Design and Implementation of a Posture Control Algorithm for Simulation Robotic Fish

Yingjie Song [1], Wusheng Tang [1,*], Gang Wang [2,*]

[1] School of Mechanical and Vehicle Engineering, Changchun University, Changchun, 130022, China
[2] School of Mechanical and Control Engineering, Baicheng Normal University, Baicheng, 137000, China
* Corresponding author: Wusheng Tang, Gang Wang

Abstract: Firstly, aiming at the posture (position and direction are collectively referred to posture) control of the simulation robotic fish, this paper introduces the simplified dynamics and kinematics model. Then, the cascade PID algorithm is proposed to control the posture of the simulation robotic fish. Finally, the corresponding strategy is written and applied to the simulation platform of URWPGSim2D software to carry out the simulation experiment. The experimental results show that it takes 31 seconds for the simulation robotic fish to reach the target posture, and the posture error is (7mm,5mm, -0.0358rad), which basically meets the requirements and verifies the effectiveness of the algorithm.

Keywords: posture control; cascade PID algorithm; the simulation platform of URWPGSim2D software

1. Introduction

The posture control of the simulation robotic fish is to ensure that the simulation robotic fish can overcome all kinds of interference to reach the specified target point in the desired direction during the swimming process. The essence of the simulation robotic fish swimming is the movement transformation between different postures. The quality of posture control directly affects the completion effect of the competition events of the simulation robotic fish, such as synchronized swimming, ball game, survival challenge, water handling, etc [1,2].

In view of the large straight swimming radian of the simulation robotic fish caused by the random fluctuations added to the URWPGSim2D simulation platform, Yang Yun et al. from Lvliang University adopted a specific swimming angle and swimming time to replace the posture function of the simulation robotic fish. Simulation experiment results showed that the improved strategy can improve the swimming speed of the simulation robotic fish and the straightness of swimming route [3]. Li Shuqin et al. from Beijing University of Information Science and Technology designed dynamic obstacles to meet the practical application requirements of real-time obstacle avoidance for the posture control of the simulation robotic fish, aiming at the fact that static obstacles lack of variation [4]. Liu Anquan et al. from Guangxi University of Science and Technology proposed an improved posture controller based on the proportional guidance, and verified the feasibility and effectiveness of the proposed controller by various experiments [5].

For the low accuracy of the simulation robotic fish with interference, Underwater Robot Water Polo Game Simulator 2D Edition (URWPGSim2D) developed by Intelligent Biomimetic Design Laboratory, Peking University is used as the simulation experiment platform to carry out simulation experiments. In order to achieve more accurate posture control, the cascade PID algorithm is built to perform the posture control of the simulation robotic fish.

2. Simplified Dynamics and Kinematics Model

2.1. Simplified Dynamics Model

The control commands adopted by the simulation robotic fish in URWPGSim2D software are the turning gears and speed gears, which are the inputs of simplified dynamics model. The combination of turning gears and speed gears is very important to the accuracy of posture control and response speed of the simulation robotic fish. The essence of the simplified dynamics model is to solve the corresponding relationship between input instructions of the simulation robotic fish (turning gears and speed gears) and output experimental data (linear velocity and angular velocity) under the collisionless state [5], and the linear velocity corresponding to the speed gear and the angular velocity corresponding to the turning gear are shown in Table 1 and Table 2.

Table 1. The linear velocity corresponding to the speed gear (mm/s).

speed gear	linear velocity	speed gear	linear velocity
0	0	8	175
1	10	9	227
2	35	10	273
3	67	11	291
4	98	12	294
5	112	13	298
6	135	14	307
7	154	15	317

Table 2. The angular velocity corresponding to the turning gear (rad/s).

turning gear	angular velocity	turning gear	angular velocity
0	-0.349	8	0.052
1	-0.297	9	0.087
2	-0.244	10	0.137
3	-0.192	11	0.192
4	-0.137	12	0.244
5	-0.087	13	0.297
6	-0.052	14	0.349
7	0		

2.2. Simplified Kinematics Model

The motion simulation diagram of the robotic fish is shown in Figure 1, and the motion constraint equations for the simulation robotic fish can be describe as follow [6]:

$$\dot{x}(t)\sin\theta(t)-\dot{y}(t)\cos\theta(t)=0 \tag{1}$$

Where, $(x(t), y(t))$ is the central coordinate of the simulation robotic fish, $\theta(t)$ is the angle of motion direction.

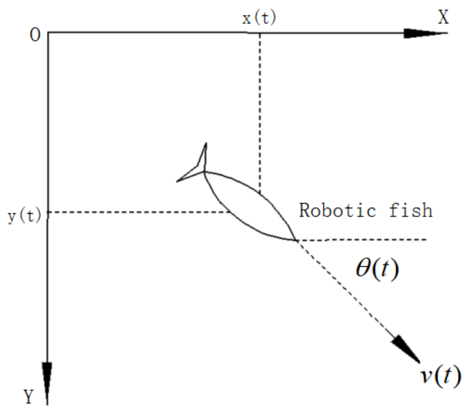


Figure 1. The motion simulation diagram of the robotic fish.

The kinematics equation of the simulation robotic fish can be described as follows [6]:

$$\begin{cases}\dot{x}(t)=v(t)\cos\theta(t)\\ \dot{y}(t)=v(t)\sin\theta(t)\\ \dot{\theta}(t)=w(t)\end{cases} \tag{2}$$

Where, $w(t)$ is the angular velocity and it is less than or equal to the maximum angular velocity. In addition, $v(t)$ is the linear velocity and it is less than or equal to the maximum linear velocity.

The continuous system equation described by formula (2) is converted into matrix form, and the matrix expression is shown as follows (3):

$$\begin{bmatrix}\dot{x}(t)\\ \dot{y}(t)\\ \dot{\theta}(t)\end{bmatrix}=\begin{bmatrix}\cos\theta(t) & 0\\ \sin\theta(t) & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}v(t)\\ w(t)\end{bmatrix} \tag{3}$$

The continuous system equation described by formula (2) is discretized, and the discrete system equation is given by the expression [7]:

$$\begin{cases}x(k+1)=x(k)+Tv(k)\cos\theta(k)\\ y(k+1)=y(k)+Tv(k)\sin\theta(k)\\ \theta(k+1)=\theta(k)+Tw(k)\end{cases} \tag{4}$$

3. The Realization of Posture Control Algorithm

The simulation robotic fish posture control schematic diagram based on cascade PID is shown in Figure 2. The linear velocity controller and angular velocity controller with fast response speed are taken as the inner loops, while the range controller and angle controller with slow response speed are taken as the outer loops to better meet the control accuracy of the simulation robotic fish.

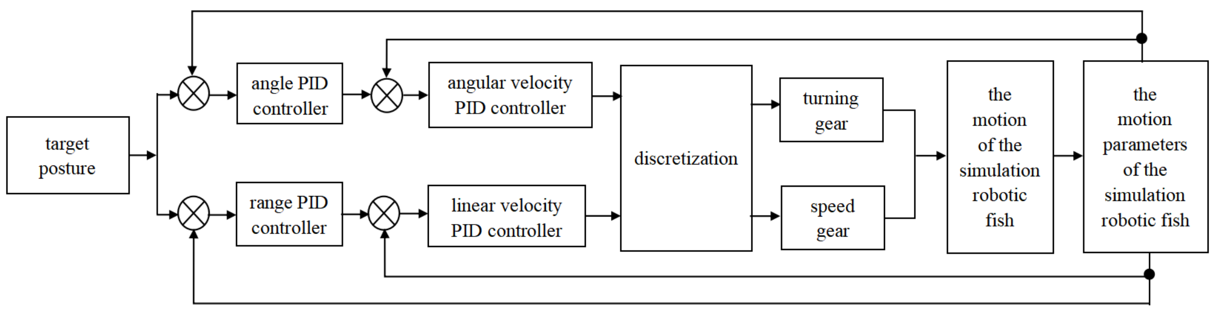
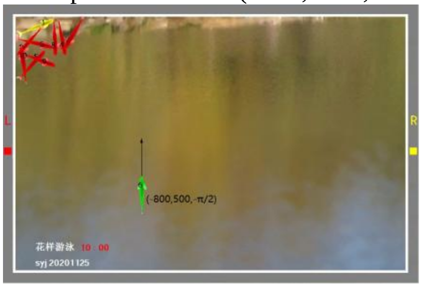


Figure 2. The simulation robotic fish posture control schematic diagram based on cascade PID.

4. Simulation Experiment Result

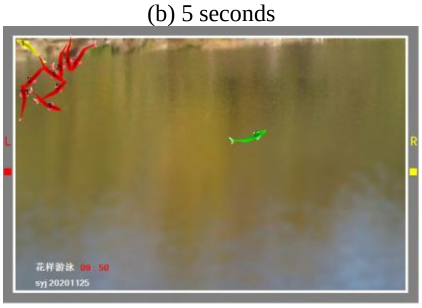
In the URWPGSim2D simulation environment, the No.6 simulation robotic fish of the non-confrontational 2D simulated synchronized swimming competition event is used as the simulation model to verify the posture control algorithm. For the convenience of distinction, the color of the No.6 simulation robotic fish is set as green, and the No.1 yellow simulation robotic fish can swim randomly in the field without being controlled by the strategy. In order to prevent the remaining red simulation robotic fishes from interfering with the movement of No. 6 simulation robotic fish, they are placed in the upper left corner without any action, that is, they are in a static state except collision. The coordinate system is defined as follows: the center of the simulation field is taken as the origin, X axis turns to the right, Z axis turns down, the angle range that negative X axis turns clockwise back to negative X axis is [-Π,Π]. The simulation experimental task is the simulation robotic fish swimming from the initial posture (-800mm, 500mm, -Π/2rad) to the target posture (600mm, -600mm, Π/6rad).

Figure 3 is the video sequence diagram of the simulation program based on cascade PID control law in URWPGSim2D environment with an interval of 5 seconds. According to the video sequence diagram of the simulation program, it can be seen that the simulation robotic fish No. 6 takes 31 seconds to reach the target posture and the posture error is (7mm,5mm, -0.0358rad).

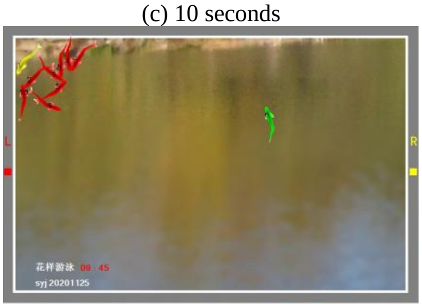


(a) 0 seconds

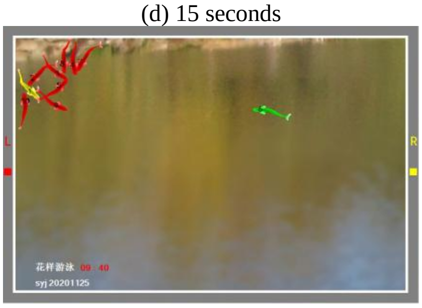
(b) 5 seconds



(c) 10 seconds

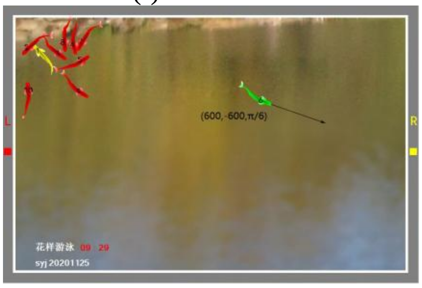


(d) 15 seconds



(e) 20 seconds

(f) 25 seconds



(g) 31 seconds

Figure 3. Video sequence diagram in URWPGSim2D simulation environment.

5. Conclusions

In this paper, according to the simplified dynamics and kinematics model of the simulation robotic fish, a simulation robotic fish posture control based on cascade PID algorithm is designed. And the posture control of the simulation robotic fish from the initial posture to the target posture is realized by using the URWPGSim2D simulation software. The simulation results show that the cascade PID controller can reduce the error compared with the original algorithm.

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