Research on parallel algorithm based on AABB bounding box coordinate chain method

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Abstract. With the rapid development of virtual reality technology and collision detection technology, virtual reality has become a lot of research fields in China. Collision detection is one of the most important technologies, and virtual surgery simulation has gradually become an important application of medicine in virtual reality technology. Virtual surgery can not only provide a skilled training platform for medical staff, but also analyze the feasibility and danger of surgical scheme, so that medical staff can have the same authenticity and strong immersion in virtual environment as in physical surgery. In this paper, a mixed hierarchical bounding box is constructed to detect the collision between the virtual human soft tissue and the rigid tissue of surgical instruments, and a parallel algorithm, fast bounding box coordinate chain calculation, compression storage and so on are introduced. For the deformation model of the software which is difficult to construct, the collision detection can be completed quickly and accurately, which can effectively save the collision detection time and improve the real-time performance of the collision.

1. Introduction
Virtual surgery is an accurate geometric, physical and computational modeling of human organs and tissues, which simulates the cutting deformation of organs and tissues realistically [1-2]. It is usually a large-scale complex scene composed of multiple static objects and moving objects, and the objects in the scene are constructed with multiple geometric elements, which are basically divided into triangles and tetrahedrons. After decades of development, virtual surgery has been able to make use of image data, which is beneficial for doctors to make the best surgical plan reasonably, locate tumors with high accuracy, cause the least surgical damage, ensure the least damage to adjacent tissues, simulate the best surgical path and effectively improve the success rate of surgery. In virtual surgery, collision detection technology is an important technology to judge whether virtual objects collide with each other. Accurate and fast collision detection algorithm can improve the authenticity, interactivity and immersion of users in virtual environment. Therefore, fast and efficient collision detection algorithm has become one of the hot spots in the medical field of virtual surgery. The focus of this paper is also the optimization of collision detection and the realization of real-time.

2. Research status of virtual surgery at home and abroad
Nowadays, virtual reality technology has developed rapidly. In recent decades, researchers all over the world have made extensive and in-depth research on collision detection in developing virtual surgery. Europe, America and Japan started earlier and are now in a leading position. In 1996, at the...
4th Medical Virtual Reality Conference, Stava put forward the concept of three-generation medical simulation system framework system and related technologies [3-4]. The related three generations of system simulation started to study the principles and applications of physical models and computational models from the first generation of simulating human geometric characteristics, creating human anatomical data sets, putting forward the concepts of limited interactivity and deep immersion in simulation technology, to the second generation of human tissue and organ modeling, adding physical characteristics of human body and organ objects. In the third generation, the simulation system went deep into the characteristics and functions of human organs, and further developed and studied the second generation simulation, and launched a detailed development framework [5]. Subsequently, great achievements have been made in the development of virtual surgery system and platform all over the world. The research in the 20th century has guided the technology in recent decades. At present, some achievements have been made in the international research on virtual surgery simulation and collision detection technology. For example, Nagoya University in Japan specializes in researching and developing a virtual surgery system that can be used by many people to simulate operations at the same time, and has established a three-dimensional surgery simulation system, and has implemented the simulation of bronchoscopy operation in the island rib laboratory [6]. At present, some models have successfully studied the three-dimensional model simulation of kidney stones, which provides convenience for the experiment of piercing pipes, especially the multi-channel lithotripsy [7]. Now, there are some related virtual surgery training systems in the domestic market. Zhejiang University and others have systematically studied the application of key technologies such as 3D reconstruction of human tissues, simulation of soft tissue cutting and self-collision detection methods in virtual surgery. Tsinghua University has also carried out related research on force feedback interaction technology based on real-time finite element.

3. AABB bounding box coordinate chain method

In this paper, AABB bounding boxes with simple structure and easy operation are added to the mixed level of middle and lower layers. In order to speed up the intersection detection between AABB bounding boxes, the bounding box coordinate chain method is added here [33]. The AABB bounding box establishes three chains corresponding to X-axis, Y-axis and Z-axis, respectively. If in any chain, the Min value of one AABB minimum point is ranked after the Max value of another AABB maximum point, then the projections of the two bounding boxes on this axis do not intersect, so it can be directly judged that the two bounding boxes do not intersect without judging other axes. Similarly, when the Min value of the minimum point is in front, the projections on this axis chain intersect, and the next axis chain continues. The bounding box coordinate chain method saves unnecessary comparison calculation for AABB bounding box, avoids impossible intersection test, subdivides into coordinate chain before intersection test, divides test area and improves detection efficiency.

3.1 Virtual surgery in the application of parallel AABB bounding box coordinate chain

In the collision detection of virtual surgery, we generally only need to study the rigid body (scalpel) and soft (human tissue) objects. Rigid objects are relatively simple models, which only need to be represented by the basic geometric elements of triangular patches. However, soft tissues are very complex. They deform when they touch. The problem of this part is me Our key issues.

In this section, the bounding box coordinate chain method is added to the collision detection of rigid bodies and software in complex scenes. An AABB bounding box is used to represent the scalpel, and then AABB is used to surround the software object. As described in 3.1, the maximum and minimum vertices of the three coordinate axes in AABB are listed in the linked list. In collision detection, the values in the coordinate chain of the rigid body are inserted into the software coordinate chain, and the collision between the two objects is judged by the position, and the disjoint element pairs are quickly discharged. When the software object is deformed or the position changes, the AABB bounding box is reconstructed quickly to determine the position, maximum and minimum value of the new three coordinate chains, and detect the new collision situation. According to the spatiotemporal correlation in the previous chapter, at two adjacent time points, the moving object may still be in the same state. It can be approximately considered that its position, shape and collision state have not
changed. When there is a small change, the data of the three coordinate chains can be adjusted through the adjacent data. In the traversal of the linked list, as long as we quickly judge that a chain does not intersect, we can directly judge that the bounding box does not intersect. In the bounding box coordinate chain method, we also add OpenMP parallel technology. The programming mode realizes the parallelization of the task processing of the three chains at the same time. In the same process, the multithreaded tasks are executed at the same time If the projections in a coordinate cannot intersect, the traversal will be stopped immediately.

In this paper, the bounding box coordinate chain method is used to omit the establishment and update of the bounding box tree. The method is simple and more efficient. After the parallel multithreading technology is added, the data processing speed of the coordinate chain is accelerated. At the same time, the impossible intersecting element pairs are quickly discharged, the useful intersecting elements are screened out, and the time of traversing the tree is shortened, which saves a lot of time processing time, thus improving the efficiency of collision detection.

3.2 AABB software object deformation intersection test process

In virtual surgery, the soft object is prone to deformation. According to the spatiotemporal correlation, when the soft tissue is deformed, part of the AABB in the object is updated, and then the position of the coordinate chain in the AABB bounding box after the change is adjusted by the following algorithm, and then the collision is determined.

AABB bounding box coordinate chain algorithm, pew > min moved in the nth chain

1. Let Pn be the node of the coordinate chain, Pn=pnow->Min
2. If the direction is backward, turn (3); otherwise, execute (2)
3. If(Pnow->Min->pre[n]!=0)
   while(Pn!=0)
     if(Pn->val[n]>=pew->Min->val[n]&&Pn)
       Pn=Pn->pre[n]
   Test the intersection between AABB and the new point,
   If it intersects, add the intersecting pairs to the set of intersecting pairs. If you don't want to intersect, do not deal with it
   elseif(Pn->Min->val[n]<pew->Min->val[n])
     Pn=Pn->pre[n]
   else
     break
   if(Pn=0)
     put pew->min at the top of the chain and point to the head
   else
     Insert Pew->min between the current node and the next node
   else
     put pew->min at the top of the chain and point to the head
End

4. If(Pnow->Min->next[n]!=0)
   while(Pn!=0)
     if(Pn->val[n]<pew->Min->Val[n]&&Pnode is the maximum)
       Pn=Pn->next[n]
   If the AABB and Pew of Pn node are intersecting pairs in the intersection set, the pair will be deleted
   elseif(Pn->Min->val[n]<pew->Min->val[n])
     Pn=Pn->next[n]
   else
     break
   if(Pn==0)
     put pew->min at the end of the chain
else
   pew - > min was inserted between PN and PN - prev[n]
else
   put pew - > min at the end of the chain
End

For the algorithm calculation of the maximum value, the operation can be carried out by changing Pew - > min to Pew - > Max and placing it at the head of the chain. The update operation of bounding box is realized by changing the position of the maximum value and minimum value of AABB bounding box coordinate chain.

3.3 Experiment and analysis

The experiment in this chapter is carried out on PC with C + + language. This paper proposes a parallel algorithm of bounding box coordinate chain based on AABB. In the mixed level bounding box, there are intersection tests between AABB bounding boxes. AABB bounding box is often used in collision detection, so it is necessary to improve the efficiency of collision detection. In this chapter, the bounding box coordinate chain method is added to help save time and improve the efficiency of collision detection. At the same time, parallel technology is added to execute multithreading tasks to accelerate the processing of data in the linked list. This experiment lists the average detection time of AABB bounding box, AABB bounding box based coordinate chain method and parallel AABB bounding box coordinate chain method when collision detection elements are the same, and then analyze and compare the results. The experimental data and comparison results are shown in table 1.

| Number of triangular patches of software objects | Number of triangular patches of rigid objects | AABB bounding box algorithm | AABB bounding box coordinate chain algorithm | AABB bounding box coordinate chain algorithm |
|-----------------------------------------------|---------------------------------------------|-----------------------------|---------------------------------------------|---------------------------------------------|
| 1                                             | 56                                          | 45                          | 6.64                                        | 5.34                                        | 4.73                                        |
| 2                                             | 579                                         | 45                          | 7.25                                        | 5.42                                        | 4.85                                        |
| 3                                             | 1249                                        | 45                          | 8.13                                        | 5.55                                        | 5.14                                        |
| 4                                             | 2036                                        | 45                          | 9.54                                        | 6.16                                        | 6.02                                        |
| 5                                             | 3904                                        | 45                          | 12.66                                       | 7.84                                        | 7.59                                        |
| 6                                             | 4998                                        | 45                          | 16.03                                       | 10.08                                       | 8.48                                        |
| 7                                             | 6872                                        | 45                          | 19.54                                       | 12.68                                       | 10.37                                       |
| 8                                             | 8729                                        | 45                          | 27.28                                       | 16.59                                       | 13.01                                       |

From the above data and experimental image analysis, it can be seen that in the collision detection of rigid body and soft tissue, the bounding box coordinate chain method is simpler than the simple bounding box method, with higher computational efficiency and shorter time. The method of bounding box coordinate chain with parallel computing is used to execute multithreading tasks, which can speed up coordinate chain processing, save a lot of processing time and improve efficiency.

When the software organization contacts with the rigid object, it is easy to deform. After using the coordinate chain method in this chapter, we can omit the establishment and update process of bounding box under the premise that the establishment of bounding box coordinate chain is the same as that of AABB construction, and the establishment time is similar. Only need to analyze and compare the coordinate chains of three coordinate axes, and at the same time add parallel technology
to screen quickly. It can improve the efficiency of collision detection by selecting the object pairs that can not intersect and processing the basic elements of intersection.

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