Realization of Fish Robot Tracking Control Using Position Detecting Algorithm

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Abstract: In this paper, we need to control the motion of the swimming fish robot in order to implement the aquarium fish underwater robot world. And, it implements positional control of the 3axes trajectory path for fish robot. The applied robot was verified the performance though the certificated fields test. It was satisfied the excellent performance such as driving force, durability and water resistance in experimental results. We can control robot motion that it is to recognize an object by using a video camera without any other sensors inside the fish robot. It is possible to find the position and control the fish robot motion control using RF (Radio Frequency) and controlled through the personal computer. In this paper, we are proposed to realize the control the motion of fish robot tracking control using fish robot position detecting algorithm with MATLAB and Simulink. It was verified by the performance test for the designed aquarium fish robot world.

Keywords-- **Fish robot, Control, RF, Aquarium robot system, MATLAB and Simulink.**

1. Introduction

The design of robots often inspires by the nature; recently developed bio-inspired robots have imitated various aspects of their live counter parts. The robotic dynamics is new sub-category of bio-inspired design. It is about learning concepts from nature and applying them to the design of real world engineered systems. More specifically, this field is about making robots that are inspired by biological systems [1] [2].

In this paper, the designed fish robot is researched and developed for an aquarium underwater robot system. The proposed aquarium consists of fish robot, scanner, PC (Personal Computer), Camera, drawing table, and beam projector as shown in the Fig.1. The fish robot model is analyzed to maximize the momentum of the robot and the body of the robot is designed through the analysis of the biological swimming. The presented fish robot consists of the head, 1st stage body, 2nd stage body and tail which are connected through two-point driving joints of the robot. We had applied the approximate method of the streamer model that utilizes techniques to mimic the biological fish [3][4]. The swimming fish robot has two operating modes such as manual and autonomous modes. In the manual mode the fish robot swimming is operated by using the RF Transceiver. In the autonomous mode the robot is controlled through the microcontroller unit. It consists of two servo motors and three PSD (Position Sensitive Detector) sensors in the fore head of fish robot to detect obstacles; Air bladder device in a head portion used to submerge and emerge in the water using the weight center

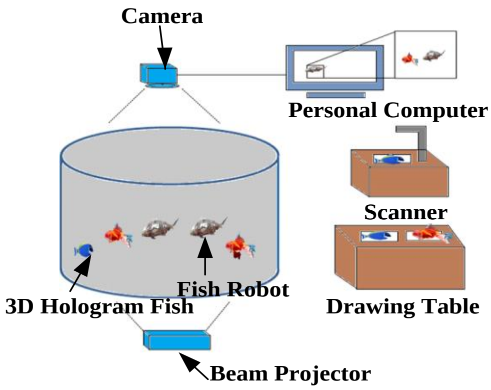


Figure 1.The aquarium fish robot world to control the fish robot.

moving methods and communication port is used to receive data. We had designed an aquarium robot world using fish robot. In this paper, we are proposed to realize the fish robot tracking control using position detecting algorithm using MATLAB and Simulink.

2. Modeling of the Fish Robot

The designed fish robot is researched and developed for an aquarium underwater robot system. The presented fish robot consists of the head, 1st stage body, 2nd stage body and tail, which is connected through two point driving joints. Because the robot is need to maximize the momentum and the body of the robot is designed through the analysis of the biological fish swimming. Also, it was applied to the kinematics analysis of fish robot swimming algorithms, which is basically Lighthill dynamics. The center of the fish robot gravity is transferred to a one axis sliding and it is possible to the submerged and emerged of robot by the weight moving unit.

In addition to the configuration of the entire fish robot control system was designed to apply an artificial intelligence algorithm and apply the AVR microcontroller in order to mimic the biological control for the robot. The control system mainly consists of RF module, three PSD sensors, two Servo motors and weight moving unit. The RF module is used to control the behavior of the fish robot in the manual mode. PSD sensors were used to detect the obstacles in the aquarium and servo motors operated with the sensor data.The weight moving unit used to balance the swimming motion of the fish robot using the sliding method and communication port designed for data acquisition unit. It has the function that is the streamer position control algorithm of autonomous mode and manual mode using the servo motors. Each fish robot body was manufactured through the assembly device in the configuration of an optimized inner area design robot. The robot dynamic force is determined by the instantaneous swimming and the robot specifications are shown in Table 1.

$$\vec{F}_i = -\frac{1}{2}\rho_{water}\begin{bmatrix} (C_{d\hat{x}_i}L_iH_i + C_{f\hat{x}_i}(H_i+L_i)W_i)v_{\hat{x}_i}\left|v_{\hat{x}_i}\right| \\ (C_{d\hat{y}_i}L_iW_i + C_{f\hat{y}_i}(L_i+W_i)H_i)v_{\hat{y}_i}\left|v_{\hat{y}_i}\right| \\ (C_{d\hat{z}_i}W_iH_i + C_{f\hat{z}_i}(W_i+H_i)L_i)v_{\hat{z}_i}\left|v_{\hat{z}_i}\right| \end{bmatrix} - \begin{bmatrix} 0 \\ \rho_{water}L_iH_iW_ig \\ 0 \end{bmatrix} \quad (1)$$

where $v_{\hat{x}_i}$: i_{th} body fixed coordinate system, $\hat{x}_i$ axis speed

W_i, L_i, H_i: i_{th} Width, length and height of the body

$C_{d\hat{x}_i}, C_{d\hat{y}_i}, C_{d\hat{z}_i}$: Drag coefficient of the each body-fixed coordinate system $[\hat{x}_i, \hat{y}_i, \hat{z}_i]$.

The acting forces on the fish robot are thrust in the forward direction is x-axis, water resistance in the reverse direction is y-axis and gravity in the vertical direction is the z-axis as shown in Fig. 2(a) and the buoyancy force acting on the fish in the aquatic environment is expressed in the force acting on the fluid propulsion to the fixed coordinate system $[\hat{x}_i, \hat{y}_i, \hat{z}_i]$ of the fish robot which can be shown as equation (1)[5]. When the fish robot is swimming, the force acting on the robot is the gravitational force acting an opposite to the fluid propulsion of the fish robot and it lifts the fish robot body as shown in the Fig. 2(b). The driving force can be obtained as equation (2) and (3) by the Lagrangian function [6].

$$L = T - V = \sum_i \frac{1}{2}m_i^2 v_i^2 + \sum_i \frac{1}{2}I_i^2 w_i^2 - E_p \quad (2)$$

where m_i, v_i, I_i, w_i: i_{th} mass, velocity, angular moment and angular velocity and E_p : Potential energy

$$\vec{F}_R = \frac{d}{dt}\frac{\partial L}{\partial \dot{q}} - \frac{\partial L}{\partial q} \quad (3)$$

So finally the force acting on the fish robot is equal to the addition of relative force acting on the body, Initial force acting on the body and weight acting on the body as shown in the equation (4).

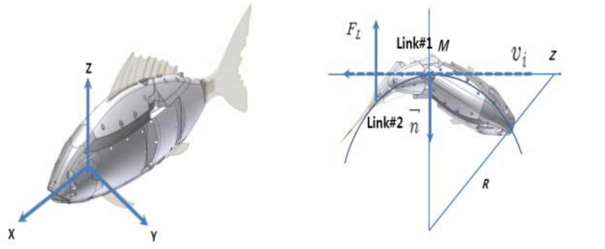
$$\vec{F} = \vec{F}_R + \vec{F}_i + w \quad (4)$$

where $W = m\vec{g}$, m is the mass of the body and $\vec{g}$ is the gravitational force acting on the robot.

The swimming form of fish robot is a continuous function with a discrete function for the kinematic streamer model

Table 1. The parameters of designed fish robot (unit:mm)

Component	*Length*	*Width*	**Height**
Head	70	72	110
1st Body	180	90	175
2nd Body	82	80	150



(a) (b)

Figure 2.(a) The acting axes of the fish robot, (b) The exerted lift and movement in the swimming rotation case.

through the proposed analysis by Light hill, which is equal to the equation (5) [5][7][8].

$$y_i(x,t) = (C_1x + C_2x^2)\sin(kx - 2\pi ft) = (C_1x + C_2x^2)\sin\left(kx - \frac{2\pi}{M}i\right) \quad (5)$$

It is defined as the error in the equation (6) which is the traveling wave approximation using the 3 joints, and the joint angle can be approximated as equation (7) by a sine wave having the same frequency as like as traveling wave.

$$error = \sum_{i=0}^{n-1}\int_{x_{,t}}^{x_{end}} \left|g(x) - f(x)\right| \quad (6)$$

$$\theta_i = a_i \sin(2\pi ft + p_i) \quad (7)$$

The swimming form of fish robot is a continuous function with a discrete function for the kinematic streamer model through the proposed analysis by Light hill, which is equal to the equation (5). In order to up and down swimming, the robots swim are designed to move back and forth to the center of gravity estimation point by the sliding weight center point method that is like as the gravity principle of bio fish.

3. Fish Robot Control Using Position Detecting Algorithm

3. 1 Detecting the position of fish robot

The Simulink model of Detecting Fish Robot has shown in the Fig.3. The process of Simulink starts from live video and ends with display of Fish Robot data. It consists of Camera live video, Resize, RGB to Intensity, optical flow, Thresholding and filtering, and 3 axes position data blocks. The camera installed on the top of the Fish Robot aquarium and it captures the swimming motion of the Fish Robot. The capturing video will be adjusted by resize block. Here, this step is very important because the original video converts into gray color by using RGB to Gray. Then, applied optical flow position detecting algorithm it will detect the motion vectors of the fish robot throughout the body as well as boundary filtering of the fish robot and it finds the position of the fish robot in two axes and other axis is the size of the fish robot. The three axes can be displayed on the three axes data display on the PC in the table format in the display block. The experimental results as shown in the Fig.6 [9][10][11][12][13].

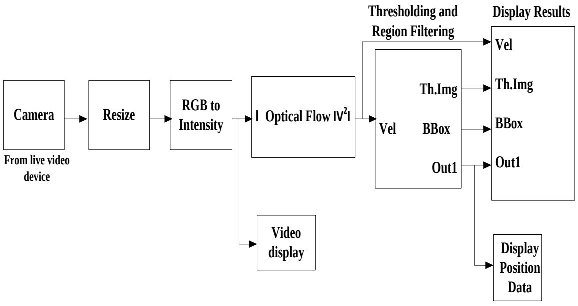


Figure 3. The Simulink model of detecting the position of fish robot.

3. 2 The fish robot control using the RF communication

The robot is operated in three modes such as manual mode, auto mode and control mode. In automatic mode, it is controlled using built-in sensors of robots through a path search optimization in the aquarium. Before control the fish robot, it has to be set in manual mode. Then, using the commands like left, right, straight, up and down motion directions of the fish robot. This control was done by using the MATLAB programming. The fish robot and PC connected with wireless communication through RF module. The RF module and PC connected through USB cable and establish the serial communication as shown in the Fig.4. The fish robot controlled in the water tank. The water in the tank is not salty and circumstance is short. So that, the 924.0M Hertz frequency is used with 5V DC power supply and radio frequency signal passed through Serial communication protocol. To catch the radio signal, whip antenna is used to transmit the signal and it covers more than 1.5 meters. Also, it controls the three joints and bladder device by the RF transceiver in manual mode which is shown in personal computer through video camera.

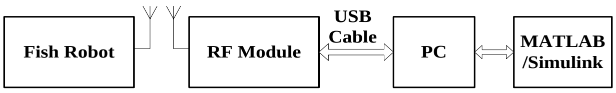


Figure 4. The Block diagram of RF communication of fish robot.

3. 3 The proposed fish robot tracking control system

The Simulink model of automatic tracking control system of fish robot has shown in the Fig.5. It consists of fish robot, camera, optical flow and 3 axes position data blocks. The position command is given to Proportional Integral Derivative (PID) controller from personal computer. The PID controller takes the position and controls it. Then, the servo motor takes the position signal and compare with actual signal, if any error will come that will be given to the negative feedback to servo amplifier. The servo amplifier will amplify the signal and fed back to the servo motor. Ironically, the camera captures the motion of the fish robot and applies to optical flow and get the data. The fish robot has built with RF module and connected with wirelessly to PC and controlled through MATLAB programming as well as Simulink through serial communication to send and receive the data to or from the fish robot. The control of the fish robot can be monitored through the live video

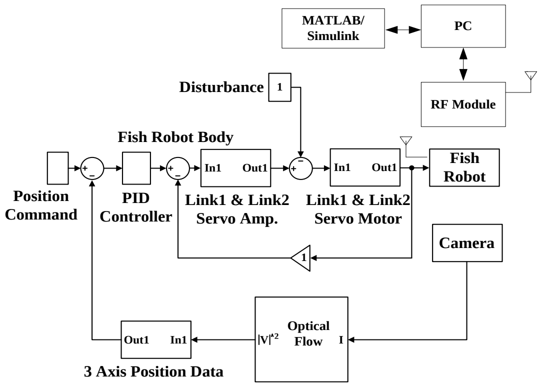


Figure 5. The Proposed fish robot tracking control system.

which is connected to the live video device that is camera and detected the boundary of the fish robot.

4. Experimental Results

The research system consists of the manufactured fish robot of Fig.2(a), RF Module, camera and personal computer in the aquarium such as Fig.1. We had designed the area of the aquarium is circular which has (height = 1m, diameter = Ø 1.8m). The experimental results of the position of the detection of the fish robot as shown in the Fig.6. The control of fish robots are orange and blue in the straight, left, right, up, down and neutral positions as shown in the Fig.7(a),7(b),7(c),7(d),7(e) and 7(f). In this algorithm, it displays the 3 axes data in the display results block. The display results block contain the 3 axes data namely x, y and z axes. The display results block, rows contains fish robot 3 axes data that is (x_1, y_1, $z_{1:}$ 172.4, 175.9, 199.6), (x_2, y_2, $z_{2:}$ 199.6, 159.7, 231.9) and (x_3, $y_{3,}$ $z_{3:}$ 114, 155.8, 165). Here, (x_1, y_1, z_1), (x_2, y_2, z_2) and (x_3, $y_{3,}$ z_3) are 3 axes coordinate of fish robots. These coordinates are representing the position of particular fish robot. The 3 axes position of the fish robot has detected correctly and the performance of experiment result is satisfied. The Fig.5 shows the automatic control system for detecting fish robot.

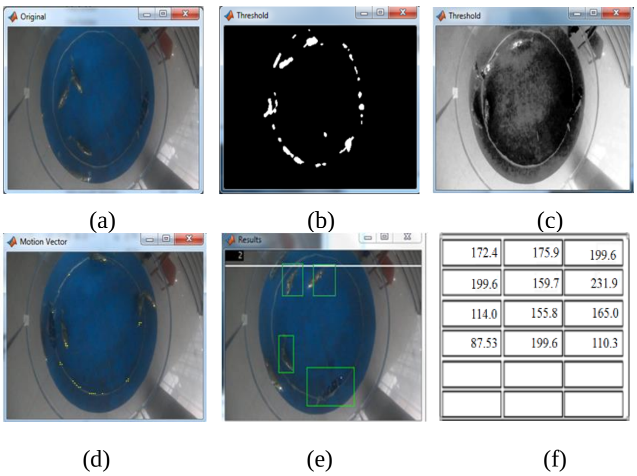


Figure 6. Experimental result of 3 axes Position detection for fish robots. (a) Video file, (b) RGB to Gray, (c) Histogram Equalization, (d) Optical flow, (e) Position detecting algorithm, (f) Display results.

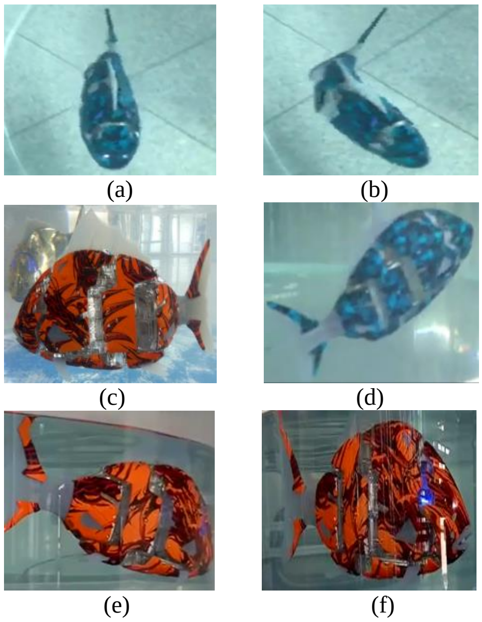


Figure 7. The control motion of the fish robot, (a) Straight, (b) Left, (c) Right, (d) Up, (e) Down, and (f) Neutral or Manual mode.

which consist of fish robots, camera for real time video, RF module and PC (Personal Computer) for control data communication. The control of the motion of the fish robot as shown in the Fig.7. In the MATLAB programme to send the data serially to fish robot via RF Module. In the programme "serial" is the MATLAB function creates a serial port object associated with the serial port specified by port. The "fwrite" (serial) is the MATLAB function writes the binary data to the device. The "hex2dec" is the MATLAB function to convert the hexadecimal data into decimal. The "set" is used to configure serial port object properties and "delete" is the function to remove the serial object from the memory. Where 53 is the start bit, 03 is the data size bit, 73 is the Manual mode, 61 is the Auto mode, 55 is the orange fish id, 47 is the fish robot will move to front, 4c is the fish robot move to left, 52 is the fish robot move to right, 55 is the fish robot move up, 44 is the fish robot move down and 43 is the fish robot stay on neutral. In the Simulink, the data will be given in constant block and connected to the serial send block. When, we give the position command like 172, 175, 199, the fish robot will be moved to the particular position in the aquarium and follow the command and the fish robot will move to automatic mode and it swims automatically. The experimental analysis of the proposed fish robot tracking control system using position detecting algorithm has been satisfied.

5. Conclusion

In this paper, we are proposing a new model to control the motion of the fish robot using the RF communication through MATLAB and Simulink. It was satisfied the performance of the experimental results using MATLAB and Simulink. It is possible to control the fish robot motion like left, right, straight, up and down through the specific commands in the aquarium fish robot world. Also, the fish robot model is designed to control the motion using the RF module controlled through MATLAB programming and Simulink from the PC. It was verified by the performance test for the designed aquarium fish robot world. It was satisfied the performnace of the fish robot tracking control through MATLAB and Simulink via RF communication from the PC and the experimental analysis of the proposed fish robot tracking control using position detection algorithm has been satisfied. We have plan that will install and operate fish robot in an aquarium of Daejeon National Science Museum, South Korea.

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