THE RESEARCH OF VESSEL-BRIDGE COLLISION DETECTION TECHNOLOGY
BASED ON OPENSCENEGRAPH

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ABSTRACT
In order to improve the facticity of Navigational Simulator, which is always applied to the assessment of navigational safety of waterways and channels, the technology of three-dimensional(3D) collision detection must be solved effectively. Based on the theory of the visual system of the Navigational Simulator, three dimensional modeling technology by Multigen Creator and the rendering technology of 3D scene by OpenSceneGraph(OSG), different methods of the models’ bounding boxes have been compared. The Axis-aligned bounding box algorithm is chosen for the collision detection, and corresponding detection technology and optimization approaches are presented.

KEYWORDS: Open SceneGraph (OSG); navigational Simulator; collision detection; vessel-bridge collision; bounding box

1. INTRODUCTION
With the increasing trend of vessel size and traffic flow density, ship navigation puts more negative effect on the safety of bridges. The vessel-bridge collision is one of the most common accident patterns. In order to reduce the number of such accidents, on one hand, an early anti-collision warning system for piers is needed; on the other hand, with the training of Navigational Simulator, reducing the incidence of vessel-bridge collision accident may be more effectively. Navigational Simulator also can be used in the simulation of water among the bridge areas, and is applying for the evaluation and influencing demonstration of navigation security[1].

The common driving technologies of Navigational Simulator are Open GVS, Vega Prime(VP), OpenSceneGraph(OSG) and so on. Among those technologies, OSG is an open library of the management of scene graph with a high quality of rendering effect and good portability [2], which provides an effective support for this project. The collision detection, an important link in the simulation system of vessel-bridge collision, is one of the key technologies in a Navigational Simulator, and it plays an important role in the authenticity of
the simulation results. Thus, with the technology of OSG, the paper has put forward a method of vessel-bridge collision and a prioritization scheme in complex situation creatively, which has satisfied results in the Three-dimensional Visual System.

2. Navigational Simulator and its Technical Support

2.1 Navigational Simulator

The Navigational Simulator is a man-in-the-loop simulation, in which a man can be a part of the simulation system and affects its results. For example, provided with the information of navigation from related machines, a man can control the ship heading and speed to do training, evaluate the navigation security and analysis maritime accidents. A Navigational Simulator is consist of coach station, master machine, radar, electronic chart and projection system and so on, with which the actions of navigation, avoiding collision and berthing and unberthing can be trained and evaluated in different water area, environment of wind and stream, encounter situations and visibility[3].

2.2 Three-dimensional Modeling Technology Based on Multigen Creator

The Software of Multigen Creator can be used to get real time optimization of datum of OpenFlight and be applied to generate terrain after vector modeling and polyhedral shape modeling among large areas [3]. And it is highly combined with the technology of OSG and holds a leading position in the world in the real-time simulation field of visual, training, city simulation and so on. With its technology, 3D models are always saved as file format of “*.flt”, which supports the organization structure of scene optimization such as LOD and BSP including the entire hierarchy. As a result, all the models not only can be put in the scene of OSG, but also can be written and read, which are big advantages to choose this technology.

2.3 Three-dimensional Rendering Technology Based on OSG

The technology of OSG provides the application development of graphic images with the functions of scene management and graphics rendering optimization [4], and it also uses the technology of Application Programming Interface (API) rendered in the bottom of OpenGL, which has been an industrial standard. The technology of OSG and its extensions covers most development of 3D scene, and it has the wonderful cross-platform nature and portability, as well as a wide application range. It can realize the functions of efficient real-time rendering,
handling models made by three-dimensional modeling technology, and supporting the multi-type peripherals.

The related extension modules of OSG make its function richer. For example, osgEarth, which is similar to GoogleEarth, has good real-time terrain generation efficiency, and can generate terrain when offline or based on elevation figure and texture, with which the functions of height measurement, vector graphics rendering and distance query can be realized. osgOcean is also a common module of OSG, which is particular in the simulation of water among large areas vividly and can be second developed to make more wonderful ocean effect.

3. Vessel-bridge Collision Detection and Response Process

The vessel-bridge collision detection and response process is as follows:

After all models have been established, they can be put in the scene by using the technology of OSG, and the scene can be driven and rendered. Then all the models can be put into collision detection and generate proper collision response. Among those, the collision point and its normal information can be gotten by the collision detection method, which provides the collision response method with necessary information. So the collision detection is the key technology of the simulation of vessel-bridge collision, which will be focused in this research.

4. The Collision Detection Technology of OSG’s Bounding Box

In the visual simulation, we always like to detect whether there is a collision happened between two models’ bounding boxes. If there is none, the two models aren’t collided. Otherwise, all the nodes’ bounding boxes, including groups and geodes, should be detected in turn based on the principle of hierarchy tree. If any collision is founded, then finish detecting and return the result information. If there is no intersection among all nodes of geode, then the two models can be judged as non-collided.
4.1 The Technology of Bounding Box

There are many types of building a model’s bounding box, and some common bounding boxes are as follows [5]

4.1.1 Bounding Sphere

Bounding sphere is built for each node when the scene is established and becomes each node’s nature, which is not built when it is calculated. When it is needed, the function of “getBound()” can be used to call. This technology is applied to models which nearly have sphere shapes, and a preliminary judgment can be made to detect if there is any collision after analysing the relationship between the sum of two bounding spheres’ radium and the distance between two centers of sphere. However, it isn’t suggested to be used in the research of models which nearly have cuboid shapes.

4.1.2 Axis-aligned Bounding Box (AABB)

Each edge of the bounding box is paralleled with each coordinate axis and its shape is always cuboid [7-8]. This technology is used to build models’ bounding boxes in OSG commonly and can be satisfied with the need of collision detection accuracy.

Fig.3: The Axis-aligned bounding box and its vertexes’ coordinate of the ship model

This is a ship’s bounding box of AABB. By recording the maximums and minimums projection on each coordinate axis reflected by the bounding box, and being saved as three matrixes, which are Mat[0]= [X_min, X_max], Mat[1]= [Y_min, Y_max] and Mat[2]= [Z_min, Z_max], the eight points’ information can be gotten by combining these matrixes. The intervals of the ship’s projection on each axis are (X_min, X_max), (Y_min, Y_max) and (Z_min, Z_max). If there is any intersection between one models’ intervals and another’s among the three axes, the two models are collided with each other, otherwise there is no collision happened.
4.1.3 Oriented Bounding Box (OBB)

The oriented bounding box is the minimum cuboid which can surround the model along arbitrary direction, and its tightness is better than those technologies above-mentioned. This technology can be realized in OSG by the improvement of algorithm and the transformation of coordinate.

4.1.4 K Direction Orientation Polytopes (K-Dop)

K-Dop \cite{8} is a kind of polyhedron bounding box, which can not only cover all elements of itself but also all its surfaces' normal vectors are determined by a fixed direction set, including k vectors. The greater the value of k is, the more closely the models can be covered. As a result, the computation process will become more complex.

Considering the objects of study are ship and pies, their structures are axes symmetry and nearly have cuboid shapes. After comparing all the common bounding boxes, on the premise of guaranteeing the accuracy of collision detection, axis-aligned bounding box has been chosen as the final technology in this paper, which is more feasible and has lower process cost.

4.2 The Algorithm of Collision Detection of OSG

4.2.1 Build Bounding Volume Hierarchy

A proper Bounding Volume Hierarchy should be build before collision detection, which can cost less internal storage when the algorithm is running and improve the efficiency of collision detection. The collision detection flow diagram and the scene hierarchy structure of the vessel-bridge collision are shown as follows.

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**Fig.4 The collision detection flow diagram**
Build a derived class named `findNodeVisitor` from the class of `osg::NodeVisitor` in OSG, which is used to read the nodes from the text of “*.flt” and detect them, such as “b_1”, “b_2”, “b_3” and “b_4” (as shown in Figure 2). And this four nodes in the hierarchy tree of the Multigen Creator are read as four bridge pies’ nodes of “brg_1”, “brg_2”, “brg_3” and “brg_4” in OSG relatively, which are used to detect whether there is any collision between the ship and bridge. At last, these four nodes are added to the group of “brg”. Limited by space, just the definition of the class of `findNodeVisitor` is given as follows, and it can be called in the main process by the function of “accept()”.

```cpp
class findNodeVisitor : public osg::NodeVisitor
{
    public:
    virtual void apply(osg::Node &searchNode); // Compare the name of the visiting node to the searching one. If it finds a match, put the node into the node list. osg::Node* getFirst(); // Get the first node that matches the searching string. ……};
```

### 4.2.2 Collision Detection Module

A class of collision detection is built in this module [5][9], which is used to detect whether there is any collision among all the bounding boxes. Its major codes are as followers:

```cpp
class DecCallback : public osg::NodeCallback
{public:
    virtual void operator()(osg::Node* node, osg::NodeVisitor* nv)
    {
        // Define the related bounding box visitor………// Define the bounding box visitor of “ship” in the coordinate system of its parent node on the higher lever. ship->getParent(0)->accept(boundvisitor1); // Define the bounding box visitor of “brg” in the coordinate system of its current parent node. bridge->accept(boundvisitor2); // Get the bounding boxes of the ship and bridge name box_ship and box_bridge ……// To sign whether there is any collision happened. collision_sign=box_ship.intersects(box_bridge); // If the ship and the whole pontic are collided with each other, then do as the followers.
```
if(collision_sign==True) {……//Judge whether there is any collision between bounding boxes of the ship and bridge piers. } } ;

The models of ship and bridge are read as nodes of “ship” and “bridge”. As they are in different branches of the scene root of “gp”, the coordinates of the bounding boxes of “ship” and “bridge” are not in the same coordinate system, and they can’t be detected with each other directly. So, the coordinates of the ship’s bounding box should be gotten in the coordinate system of its parent node. Then it can be detected with the bridge correctly [7]. Each frame can be updated in the scene by using the flowering codes.
gp->setUpdateCallback(new DecCallBack);

This algorithm of collision detection can be calculated in real time, and has a certain collision precision. Its effect of collision detection is shown as follows.

Fig.6: The situation of vessel-bridge collisionless

Fig.7: The situation of vessel-bridge collision

5. CONCLUSIONS

By using the technology of OSG to build the models’ bounding boxes, the collision between the ship and bridge can be detected and simulated well, which has been applied into the Navigational Simulator. This technology can get the world coordinate and its normal information of the collision point, which can provide the latter collision response with a technical support.
REFERENCES


