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Collision detection Based on OBB Simplified modeling

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Abstract. This paper has analysed the most common algorithm of collision detection based on Oriented Bounding Box (OBB) simplified modeling. After that, in order to improve the efficiency of traditional collision detection algorithm in practical applications, an improved OBB collision detection algorithm is proposed. Moreover, a collision detection algorithm and the double robot coordinated motion model were built by matlab software, at the same time, a trajectory where two robots can collide with each other was built. In addition, the two algorithms were compared by changing the calculation accuracy in robot trajectory planning. Finally, the results show that the algorithm can greatly improve the efficiency of collision detection in dual robot systems.

1. Introduction

With the development of global robot technology, the application research for multi-robot coordination tasks is more and more extensive. Compared with a single robot, the dual robot system can complete some welding operations that cannot be completed by a single robot. In the dual robot model, we usually use the coordinated motion method to simultaneously actuate the two robots. For safety reasons, we need to perform collision detection before each step of the robot to prevent accidents. However, a collision detection is performed before the robot performs each step, which not only reduces the efficiency of the trajectory planning, but also does not require collision detection when the robot is in an absolutely safe position.

Collision Detection Algorithm based on paper[1], it propose an optimizing overlap test algorithm of bounding box and primitive. This method eliminates the bounding boxes of leaf nodes and streamlines the OBB hierarchical layer. And in paper[2], compared with ordinary method, it combine Sphere with the OBB method. Through extensive literature review, it is found that the current algorithms for OBB bounding boxes are mainly focused on modeling, with the aim of improving the fit of the bounding box[3-5]. And in the paper[6], it presented an algorithm for determining the euclidean distance between compact sets, the emphasis has been on polytopes in \( \mathbb{R}^3 \). By comparing these documents, it is easy to find that in the OBB bounding box collision detection, Most researchers focuses on the improvement of the OBB bounding box package and the collision detection algorithm by changing the OBB bounding box algorithm itself. In this paper, the efficiency of the entire collision detection process is improved by reducing the call of the OBB bounding box algorithm in unnecessary situations.

2. Collision detection based on OBB

Oriented Bounding Box is a space cuboid bounding box, according to paper[7], there are fifteen split
axis unit vector between two cuboid bounding box OBB₁ and OBB₂, 
\[ d = [d_1, d_2, d_3, d_4, d_5, d_6, d_7, d_8, d_9, d_{10}, d_{11}, d_{12}] \], as the picture shows among them \( d_1, d_2, d_3, d_4, d_5, d_6 \) are six-sided vectors, and Other nine vectors are obtained by cross-multiplication, eg: \( d_7 = d_1 \times d_4, d_8 = d_1 \times d_5, d_9 = d_1 \times d_6, d_{10} = d_1 \times d_7, \ldots \)

![Figure 1. Split axis unit vector](image1.png)

![Figure 2. Separation axis theory](image2.png)

According to the figure 2, we set the point \( O_1 \) and \( O_2 \) as the center of the two boxes respectively. \( T = O_1O_2 \), for every split axis unit vector \( d_i (i = 1, 2, 3 \ldots 15) \), we could get the formula

\[
|T \cdot d| > \sum |a_j \cdot d| + \sum |b_j \cdot d| \quad (2-1)
\]

In figure 2, \( a_j \) and \( b_j \) (j=1,2,3) called half length, represent the half length width and height of boxes OBB₁ and OBB₂, respectively. Corresponding to the \( a_j \) and \( b_j \), we define \( A_j \) and \( B_j \) as unit vectors in the direction of length, width and height directions of boxes OBB₁ and OBB₂. In addition, the projection radius of boxes OBB₁ and OBB₂ on the spatial \( d_i \) axis are \( r_A \) and \( r_B \).

Method for judging whether two OBB boxes interfere with each other: ① there no interference between two boxes if any element \( d_i \) in \( d \) satisfies equation 2-1, ② when all the elements in \( d \) do not satisfy the expression 2-1, it means that interference occurs between the two OBB boxes.

In order to introduce the algorithm in this paper better, we define the distance in the direction of the unit direction vector \( d_i \) in \( d \) to \( L_{d_i} \), for example, in equation 2-2, when \( L_{d_i} \) is positive, it indicates the separation distance on the \( d_i \) axis; conversely, when \( L_{d_i} \) is negative or zero, it indicates the penetration distance on the \( d_i \) axis.

\[
L_{d_i} = |T \cdot d_i| - \sum |a_j \cdot d_i| - \sum |b_j \cdot d_i| \quad (2-2)
\]
3. Improved collision detection algorithm

The collision detection algorithm of the OBB boxes shows that, when we are in collision detection for two moving bounding boxes, we need to make projection judgments in 15 vector directions in every time the object goes further. And we know that in the coordinated task of the two-robot system, in general, the relative position of the two robot bases is fixed, and the range of motion that each robot can reach is also fixed, in other words, when we are in the dual robot coordinated motion trajectory planning, it is only necessary to perform the collision detection algorithm when the two robots have the possibility of collision in their common motion range space.

In addition, in the general dual robot coordination task, the base coordinate system of the robot R1 is set to the world coordinate system, and the base of the robot R1 is directed to the base direction of the robot R2 in the X direction, and the direction perpendicular to the ground is the Z direction. Therefore, in this world coordinate system, as long as the two robots collide, the minimum x coordinate value of the end of the robot R2 operating arm must be greater than or equal to the maximum x coordinate value of the end of the robot R1 operating arm. Therefore, when min \(R2(x)\geq\max R1(x)\) is detected, OBB collision detection is not required. Otherwise, when min \(R2(x)\leq\max R1(x)\) is detected, constructing a linear function of the two robot base coordinate system origins \(O_{R1} O_{R2}\) and their respective maximum points, analogous to the projections \(L1\) and \(L2\) of the two robots on the ground, at the same time, calculate the abscissa value \(X_{12}\) of the intersection of \(L1\) and \(L2\). If min \(R2(x)\leq X_{12} \leq \max R1(x)\), we call the OBB collision detection algorithm again, and the system will save a lot of time when no OBB collision detection is needed. The algorithm flow is shown in Figure 3.

![Algorithm flow](image-url)
4. Collision detection experiment

Firstly, using the Robotics Toolbox toolbox of Matlab software, built a dual robot model, and a trajectory of coordinated motion of the two robots was planned. Then discretizing the joint values corresponding to the two robots executing the trajectory of the segment, then through the learned kinematics of robotics, calculate the maximum x coordinate of the robot for each step. The dual robot model established by matlab and The coordinated motion trajectory of the dual robot is shown in Fig 4.

![Figure 4. The dual robot model and the coordinated motion trajectory](image)

5. Conclusion

In this paper, an algorithm based on OBB for coordinated motion detection of dual robots is proposed. Compared with the original collision detection method, the new collision detection method joins the human mind, and the computer does not need to aim for collision detection all the time, which means that collision detection is not required every step of the trajectory planning process. The number of calls of the collision detection algorithm when the robot is in the safe zone is greatly reduced, and the planning time is saved, and the efficiency is greatly improved. The higher the accuracy of the trajectory planning of the robot, the more obvious the relative efficiency is improved.

| Calculation accuracy | 1/100 | 1/500 | 1/1000 | 1/2000 | 1/3000 | 1/4000 | 1/5000 |
|----------------------|-------|-------|--------|--------|--------|--------|--------|
| (Time)Before improvement | 1.236 | 3.369 | 6.320 | 13.605 | 22.793 | 33.306 | 45.490 |
| (Time)After improvement | 1.113 | 2.449 | 4.260 | 7.837 | 11.623 | 14.946 | 18.510 |
| Efficiency improvement | 9.95% | 27.31% | 32.59% | 42.13% | 49.01% | 55.13% | 59.31% |

Table 1 Running time comparison of algorithm

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