying to develop intelligent space. This implementation should replace the hardware sensor-based existing intelligent space environments.

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