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The framework of collision detection for rigid bodies in the virtual environment

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Abstract. Collision detection includes the detection of a collision between the object in the virtual environment especially to stop the moving object through each other. However, the collision detection refers to the detection of the intersection between two or more objects. There are two basic types of collision detection namely rigid bodies that refer to the hard object and constant distance between vertices, and the deformable object that refers to soft bodies like cloth may collide with themselves. Usually, the main problem of collision detection for rigid bodies that often studies involves the fast, effective and efficiency of the collision response. In this paper, the hierarchical representative bounding volume introduced to develop the new framework of collision detection and analyse which technique performance is fast and effective for collision detection for rigid bodies in the virtual environment. The bounding volume (BV) technique such as Axis-Aligned Bounding Box (AABB), Oriented Bounding Box (OBB), Sphere and Discrete Oriented Polytopes (k-DOPs) will be applied to construct the hierarchical representative bounding volume.

1. Introduction

The field of collision detection (CD) receives more attention from the researcher and is fundamental to the varied application, such as computer games, physically-based simulations, robotics, computer graphics, and virtual prototyping. Generally, collision detection is the process of detecting when two objects are about to collide or already collided. However, there are mainly two different types of collision detection methods which are discrete collision detection (DCD) and continuous collision detection (CCD)[1]–[5].

Between dynamic collisions of rigid and deformable models, continuous collision detection (CCD) has been widely accepted as the common tool to detect a collision, especially for use as an accurate collision method. While discrete collision detection (DCD) is implementation by taking the sample of the object moves towards the object that is going to be intersected and detect the object interpenetrations. DCD has been used to perform collision detection in term of speed. Meanwhile, continuous collision detection (CCD) is computed from the first time of contact when an object collided; performs a higher-order check to find out if there are any intersections between two objects through the distance defined by configuration points.
In the virtual environment, performing collision detection between various 3D objects requires innovative steps to be followed in order to visualize the effects correctly. The virtual environment (VE) can be defined as an interactive computer-generated “world” seen from the first-person point of view and gives users the illusion of displacement to another location[6]. Furthermore, the immersive virtual environment is a real-time 3D synthetic environment that appears to surround the user in space. The purpose of the environment might vary according to the complexity of the environment itself.

Therefore, based on previous researchers, the collision detection for rigid bodies (RB) has been studied by using the variety of techniques such as sphere tree and distance field [7], [8], Earlier Node Detection Traversal Algorithm (E-Node-4D) [9], Quadratic Program (QP) [10], and interval arithmetic and OBB hierarchies [2]. Those techniques are used to improve the fast and accurate collision detection between two objects and speed up collision detection methods. It is expected that the new algorithm can improve the fast and effectiveness of collision detection for rigid bodies in the virtual environment.

Hence, the main contribution of this research can be outlined as follows:

- A new framework of bounding volume (BV) in collision detection algorithms for rigid bodies in the virtual environment.
- The fast and effective hierarchical representative collision detection for rigid bodies.

The rest of this paper discusses the following: Section 2 gives a brief explanation about related work in collision detection rigid bodies and virtual environment. Besides, it also addresses specific information about proposed bounding volume and its technique. Section 3 deals with testing and technique implementation of collision detection in a virtual environment. The final section gives a conclusion about our current research and sums up some future work for issues regarding our current project in the virtual environment.

2. Related work

In this section, we will briefly review related work on collision detection rigid bodies and virtual environment. The primary type of collision detection algorithms deals with static positions. But many recent studies are concentrated in the more difficult situation such as deformable models rather than rigid body models. The problem of collision detection in a virtual environment has been extensively studied. However, we will limit our discussion to collision detection between rigid bodies in the virtual environment.

2.1. Collision detection Rigid Bodies

There are a few of the research on collision detection for rigid bodies. Most of the researchers have different framework and algorithms that they are used to improve the efficiency of collision detection for rigid bodies. Collision detection (CD) has been studied extensively in computer graphics, robotics and virtual environment. Briefly, collision detection (CD) is the process of detecting two or more object and shape are about to collide or already collided. Besides, the rigid body is a solid object that cannot be deformed in any way [11]. According to [3], [12], collision detection generally is to generate or record any intersection that exists between two or more object.

Besides, the fracture is the one example of collision detection that can be implemented on the rigid model. The fracture usually happens in crashes and explosions, in video games and essential ingredients of action entertainment both in feature films. Multiple object fragments collide and pile up when the objects are a fracture, making fracture simulations extremely collision intensive [8], [13]. Two major challenges are applied in the simulation of fracture on collision handling. First,
acceleration data structures for collision detection need to be created or updated at runtime, due to topology changes. Second, the newly created crack surfaces arise in parallel close proximity, and it a worst-case for collision detection and response; with many surface primitives in contact, fewer chances for high-level culling, and no temporal coherence.

Besides, the idea of adding fracture effects to rigid-body simulations has received a lot of feedback from the computer graphics community, both in recent research as well as in industrial applications. The most methods usually used either on pre-fractured models, where constraints between individual fragments are removed at a suitable time or on pre-defined fracture patterns that are applied when and where collisions occur. In addition, [14] present a fracture algorithm based on the boundary element method (BEM) to a rigid-body simulation where the resolutions of the collision mesh and the implicit surface containing the resulting geometry can be freely chosen by the user. Thus, the boundary element method (BEM) is used to avoid complicated volumetric meshing operations and reduce the required number of degrees of freedom.

![Figure 1](image1.png)

**Figure 1.** Arguing armadillos cause collateral damage[14]

![Figure 2](image2.png)

**Figure 2.** Rigid body brittle fracture simulation[15]
Moreover, Virtual Environment applications allow users to enter a computer-generated virtual world and interact with graphical objects and virtual agents with a sense of reality. Besides, such systems may be either immersive or desktop-based [14]. One thing they have in common is a requirement for extremely high and constant frame rates. Physical interactions such as touching, hitting and throwing are usually triggered by the collision.

Fundamental of the virtual environment work is, in addition to high-level three dimensional (3D) graphical and multimedia scenes (visual output); is the research on advanced methods of interaction and the development of behavioral models. In most virtual environments, collision detection allows the virtual representation of the user, for example, the virtual hand to interact with other virtual objects. In virtual environments, there are several types of volume trees have been widely chosen because it is very easy to implement and fast to find collisions between two such volumes [16], [17]. Thus, to build the oriented bounding tree is not an essential issue for virtual environments applications; because it is a pre-processing step which does not influence the interactive component of a virtual environment.

![Figure 3. Example of Virtual Environment](image)

A bounding volume is a common method to simplify object representation by using the composition of geometrical shapes that enclose the object. It is the most common approach for accelerating collision detection for rigid bodies and deformable object [4], [18], [19].

Performing collision detection for rigid bodies using primitive intersection checking required expensive computation cost. So, some model might have thousands of polygons that need to be checked for collision when some other objects undergoing intersection test with the model. Hence, Bounding-Volume (BV) are used to reduce the computational cost to detect object interference. If the primitive testing performs without applying BV, it consumes longer time as it needs to check each triangle with other object triangle set [20], [21]. Referring to [3], [19], the bounding volumes (BV) are one of the algorithms widely used in collision detection application which has several techniques such as Axis-aligned bounding box (AABB), bounding sphere, oriented bounding box (OBB) and discrete orientation polytopes (k-DOPs) [22].

2.2. Project Background

The aim of this research is to propose a framework of hierarchical representative bounding volume that can be used in a virtual environment for fast and effective collision detection of rigid bodies test.
At the end of this research, the simple simulation has been developed for collision detection of rigid bodies. Figure 3 shows the example of a simple simulation interface for collision detection.

Furthermore, the simple simulation has been made by using Microsoft Visual C++ with OpenGL or Unity3D.

3. Framework Overview

The framework of hierarchical representative bounding volume for collision detection of rigid bodies is conceptual as follows in figure 5.
According to Figure 5, it is the HRBV framework to test the fast and effective collision detection algorithm for rigid bodies in the virtual environment. The rigid bodies in this research consist of the static object and moving object to test the collision detection then the information of the point intersection (x,y,z) will be selected. The framework will start with the load all the 3D model object (.obj) that was programmed. Besides, the framework consists of several steps to construct the hierarchical representative bounding volumes (HRBV). After the object loaded into the virtual environment, the BV will start load to the object. Next, the construction process of hierarchical representative bounding volume will be performed and applied to the model.

Next, collision detection testing is performed when the moving object is moving towards the static object and involving detecting two collided pair. The collision testing will be tested by using different BV, which is AABB, OBB, Sphere and k-DOPs. Meanwhile, the testing will be repeated by the construction testing of HRBV. At the end of this testing, the result of the proposed framework will be recorded.

4. Conclusion and Future Work

As a conclusion, a new framework of a hierarchical representative bounding volume of collision detection has been approached to create the fast and effective collision detection of rigid bodies in the virtual environment. In this paper, a framework has been presented of our research using hierarchical representative bounding volume for detecting object interference in a virtual environment. The research is still in progress to determine the suitable collision detection for our proposed framework. Several methods of collision checker have been discussed and found that bounding volume is the most suitable approach to be used as a collision detector for virtual environment application. Bounding-
Volume (BV) is the most preferred choice are used to reduce the computational cost to detect object interference and have fast collision checker. In future work, we will conduct an experiment to test and show the result of our proposed method.

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