The Non-precision Goal Algorithm of Robot Fish Based on Fuzzy Control

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***Abstract*—In the water polo match, the key to win the match is to seek a rapid and precise goal method. To solve this problem, the non-precision goal algorithm based on fuzzy control is proposed in this paper. The relative position of the water polo and the robot fish is described as the input of the fuzzy control algorithm, a fuzzy controller is built according to the experience, defuzzification is achieved using the gravity-center method, and the output are the swimming angle and velocity of the robot fish at next moment. During the process, the robot fish adjusts its angle and velocity, then swims to the water polo and puts the ball into the goal. The results of simulation experiment based on the URWPGSim2D (Underwater Robot Water Polo Game Simulator 2 Dimension Edition) show that the algorithm proposed in this paper significantly reduces the goal time and improves the reliability.**

Keywords-goal algorithm; fuzzy control; robot fish

I. INTRODUCTION

With the development of biological science and engineering technology, the research on biomimetic robots has become a hot topic in recent years [1]. The biomimetic robot fish is a hot spot in the research field of biomimetic robot, because of its high efficiency, good maneuverability and strong adaptability. The simulation match of robot fish, which is based on the platform of URWPGSim2D, provides good opportunity for researching the biomimetic features and control mode of the robot fish. The players in the match are simulated robot fishes which play confrontational match in the simulated water environment. The key to win the match is to improve the goal efficiency.

Researchers have proposed various goal strategies successively for the complex underwater robot fish simulation match. Yu Junzhi put forward point-to-point control algorithm, which not only wastes time and takes up a lot of memory resources, because it detects the best polo-heading point in each cycle on the URWPGSim2D platform with a period of 100 milliseconds [3]. In the non-precision strategy proposed by Wang Xiaowei [4], when the distance between the fish and the water polo is within certain range, the fish must swerve with large curvature to get goal. Thus the deadlock usually occurs with the single condition of distance, this means, the fish does not move in a certain position or direction. To overcome these shortcomings, a new non-precision goal strategy based on the fuzzy control algorithm is proposed in this paper. The simulation proves that this new method can shorten the goal time and improve the goal efficiency.

II. SIMULATION WATER POLO MATCH OF THE ROBOT FISHES

A. Rules of the Match

The experimental platform in this paper is URWPGSim2D. The initial state of the simulation water polo match is shown in Figure I.

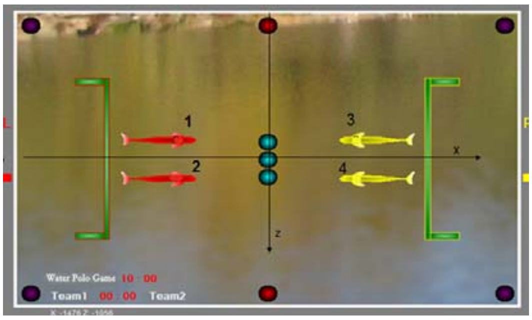


FIGURE I .THE INITIAL STATE OF THE WATER POLO MATCH

As is shown in Figure I., the origin O is the geometric center of the field, the positive X axis is horizontally rightward, the positive Z axis is vertically downward. The positive direction of the angle is defined from the positive X axis to the negative X axis, which are from 0 to π clockwise and 0 to -π anticlockwise. The water polos are located in the four corners of the rectangle field and at the two mid-points up and down. There are two opponent teams in the field. Team 1 is composed of fish 1 and fish 2, and team 2 is composed of fish 3 and fish 4. For pushing the water polos into their target goal to achieve scores, each team tackles, dribbles, shoots, blockades and guards the gate using their own methods during the match. Game time is 10 minutes. The team getting higher scores wins the match when the match is over.

B. Analysis of Goal Strategy

On the URWPGSim2D platform, the rigid-body center (the geometric gravity center) of the robot fish represents the location of the fish by default. Thus, this may cause wrong judgment about the relative position of the robot fish and the water polo. For example, as is shown in Figure II, the platform judges the water polo is on the lower right of the robot fish, but in fact it is on the lower left of the robot fish.

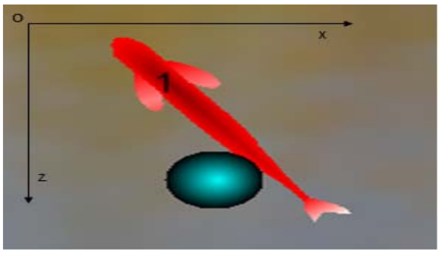


FIGURE II. MISJUDGMENT OF THE POSITION BETWEEN THE ROBOT FISH AND THE WATER POLO

The goal area is relatively wide in the match and there are continuous interception and interference from the opponent team, therefore, missing the polo often occurs. From the simulation experiment, we found that the disturbance would be reduced if the fish heads the polo using its side of the body. So, the side of the body is used to head the polo in this paper. Because the fuzzy control algorithm has good robustness and strong fault-tolerance ability, it is used as the judging condition of whether the action of heading the polo should be taken. Therefore the non-precision goal strategy based on the fuzzy control algorithm, is adopted to improve the goal efficiency.

III. THE NON-PRECISION GOAL ALGORITHM BASED ON FUZZY CONTROL

A. *Judging the Position between the Robot Fish and the Water Polo*

Suppose the radius of the water polo is r; take d≤2.5r, based on the experience, as the optimum distance between the water polo and the robot fish to head the polo; the direction of fish is α.

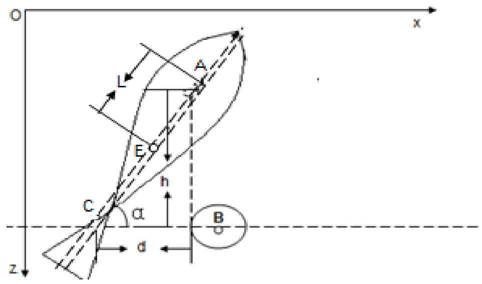


FIGURE III. THE GEOMETRICAL RELATIONSHIP OF THE FISH AND THE WATER POLO

In Figure III, point A, whose coordinates are (FX, FZ), is the rigid-body center of the robot fish; point B, whose coordinates are (BX, BZ), is the center of the water polo; the double dashed line represents the robot fish's middle axle; point C, whose coordinates are (FX1, BZ), is located on the middle axle and its Z-coordinate is the same as that of the water polo. According to the geometrical relation, we have:

$$FX1 = FX - d\ ,\ d = h/\tan(\alpha) \quad (\text{when } BZ < FZ) \tag{1}$$

$$FX1 = FX + d\ ,\ d = h/\tan(\alpha) \quad (\text{when } BZ > FZ) \tag{2}$$

The judgment rules for the position between the robot fish and the water polo are as follows:

When FX1<BX, the fish is on the left of the water polo, when FX1>BX, the fish is on the right of the water polo.

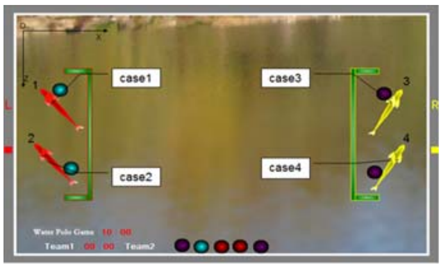
In Figure III, point E, whose coordinates are (FXE, FZE), is the mid-point of the fish's middle axle. It is used to determine the fish heads the polo using its upper part or lower part of the body. The distance between point A and point E is L. From Figure III, we can get:

$$FXE = FX - \cos(\alpha) * L \tag{3}$$

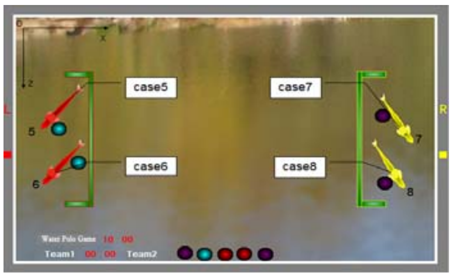
$$FZE = FZ - \sin(\alpha) * L \tag{4}$$

B. *The Goal Strategy Based on Fuzzy Control*

The fuzzy control is defined as using natural language to outline the complex system that is difficult to be described with the existing law and it is expressed with the help of qualitative, imprecise and fuzzy conditional statement [5]. The core of fuzzy control is the fuzzy inference engine, in which the fuzzy-rule bank or knowledge bank containing expertise experience in relevant field is mainly stored. Some fuzzy-control rules in the form of 'if X1 is A1 and X2 is A2, and Xn is An, then Y is B', in which Xi and Y are fuzzy variables and Ai and B are fuzzy sets, are included in the bank. The fuzzy-control algorithm, according to the specific controlled objects, determines the structure of fuzzy controller, including the input and output variables, fuzzification algorithm, fuzzy- inference rules and precise algorithm [6]. This algorithm combines the fuzzy control's robustness with the behavior of sensation-action based on physiology, to provide the new method for the robot fish to get goal. As is shown in Figure IV, according to the goal method, there are totally 8 situations in which fuzzy control can be achieved.



(a) The angle of the fish is negative



(b) The angle of the fish is positive

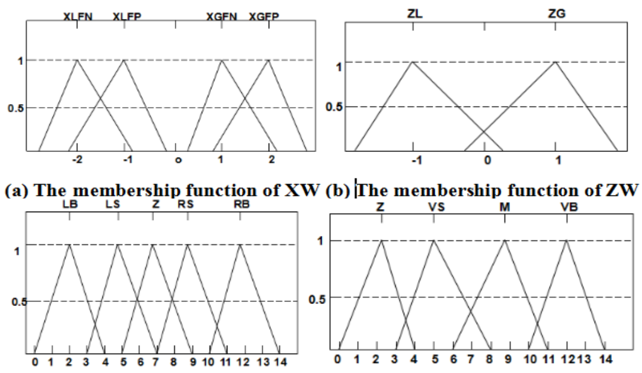
FIGURE IV. THE ALL RELATIVE POSITION BETWEEN THE ROBOT FISH AND THE WATER POLO

The fish's angle is defined as the included angle between the line segment from the fish's tail to its head and the X axis along the fish's middle axle. In the Figure IV, (a) describes the angle of the fish is negative, (b) describes the angle of the fish is positive. According to experiences, the fish's current angle and coordinate, the position of the water polo relative to the robot fish, the swimming angle and velocity of the robot fish at next moment are represented by fuzzy control variables XW, ZW, W{T, V} respectively. The detailed fuzzy control variables and fuzzy sets are shown in Table I.

TABLE I. FUZZY CONTROL VARIABLES AND FUZZY SETS

Fuzzy control variable	***Meaning of the variable***	***Fuzzy set of the variable***	***Meaning of the fuzzy set***
XW ***(X: X-direction W: whether)***	The fish's angle and coordinate are described as input variables	{XLFN, XLFP, XGFN, XGFP }	X:FX, L: less than Ball.X and greater, than Ball.X-2.5r, G: greater than Ball.X and less than Ball.X+2.5r, F: Frad, P: positive, N: negative
ZW ***(Z: Z-direction W: whether)***	The position of water polo relative to the robot fish	{ZG , ZL}	Z: FZC, G: greater than Ball.Z and less than Ball.Z+2.5r ,L: less than Ball.Z and greater than Ball.Z-2.5r
W{T,V} ***(T:angular velocity*** ***V: velocity)***	The swimming angle and velocity of the robot fish at next moment	The fuzzy set of T is {RB, RS, Z, LB, LS} The fuzzy set of V is { VB, M, VS, Z}	R: right, B: big,S:small, L; left , Z: zero, M: middle

Based on the feature of platform, the fuzzy variable XW is divided into 5 discrete values [-2,-1,0,1,2], the fuzzy variable ZW is divided into 3 discrete values [-1,0,1] and the fuzzy variable W{T,V} is divided into 5 discrete values [-2.-1, 0, 1, 2] and 4 values [0, 1, 2, 3] respectively. The values of velocity V and angle T of the simulation platform both include 15 integers from 0 to 14. The fish's velocity increases with the values. The integers of the deflection angle are from 0 to 14, specifically, 6-0 represent turning left, and 8-14 represent turning right. The more the number deviates from 7, the larger the angle is. Here the fuzzy-membership function of the fuzzy variables is chosen as unary piecewise function. The detailed distribution is shown in Figure V.



(a) The membership function of XW (b) The membership function of ZW

(c) The membership function of T (d) The membership function of V

FIGURE V. THE MEMBERSHIP FUNCTION

The fuzzy controller is built based on the experience in this paper, and the rules of fuzzy control [7] are shown in Table II.

TABLE II.THE RULES OF FUZZY CONTROL

W(T,V) \ XW / ZW	***XLFN***	***XLFP***	***XGFN***	***XGFP***
ZG	W (RS,M)	W (LS,S)	W (LS,M)	W (RS,S)
ZL	W (LS,B)	W (RB,M)	W (RS,B)	W (LB,M)

The gravity-center method is used for defuzzification in this paper. The elements in standard domain corresponding to the gravity center of the area enclosed by the membership function of the inferred fuzzy subset W{T,V} and the X axis of (c) and (d) in Figure I.X are described as the precise result, then, the deflection angle and swimming velocity of the robot fish to head the polo at next moment are obtained. The goal process in the water polo match is shown in Figure VI.

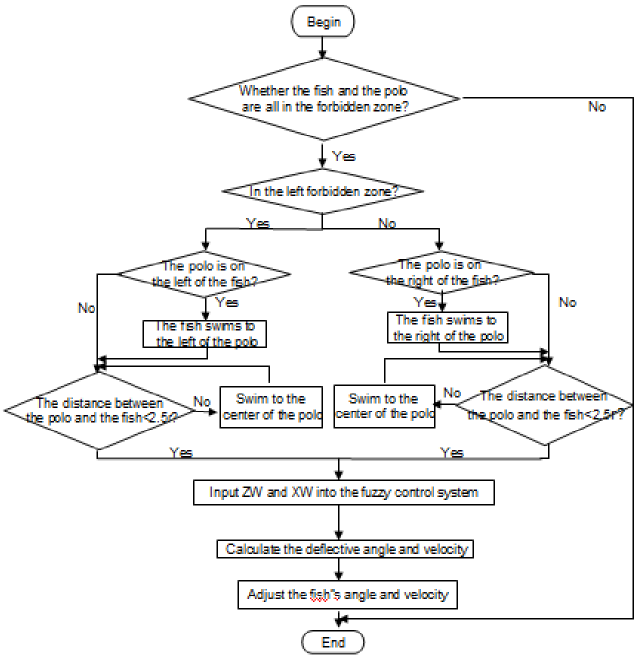


FIGURE VI. THE FLOWCHART OF THE GOAL ALGORITHM

IV. SIMULATION

This paper discusses how the robot fishes push the water polo into the goal rapidly under the interference and confrontation of the opponent. As is shown in Figure VII., team 1 is composed of fish 1 and fish 2, and team 2 is composed of fish 3 and fish 4. Currently, team 1 is pushing the polo into the goal, and the opponent team 2 is preventing it.

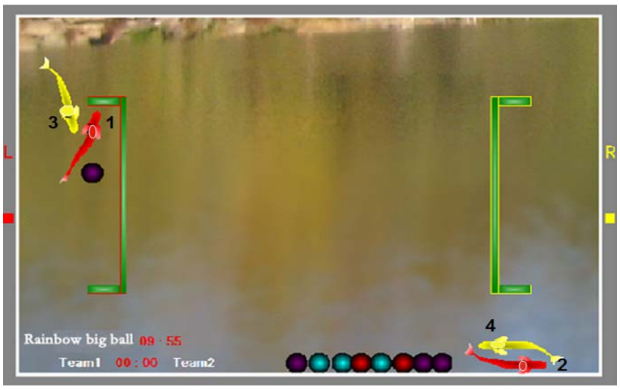


FIGURE VII. SIMULATION DIAGRAM OF CONFRONTATIONAL MATCH

Three methods are adopted in the experiment, including the non-precision goal method proposed by Wang Xiaowei, the point-to-point control algorithm proposed by Yu Junzhi, and the goal method based on fuzzy control proposed by this paper. The simulation goal results of team 1 are shown in Table III.

TABLE III.THE GOAL TIME USING DIFFERENT METHODS

Goal method	***Goal time in the first simulation***	***Goal time in the second simulation***	***Goal time in the third simulation***	***Goal time in the fourth simulation***	***Goal time in the fifth simulation***
non-precision goal method	10S	10S	30S	9S	34S
Point-to-point control algorithm	10S	40S	27S	15S	50S
The goal method based on fuzzy control	10S	9S	10S	10S	10S

It can be seen from Table III that the point-to-point control algorithm takes longer time to get goal than the other two algorithms do, due to the worse tendency to miss the polo and more interferences by the counterparts. The non-precision goal method must try many times to push the polo into the goal, because the misjudgment of the location of the polo relative to the fish happens often. Obviously, among the three methods, the goal method based on the fuzzy control proposed by this paper takes the least time to goal and has the best effect.

V. CONCLUSIONS

To achieve rapid goal under the circumstance that the robot fishes are interfered by their counterparts, the fuzzy control algorithm is introduced in this paper. Based on the traditional non-precision goal method, the fish's current angle, coordinate and the position of the water polo relative to the robot fish are defined as the input. The deflection angle and the swimming velocity of the fish at next moment are outputted by the fuzzy controller, thus increasing the speed to score goal. The simulation results show that in the confrontational match, compared with the traditional non-precision goal method and the point-to-point control algorithm, the goal method based on fuzzy control proposed in this paper significantly reduces the goal time, and increases the goal efficiency.

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REFERENCES

[1] Sfakiotakis M,et al. Review of fish swimming modes for aquatic locomotion[J].IEEE Journal of Ocean Engineering,1999,24(2): 237~252.

[2] Wang K, Yu J Z, An embedded vision system for robotic fish navigation. Proceeding of International Conference on Computer Application and System Modeling.Taiyuan, 2010:333.

[3] Yu junzhi, Chen Erkui, Wang Shuo et al. Research on the Control Algorithm of Basic Movement of the Biomimetic Robot Fish[C]. Beijing: Chinese Association of Automation, 2002: 152-157.

[4] Wang Xiaowei, Investigation on the non-precision strategy in the Robot Fish's Water-Polo Game and Technical Application, Army Aviation College, Beijing 101123.

[5] Wang M, Liu J N K. Fuzzy logic based robot path planning in unknown environment[C]. International Conference on Machine Learning and Cybernetics, 2005,2:813-818.

[6] Juidette H, Youlal H. Fuzzy dynamic path planning using genetic algorithms[J].ELECTRONICS LETTERS, 2000, 36(4): 374-376.

[7] Medhdi Abbasi, Mohammad Dauesh, Mostafa Ghavour. A path fuzzy planner for autonomous under water vehicles to avoid moving unknown obstacles[J]. Proceeding of the 2010 IEEE International Conference on ference on Mechatronics and Automation, 2010:1264~1269.