

A shooting algorithm based on Angular Bisector Path Planning

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Abstract—In order to improve the Underwater Robot's probability of success of the shot and the speed of the shot in water polo competitions, a shooting algorithm based on Angular Bisector Path Planning using geometric method was proposed. The algorithm computes rapidly and shoots in high efficiency. The algorithm implementation was given and tested on the simulation platform. The effects were also evaluated. The algorithm has been successfully applied in actual competitions. The results proved that has a rapid offensive and strong interference suppression. The feasibility and effectiveness of the algorithm was verified by the experiment.

Keywords—robot fish; Angular Bisector; path planning; shot

I. INTRODUCTION

For the past few years, the Robot Technology is developing rapidly. It takes the Biomimetic Robot Fish as the subject in the robot polo competitions, which is similar with the match play about the robot soccer match on land^[1]. The match not only involved all kinds of technologies on Robot Soccer Applications, but also referred to many fields such as Hydrodynamic analysis and anti-jamming technology and so on^[2]. There are some technical challenges, as well as enjoyment. Thus, it's a perfect combination of scientific research and science^[3].

When the two teams confront with each other in robot fish match, one team wins if it shoots water polo into the opponent's goal more times than the other team during a limited time. And the key to triumph is shooting^[4]. Pros and cons of shooting algorithm and strategies to deal with special circumstances will influence the probability of success directly. For robot fish in water polo competitions, a new shot algorithm based on bisector path planning was proposed. The simulation platform's name is URWPGSim2D, which is developed by Peking University. The algorithm obtains a set of robot fish's temporary target points. It is just making robot fish, water polo and target point in a straight line. And then the robot fish gets to the point of head polo. The fish can easily take the water polo into the opponent's goal. The algorithm improves the efficiency of shooting greatly.

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II. INTRODUCTION OF ROBOT FISH

Taking the simulate robot fish as the research object on the simulation platform, The fish's structure, size, color and motion parameters of four aspects are described as following, which is according to the definition of the robotic fish's 2D model.

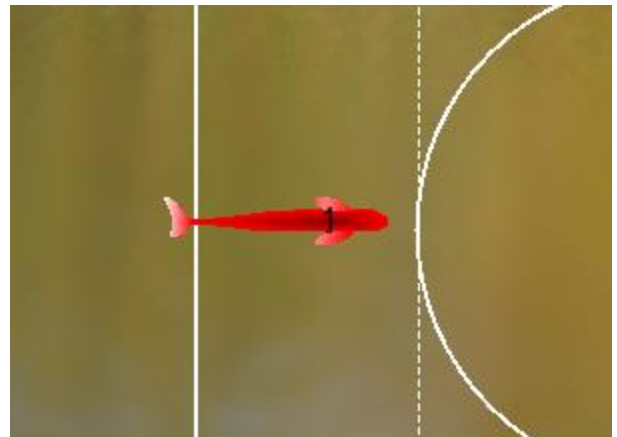


Figure 1. The Robot Fish

As shown in Figure 1, the black digital on robot fish body indicates its order in its own team. The robot fish parameters are designed as the entity fish.

A. Structure

The fish's shape consists of three parts. It includes a curved head, a rectangular body, an elongated rectangular tail fin and two pectoral fins in right triangle. And the body is divided into three small parts. Each small part is isosceles trapezoid. And the bottom edge of the length of isosceles trapezoid is diminishing.

B. Size

The radius of arc head is 22 millimeter, rectangle of fish about Length * Width is 160mm * 45mm. Three bottom edge's length of isosceles trapezoid are 45mm, 30mm and

18mm. The height of the three trapezoid are 88mm, 66mm and 55mm.

C. Color

Robot fish color of the rectangle can be configured by the platform module. Different teams have their own color.

D. Motion Parameters

The robot fish have 15 kinds of speed gears and direction gears. Speed setting higher the value, the faster of the robot fish's movement speed it is. The direction gears are divided into 3 parts. 0~6 represent robot fish turn left, 7-speed represent robot fish swim straightly and 8 to 14 gears represent robot fish turn right.

III. A SHOOTING ALGORITHM BASED ON ANGULAR BISECTOR PATH PLANNING

Angular Bisector Path Planning conforms the robot fish's trajectory according to the points of fish, water polo and the goal. When the connection line of fish and water polo is not horizontal, robot fish use the algorithm to adjust its direction continuously in the process of arrival at water polo. The fish's orientation is just the same as the direction of connection line of the ball and the goal when fish just arrives at the head point of water polo. This would ensure that the fish can reach the head point within a short time to head the water polo, thereby increasing the efficiency of shot.

A. Conditions for the Algorithm

(1) Requirements for selecting target

The simulation platform's default target is the center of the goal. As shown in Figure 2, the target is the point of G_0 , and in order to augment shooting angle, the position of the target point G_0 could be adjusted dynamically. The point G_0 can be changed with the changing of water polo's position. Target point could be located in a position that above the central point, namely point G_1 and the Z-axis coordinate value is $Z_g = -\sigma$ when water polo's Z-axis coordinate (just below the platform is the Z-axis) is greater than zero. Similarly, Target point also could be located in a position that below the central point, namely point G_2 and the Z-axis coordinate value is $Z_g = +\sigma$ when water polo's Z-axis coordinate is less than zero. Setting $\sigma = 100mm$ based on experience.

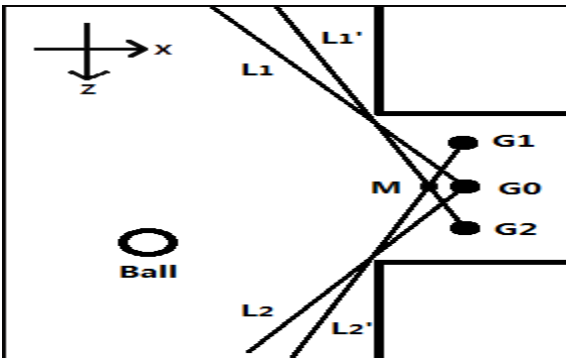


Figure 2. Selecting the target

Target set in the region of goal are between point G_1 and point G_2 . It has a bigger angular of shooting than that selecting of the target position for the center of the goal simply. Shooting angle is the angle formed by line L_1G_0 and line L_2G_0 when target at the center of goal. However, the shooting angle would increase to that formed by line $L_1'M$ and line $L_2'M$. Thus, the probability of success of shooting would increase obviously.

(2) Requirements for shooting distance

Own goals often happens in the actual match. There are two main reasons. One happens when two teams scramble for the water polo. The other happens when fish shoot in an improper playing area. Although the target point is not that is its own goal, the robot fish does curve movement might take water polo into one's own goal. For the two reasons described above, two restrictions are set as following.

- Water polo should have a distance that in the range of 300mm~500mm from the target point.
- Robot fish should be within the scope of the circumference to the water polo center, at a distance d (typically take 700mm~900mm) as the radius.

These two restrictions ensures that robot fish could be in the vicinity of the opponent's goal when shooting at goal.

B. Description of the algorithm

In the simulation platform of competition area, robot fish needs to take water polo into the target point *Goal*. As shown in Figure 3, the default coordinate system of the simulation platform is X-Z coordinate system, which is shown on the uppright corner.

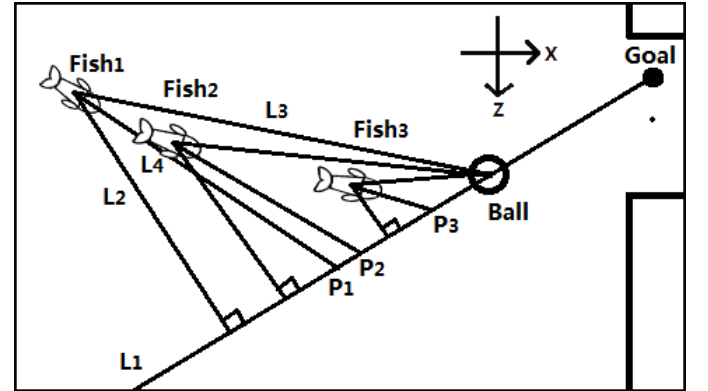


Figure 3. The shooting algorithm based on angular bisector path planning

Specifics steps of the algorithm is as follows:

Step 1: Make a connection between point *Goal* and point *Ball*. And make its reversely extension cord, named L_1 .

Step 2: Cross the fish and make the vertical line L_2 of line L_1 , then make a connection line L_3 between point $Fish_1$ and point $Ball$.

Step 3: Make the angular bisector line L_4 which is between line L_2 and line L_3 . And the intersection of line L_1 and line L_4 is referred to as point P_1 .

Step 4: Robot fish takes point P_1 as the interim target point to swim.

Step 5: If the fish reaches the position of water polo, then it just head the ball forward, otherwise, go *Step 1* mentioned above.

Robot fish calls the above algorithm constantly during the motion. The interim target point changes to be point P_2 when robot fish reaches at point $Fish_2$. And the interim target point also changes to be point P_3 when robot fish reaches at point $Fish_3$. The fish's orientation is just agree with the direction of connection line of the ball and the goal, namely line L_1 , when fish just arrives at the head point of water polo. And the position is very favorable shot for the robot fish.

Note that robot fish's position changes constantly and the water polo's might also changes continuously during the process of motion. Therefore, robot fish should call the above algorithm to adjust its path continually during every refresh cycle.

C. Design Parameters

● Mathematical Symbols

The meaning of model mathematical symbols is shown in Table 1.

TABLE I. SYMBOLS AND DEFINITIONS

Symbols	Notations
k_i	The slope of straight line i
θ_i	The angle between the straight line i and X-axis positive direction
X_j	The value of X coordinate of point j
Z_j	The value of Z coordinate of point j

● Equations

The key to algorithm solution is to find the angle between line L_4 and X-axis. Although the point Goal's coordinate depends on water polo's value of Z coordinate. However, the ball's position $Ball (x_b, z_b)$ could be obtained real-time in the global visual simulation environment.

Thereby, the point $Goal (x_g, z_g)$ can be confirmed.

Assuming the slope of line L_1 is k_1 , as in

$$k_1 = \frac{z_g - z_b}{x_g - x_b} \quad (1)$$

Line L_1 is vertical with line L_2 , so the slope of line L_2 is k_2 , as in

$$k_2 = -\frac{1}{k_1} \quad (2)$$

The fish's position $Fish (x_f, z_f)$ also can obtain, so the slope of line L_3 is k_3 , as in

$$k_3 = \frac{z_f - z_b}{x_f - x_b} \quad (3)$$

θ_2 And θ_3 could calculate by equation (2) and (3).

The angle between the line L_2 and X-axis is θ_2 , as in

$$\theta_2 = \arctan k_2 \quad (4)$$

The angle between the line L_3 and X-axis is θ_3 , as in

$$\theta_3 = \arctan k_3 \quad (5)$$

The angle between the line L_4 and X-axis is θ_4 , as in

$$\theta_4 = \min\{\theta_2, \theta_3\} + \frac{|\theta_2 - \theta_3|}{2} \quad (6)$$

According to these six mathematical formulas, the robot fish's shooting algorithm can be implemented using C# language in .Net Programming environment.

IV. SIMULATION AND ANALYSIS

Based on URWPGSim2D simulation platform, the motion track of robot fish is shown in Figure 4. Firstly, the robot fish use the shooting algorithm based on angular bisector path planning move along the curve line L_1 . Then it head the water ball directly into the goal along with line L_2 .

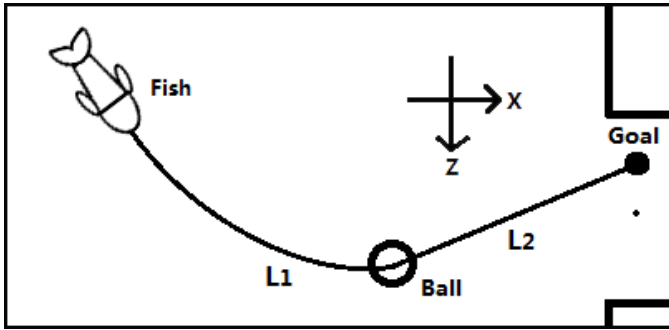


Figure 4. Motion path

After many simulation tests, it is found that there is a high probability of scoring using the shooting algorithm based on angular bisector path planning. And the algorithm is simple and efficient.

Its advantages were summarized as the following:

- In the process of reach the point of ball movement, the robot fish could adjust their own direction constantly. There is a high efficiency to shoot the goal along a straight line directly after it reached the ball point.
- The algorithm could be used in the situation that the distance is great.
- By adding the constraints of shooting, the own goal is prevented effectively.
- The angle of shot options are expanded, and the chance of shooting is increased indirectly.
- By solving several simple mathematical formula, the runtime of algorithm is constant magnitude. And it has a high running speed.

The algorithm also has shortcomings. When the fish is located in the middle of ball and the target point, it will waste a lot of time to look for angle bisector and the target point and the ball attachment reverse extension point. The shooting efficiency will be reduced.

V. CONCLUSIONS

A new shooting algorithm based on angular bisector path planning of shot is proposed. The main method is to adjust its direction constantly in the process of moving. Meanwhile, fish body's direction to keep the ball and the direction of approaching the target point connections, making it possible to begin to head the ball to travel along a straight line to head the ball points. The algorithm has been applied to the simulation platform match scene 3 VS 3, and the good results are obtained. It could be applied in ball big battle and water polo events in the snooker. This algorithm is used in addition to the main underwater robot fish, it could also be used for 3D robot soccer game shooting.

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