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Research on Robot Trajectory Planning Strategy for Water Polo Confrontation

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Research on Robot Trajectory Planning Strategy for Water Polo Confrontation

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Abstract: In the multi-joint robot water polo competition, it often occurs that the robot fish glances off the ball when pushing it due to the water waves generated by the fish swimming and the influence of the opponent fish's attack behavior on the target ball. In order to improve the success rate of the robot fish hitting the ball, this paper proposes a long-distance posture adjustment strategy and double-fish alternative attack strategy. The long-distance posture adjustment strategy is based on the detailed division of the relative positions of the fish, the ball and the goal. The probability of the fish, the ball and the goal being in a three-point line is improved by setting the distance through which the fish body reaches the preset hitting point and the posture adjustment strategy. Besides, the double-fish alternative attack strategy is proposed on the basis of this ball-pushing strategy. The cooperation between the two fishes is strengthened by developing another fish's returning strategy during the opponent fish hitting the ball, thereby improving the attack efficiency. The experimental results show that the underwater robot fish can avoid the close touch-ball and can attack the ball into the goal more quickly and accurately.

1.Introduction

Since 1997, the International League of Underwater Robot (ILUR) has organized 21 global vision-related competitions for the International Underwater Robot Competition. Combined with cutting-edge technologies in multi-disciplinary fields like advanced electronic circuit technologies, control algorithm technology, marine science and technology, bionics and artificial intelligence, the water polo 2V2 is a highly competitive project [1-2]. The robot water polo competition is a fierce confrontation with small bionic robot fishes as the research subjects, analogous to the of robot soccer games on land. The competition venue is a rectangular pool (as shown in Figure 1). The supporting facilities include 1 water polo, 2 goals (one for each of Party A and Party B), and 4 multi-joint robot fishes (two for each of Party A and Party B). The competition parties (Party A and Party B) control the CCD camera of the terminal global vision device, and the supplementary light source. In the robot water polo competition, the two teams of robot fishes competed against each other, and the party who has headed the water polo into the opponent's goal more times will be the winner. The game is divided into two halves, during which the two teams of robot fishes need to exchange their competition areas. Either team needs to score more goals if it wants to win the game.



For the ball-pushing strategy of robot fishes, Literature [3] divides the area with the ball as the center into the main attack zone, aided attack zone and buffer zone, but the accuracy is not enough. Literature [4] proposes the Algorithm of Cut Round Push Ball aiming to the posture adjustment of the fish body. Such algorithm defines the cut round based on fish, drives the fish to move to the boundary of the driving round, and then moves to the ball-pushing point. Literature [5] proposes a control strategy based on area division, divides the pool of the whole competition, and develops different offensive and defensive strategies for each area. As the result, the division of labor between the two fishes is more clear. The surrounding area of the ball is further divided, so that the fish moves according to different pushing strategies in different surrounding areas.

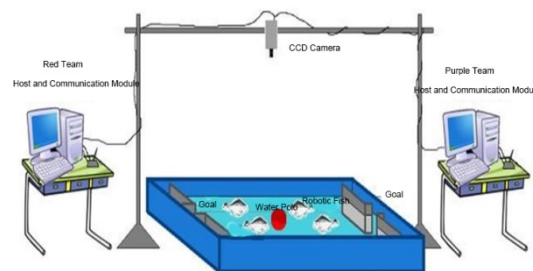


Figure 1 Global Visual Game Diagram

However, the robot fish is also affected by the water wave disturbance when performing the tracing action, which causes the fish to deviate itself from the relative position of the target ball when it reaches the preset ball-pushing point; in addition, it is also necessary to consider the influence of uncertain factors such as changes in the position of the target ball caused by the attack of the opponent fish on the target ball. The influence of the two on the fish trajectory control strategy is the most obvious during the actual competition, the situation that the fish glances off the target ball. Therefore, what kind of ball-pushing strategy is used to make the fish hit the ball accurately is a crucial factor.

2.Bionic Robot Fish

A bionic robot fish is composed of three parts: fish head, fish body and fish tail. As shown in Fig. 2, the fish head consists of a control circuit board, a battery, a communication module, a power switch, and a pectoral fin, and a blowing hole, a charging head, and an antenna are reserved for the fish head.

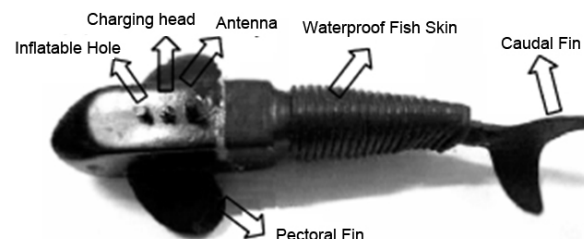


Figure 2 Structure of A Bionic Robot Fish ^[6]

The fish body consists of three joints in series, and each joint is a steering engine, with the advantages of low cost, good stability and accuracy. In the laboratory or competition environment, the

global vision can be used to obtain the position and posture information of the robot fish.

A bionic robot fish has 15 speed gears and 15 direction gears. The higher the speed gear is, the faster the speed will be. The direction gears are divided into 2 parts, 0 to 6 gears means left turn, 7 means swimming straight, and 8~14 gears means right turn.

3. Problem Description

For hitting the target ball, the optimal moving route should be that the whole fish, the ball center point B and the goal midpoint C are in a three-point line. As shown in Figure 3, when the fish is at point A, the ball-hitting distance in the A-B-C direction is the closest, which not only reduces the possibility of interception by the opponent, but also has a high fault tolerance rate, that means, even if the fish deviates from the preset route BC when pushing ball, there is still a high probability to score.

However, the relative positions of the fish and the ball during the competition is full of randomness. The coordinate information that the global vision system can acquire only contains the fish head and the fish center (not including the fish tail), and there is an error; the fish body turning is not flexible (compared with the fish in nature), and it is difficult to reach the position of the ball exactly when the fish is approaching to the ball during the competition, as the result, the situation that the fish moving around the ball or the fish glances off the ball often happens. Therefore, if the competitor chooses the fish to hit the ball by location or distance, it will often be inefficient and even cause an own goal.

The competition pool is as shown in Figure 3. Based on the relative positions of the ball (point B) and the goal (point C), we make a straight line L according to the three-point line of the fish, the ball and the goal, and divide the pool area into two halves according to the vertical line Line L' of Line L through which the ball passes. When the fish head is in Location 1 or Location 2 of Figure 3, it is not suitable for the fish to hit the ball. At Location 2, the fish head has exceeded the ball. If the fish is controlled to hit the ball in this case, it is likely to touch the ball in the process of U-turn, thus making the ball moving forward to its own goal, which is unfavorable its own party, and may even lead to the situation of the own goal. At Location 1, although the fish head does not exceed the ball, the fish tail coordinates cannot be obtained since only the fish head coordinates and the fish center point coordinates can be obtained in the visual system. When the fish body direction M (the vector established by the fish head and the fish center) coincides with the BC direction (Line L), the fish tail does not coincide, and when the fish tail is properly posed, the fish head will deviate again. This is often the reason why the fish is difficult to reach the ball at Location 1. The smaller the included angle α between the fish body direction M and the BC's vertical line is, the closer the fish to the ball will be, and the higher the probability of failing to push the ball will be. Note that although the preset hitting point is within the scope of Hit Region, the situation that the relative distance and angle of the fish body to the ball are often at Location 1 or Location 2 because the opponent's fish is ready for attacking and the ball and fish are affected by water waves.

In summary, in order to facilitate the follow-up discussion, this paper divides the positions of the fish and the ball into the following three circumstances:

1) Fish head exceeds Line L'

In this case, the fish is still dangerous to attack the ball. In order to shorten the attack time, the current strategy tends to drive the fish to an area closer to the ball. Once the fish swims to the front of the ball, it cannot push the ball to the opponent's goal, and will hinder another fish hitting the ball, thus

wasting an attack opportunity.

2) The fish head does not exceed Line L', but the included angle α between the fish body and Line L' is too small.

If the angle α is too small, it will increase the difficulty of adjusting the posture, coupled with the limitations of the actual hardware and software, this situation often causes the fish to move around the ball and fail to hit the ball forward.

3) The fish body is in the Area A and its posture is straight

When the included angle between the fish body direction M and Line L is smaller than β (set to 15 degrees in this paper), the fish can move forward accurately in the BC direction when hitting the ball.

4. Long-distance Posture Adjustment Strategy and Double-fish Alternative Attack Strategy

Based on the above mentioned problems, this paper proposes a long-distance posture adjustment strategy and a double-fish alternative attack strategy, which are respectively used to adjust the posture of the fish body to reach the preset hitting point, and improve the probability that the fish, the ball and the goal are in a three-point line, and the double-fish alternative attack strategy based on this strategy.

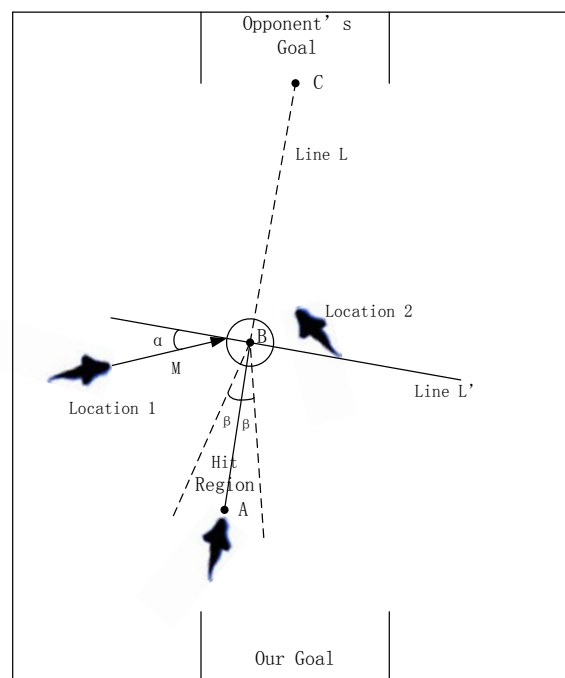


Figure 3 Classification of Relative Positions of the Fish Body and the Ball

4.1 Long-distance Posture Adjustment Strategy

It is necessary to adjust the posture of the fish before it hit the ball every time. According to the description of Section 2, when the included angle between the fish body direction M and AB is less than 15 degrees, the fish can accurately score a goal straight according to the preset trajectory BC (such as Hit Region in Figure 2). For this reason, a preset hitting point is set in many strategies so that the fish can adjust the posture during the process of reaching this point [3, 5]. During the competition,

however, the system can only acquire the coordinate information of the fish head and the fish center, and there is an error; besides, the coordinates of the fish tail cannot be obtained, which directly leads to the failure to acquire the included angle between the fish body and the ball, that means, there may be multiple possible postures and distances for the fish (point A) relative to points B and C. How to ensure that the included angle between the fish body M and AB is less than 15 degrees when the fish swims to the ball, is a key issue.

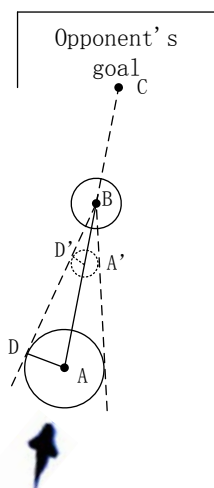


Figure 4 Long-distance Posture Adjustment Strategy

According to the observation during competition, in order to achieve an attack on the ball as soon as possible, a short posture adjustment is set in common posture adjustment strategy (e.g. preset points A' and ball position B as shown in Figure 4), but this will lead to what contact with the ball finally are all the parts of the fish body instead of the fish head. If the hitting position is not the fish head, the ball will not move forward rapidly in the BC direction no matter whether the posture adjustment (it's too late to achieve the adjustment because the ball is too close) or hitting the ball with the fish or the fishtail is implemented. And also, the ball will deviate from the predetermined trajectory, so that the next preset point deviates greatly, thus increasing the adjustment time.

In this regard, this paper proposes a ball-pushing strategy with long-range posture adjustment. Point A far from the ball position (Point B) is set as the preset point. The fish will push the ball after reaching the preset point A. In this way, no matter whether the direction of the fish body (i.e. the posture) is directly opposite to the BC direction, it can be fully adjusted in the $A \rightarrow B$ segment to avoid the interference of the fishtail and improve the accuracy of ball-pushing. In terms of speed setting, when the preset hitting point is close to the ball, only a low speed can be set to match the posture as the fish is to be turned near the ball, while the long-distance posture adjustment strategy is not bound by the speed, so the fish can swim at the fastest speed. It is worth noting that, during coding, the system for acquiring coordinates is not accurate, if only the coordinates of Point A are given, it is difficult for the fish to reach Point A, which is likely to cause a situation that the fish moves around Point A. Therefore, this strategy establishes a circle D with Point A as the center, and uses DA as the radius to set the preset ball-pushing area. When the fish center coordinates enter the range of Circle A, the ball-pushing may be achieved. The calculation of DA is shown in Formula 1:

$$DA = \sin 15^\circ * AB = (\sqrt{6} - \sqrt{4}) / 4 * AB \quad (\text{Formula 1})$$

4.2 Double-fish Alternative Attack Strategy

The long-distance posture adjustment strategy is an attack strategy for a single fish, which is not enough to show the attack ability of double fishes. To this end, this paper designs and implements the Double-fish Alternative Attack Strategy based on the long-range posture adjustment strategy (Figure 5).

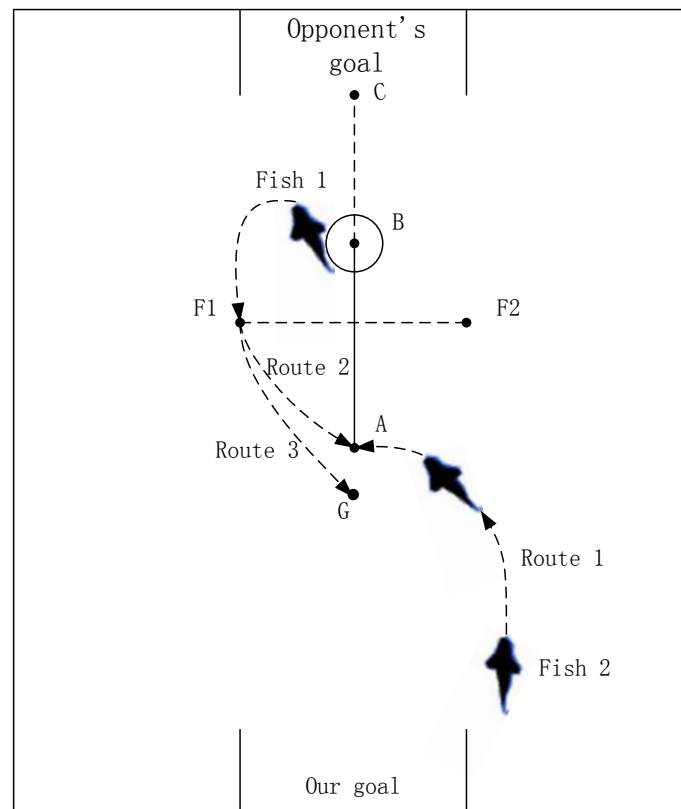


Figure 5 Double-fish Alternative Attack Strategy

The double-fish alternative attack strategy uses the "round" as the control period until the ball is scored into the opponent's goal. Each round is divided into the following four steps (the strategy flow is shown in Figure 6):

1) Select Fish 1 to go to Point A and Fish 2 to Point A. During the attack, when the distances of the two fishes to Point A is similar, there may be a situation that the two fishes collide with each other. To this end, Point G is set as a backup pre-hitting point. The front fish (Fish 1) is approaching to the ball (Point A) along Route 2, and the following fish (Fish 2) will enters Point G along the route 3 to adjust the posture.

2) Fish 1 swims towards the ball immediately after reaching Point A. When Fish 1 exceeds Point A by the distance of a fish body, Fish 2 (from Point G) will go to Point A. Note that the coordinates of the ball may change at any time during this process, and Fish 2 can continue to adjust the posture with the coordinate position of the ball at this stage and maintain the position at the preset hitting point.

3) When the center coordinates of Fish 1 crosses the straight line F1F2, Fish 2 will leave Point A to

get ready for pushing the ball.

4) When the ordinate of Fish 1 exceeds the ordinate of the ball, Fish 1 stops pushing the ball. Make a judgement on the center coordinates of Fish 2, if the fish 2 is located between A and B, then dispatch Fish 1 to go to Point G, otherwise, dispatch Fish 1 to go to Point A, which can prevent the fishtail from affecting the ball when the fish turns, and avoid the interaction between Fish 1 and Fish 2 when they prepare for return.

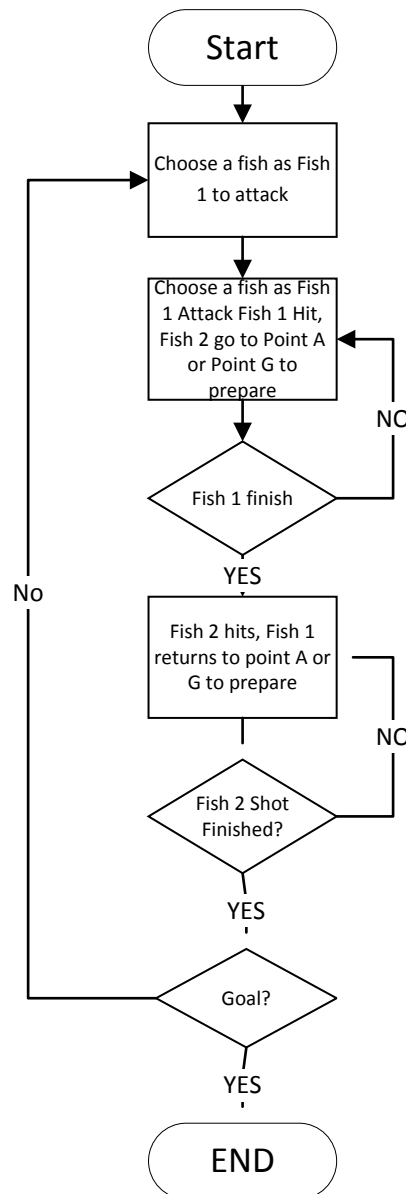


Figure 6 Double-fish Alternative Attack Strategy Process

5. Experiment

The experimental scene of the ball-pushing accuracy test is as shown in Figure 7. The fish (Fish 1/2) hitting the ball is let start from the corner of the pool, the ball is on the diagonal focus (B), and an interference fish with head being fixed (Fish 3) is placed one side of the pool.

Table 1 Ball-hitting Test with or without Interference (number of test times: 30)

Starting Position	Without Interference	With Interference
Position 1	Hit 28 times	Hit 25 times
Position 2	Hit 27 times	Hit 27 times

Table 2 Hitting Time (second) with or without Interference

Starting position	Without Interference	With Interference
Location 1	13.7	13.9
Location 2	6.4	6.2

At the beginning of the experiment, Fish 1 (Fish 2) starts from Position 1 (2), and is tested 30 times. The number of hit times that the hitting fish hit the ball accurately in the direction of the BC is recorded, as shown in Table 1. It can be seen that the probability of accurately hitting the ball in a predetermined direction is high and is not greatly affected by the position of the fish.

Then test the hitting speed. Set the speed gear to 15 (full speed), let the fishes start from Position 1 and Position 2 respectively, and test the time consumed when hitting the ball. Each position is tested 30 times, and take the average.

It can be seen that at Position 1, the distance traveled is longer, and the angle that needs to be turned after reaching the point A is larger (the fish posture needs to be adjusted so that the fish body faces the BC direction) accordingly. However, the speed is always kept at the highest level, it is not necessary to slow down (this is not available in the short-distance posture adjustment strategy. See the bottom of Figure 4 in Section 3.1 for details.), and the average duration can be controlled within 14 seconds.

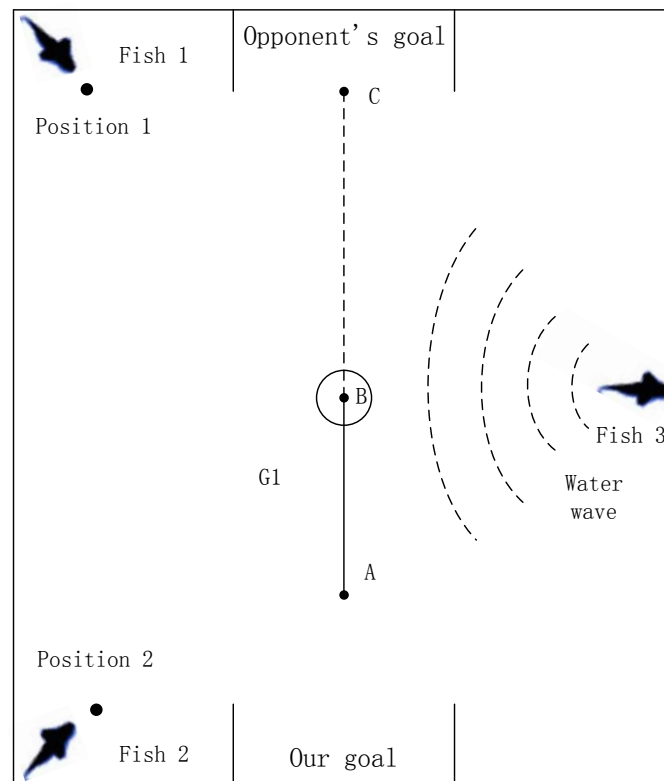


Figure 7 Setting of the Experimental Scene

At Position 2, the distance and angle are smaller, so it takes less time. In the actual competition, the fluctuations in the water will be more severe than in the test, but the position of the fish hitting the ball will be closer to the ball. This test has a certain reference value.

6. Conclusion

In the 2V2 robot fish water polo program of the 2019 Robotics Competition of Five Provinces in North China, two fishes were controlled to cooperate for attack based on the long-distance posture adjustment ball-pushing strategy proposed in this paper. Beijing Information Science and Technology University won the second prize in the 2V2 robot fish water polo program of the 2018 Robotics Competition of Five Provinces in North China. Therefore, the effectiveness of the strategy has been validated.

7. Acknowledgements

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