Autonomous Water Pollution Source Tracking System Using Fish Robot

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Abstract: - We introduce water pollution source tracking system which a fish robot searches the source of water pollution or something else. To simulate and verify the possibility of water pollution source tracking system, we made small water pool (2.4*2.4m) which a fish robot pursues infrared. The model of water pollution consists of color map, LED emitting infrared and phototransistor sensing the same wavelength light. Different color has different reflectivity for same wavelength light source, therefore this simulation model imitates the diffusion of water pollution source, LED and phototransistor is replaced with water pollution sensor. A fish robot avoids obstacle and find the place which has the highest reflectivity in water pool.

Key-Words: - Fish Robot, Water Pollution, Autonomous Tracking System, Obstacle Avoidance

1 Introduction

We have presented several types of small scale fish robots and submersibles in our lab[1][2][3][4]. They have been tested in a small tank, for collision avoidance, maneuverability, control performance, posture maintenance, path design, and data communication. All control actions of motors for fins, data acquisition from various sensors, for example, infrared distance sensors, pressure sensor, acceleration sensors, and illumination, and communication for monitoring and data processing are processed based on the MSP430F149 by TI. User commands, sensor data and images are transmitted by Blue-tooth modules between robots and a host notebook PC while fish robots are operated within a depth of 10cm. RF modules are used when the depth is greater than 10cm. They are operated in autonomous and manual modes in calm water. Manual operations are made by remote control commands in various ranges of Bluetooth protocol depending on antenna configurations.

The use of simple IR type distance sensors is proposed rather than using a camera or a sonar module for fish robot's eyes[2][4]. Three distance measuring sensors for a general purpose are mounted on the foreground and left and right side from the head of a fish robot. Simple plane obstacles composed with water pool is detected, and a fish robot can easily avoid the obstacle.

In this paper, we present new method for water pollution surveillance and tracking system using a fish robot and show the possibility the presented method is effective in the simulation. Water pool imitates the similar situation, for example, the diffusion of real water pollution source. A fish robot searches higher intensity of light source to track the highest position. Experimental results show the successful source tracking of the fish robot without collision.

We present a fish robot for water pollution tracking system in section 2, the simulation of water pollution circumstance in section 3, experimental results in section 4, and finally conclusion.

2 A fish robot

2.1 A fish robot

It is designed and developed fishlike underwater robot in our lab. Fish robot has a shape of real fish and imitates the swim. Four servo motors are used at the caudal fin for propulsion and horizontal direction control. Distance sensors are mounted at frontage and two sides of head to measure the distance from obstacle. All signals are processed based on the MSP430F149 by TI. Also, user commands and sensor data are transmitted between fish robot and a host notebook PC either by Bluetooth modules of class 1 or by an RF module depending on the operation depth. Fig. 1 shows a fish robot.

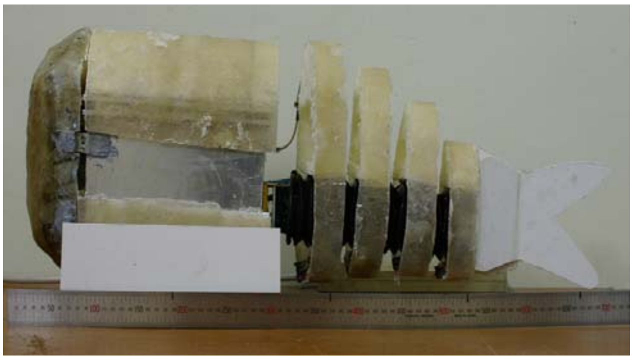

Fig. 1. Fish robot (73*12.5*22.5Cm, 5Kg)

To measure the distance between robot and obstacle, it is very common to use infrared distance sensor regardless obstacle colors, size and angle. Three infrared distance sensors, GP2D12s, are used to measure the distance between fish robot and wall or obstacles. The range of sensor is 10-80Cm in air, but the detectable range is reduced about 12-30Cm underwater. It is necessary to use transparent cover to keep the focal distance of lens underwater and to make the sensor waterproof. Three distance sensors are mounted in frontage of head and two sides of head. Measured distance information is used to determine of direction change. Characteristics of infrared distance sensors are shown in Fig 2.

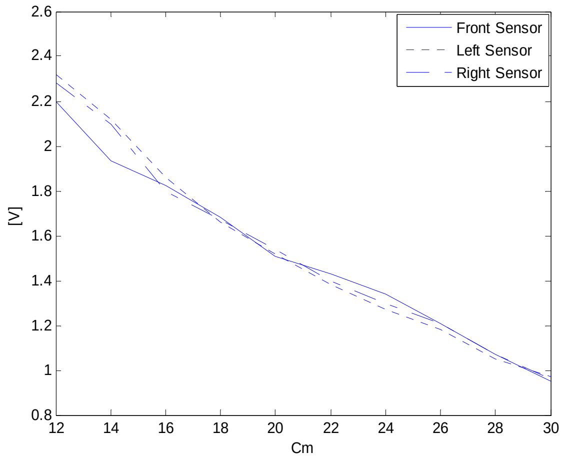

Fig. 2. Distance sensor outputs

Obstacle avoidance is the most important problem in mobile robot including wheel based or not, so many works present various methods and applications[2] [4][5][6][7].

2.2 Swim

Real fish turns skillfully using not only caudal fin but also pectoral fins or ventral fins, but we determined simple structure of the fish robot, which turns with only swing of caudal fin. As the caudal fin is used for propulsion and turning, the fish robot gets simple structure. In this case, we can think that there are two turning modes, called as slow turn and quick turn. Real fish swings its caudal fin to one side slowly or quickly for slow and quick turn during a turning [8][9]. Generally, when fish turns slow, fish swings caudal fin as well as turn of caudal fin. And when fish turns quickly, fish turns its caudal fin to one side quickly without swing and sustain its caudal fin during turning motion. We consider that these two modes are the most fundamental and important turning modes, because the fish robot imitates swim and turning of real fish. General swim function is shown equation (1).

$$A_i(t) = K_i Am_i \sin(2\pi ft - \theta_i) + \Delta_i(t) \qquad (1)$$

A_i is the angle of *i*-th tail motor, K_i is amplitude factor, Am_i is amplitude, f is frequency of caudal fin, θ_i is phase delay of *i*-th motors, and Δ_i is deflection angle for slow and quick turn. We use 10 degree maximum amplitudes of angle and 35 degree phase delays for general swim respectively. Swim frequency is 0.5Hz. Generally, deflection angle Δ_i varies smoothly for slow turn, but varies quickly for quick turn. When fish robot turns quickly its direction, K_i is zero.

3 Simulation of water pollution circumstance

We present new system which a fish robot pursues the water pollution source in real circumstance. The most important indexes of water pollution are BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand). But it takes so many times to get the exact values of these indexes. It is impossible to get the exact values of these indexes real-time. Instead of these two indexes, we can get some other indexes for water pollution, for example, DO (Dissolved Oxide), pH, Conductivity, and ORP (Oxidation Reduction Potential) real-time. But it is very difficult to find or make some contaminated place. To develop good water pollution tracking system, we need similar simulation circumstances presenting water pollution.

Fig. 3 shows the pollution source tracking system using a fish robot.

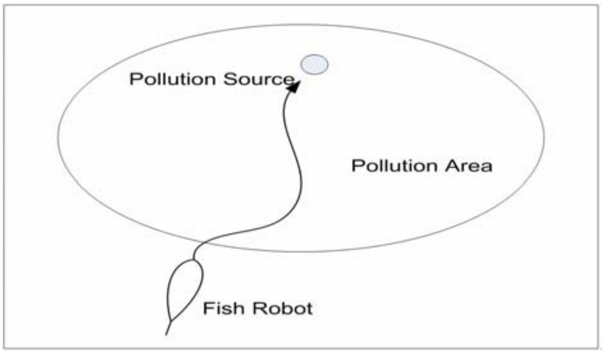

Fig. 3. Autonomous pollution source tracking system

To verify and simulate our attempt, we made artificial circumstance which is similar to real circumstance. Generally, water pollution source diffuses widely and in a circle at static condition, for example, in lake and sea except river which has strong stream. We made similar distribution of water pollution in small size water pool in our lab. We made some color map which reflects light source to imitate the water pollution, LED which produces infrared and photo transistor which reacts in infrared wave length very well. We use blue and red color to make different reflectivity of infrared. The depth of two colors makes smooth gradation in bottom of water pool. And white color which makes the highest reflectivity show water pollution source. Fig. 4 shows the artificial circumstance which imitates water pollution.

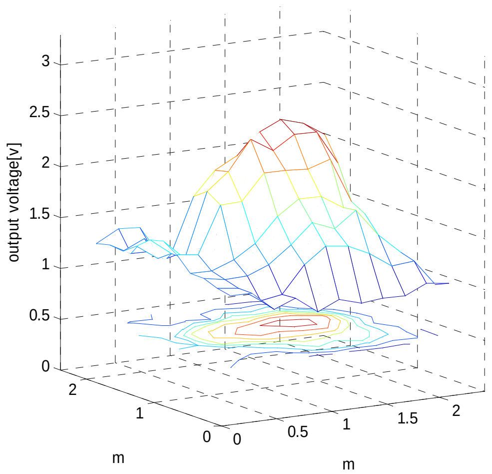

Fig. 4. Light Intensity distribution to simulate water pollution circumstance

A fish robot finds higher intensity of infrared which is reflected by bottom with different color produced by LED. To search the place which shows higher intensity, it is necessary to make the head of fish robot swing periodically to search wide area for one period swimming. The basic strategy for tracking is swing of body. A fish robot changes the direction to search higher intensity of light source. Fig. 5 shows the sensor configuration of fish robot. IR distance sensors which recognize and avoid obstacle are mounted in head of fish robot, and the direction of measurement is frontage. The direction of measurement of LED an photo transistor is bottom.

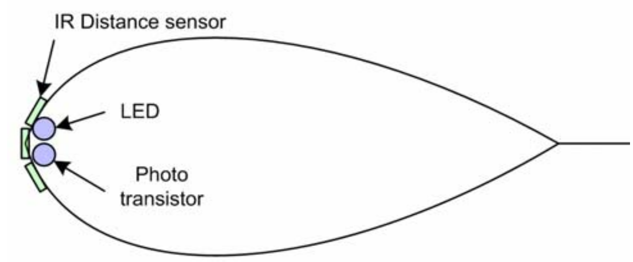

Fig. 5. Sensor configuration of fish robot

4 Experimental results

4.1 Basic strategy for tracking

The basic strategy of the tracking for higher light intensity is to search wide area while a fish robot swims. The swing of tail fin makes swing of the body and head. The sensor measures the intensity of infrared in swing trajectory and finds the highest intensity during half cycle of swing. When the highest intensity is find right side of center, a fish robot must change the direction right side. Therefore Δ_i in equation (1) must be decreased for the right direction change and increased for left direction change. A fish robot changes continuously the direction for the place which shows higher intensity of light source and can find the highest intensity place. For autonomous tracking of the source, we use simple command for the change of direction like that 'If the intensity of left side is higher than right side, then turn left', 'If the intensity of right side is higher than left side, then turn right', and 'If the intensity of one side is similar to the other side, go straightly'. These simple and concrete commands make good results for tracking the intensity source. But it is impossible to apply these oral commands to our microcontroller sophisticatedly. We use simple fuzzy logic for the easy implementation of controller.

4.2 Fuzzy logic controller for tracking problem

The fuzzy inference system[10][11][12] is used to control the direction of a fish robot. Since the main propulsion for a fish robot is provided by the tail fin which moves by four servomotors, there is a continuous swing action at both head and tail of the fish robot. This swinging movement covers some region to recognize the difference of intensity. Control input is one cycle intensity data from the photo transistor. A fish robot finds the maximum value and the position of the head, and fuzzy system determines the value of Δ_i for the change of direction. We used very simple and concrete oral command for direction control. Fuzzy control command processes the vagueness of instantaneous sensor noise and ambiguous oral commands. We show some commands for the control.

"If the intensity of left side is slightly higher than right side, then turn left slightly"
"If the intensity of left side is highly higher than right side, then turn left much"

Gaussian membership functions are used for input membership functions.

$$F(x) = e^{-\frac{(x-c)^2}{2\sigma^2}} \qquad (2)$$

The i-th fuzzy rule for TSK inference is given as

R^i : IF x_1 is F_1^i and … x_k is F_k^i …, Then
$$z^i = c_0^i + c_1^i x_1 + \ldots + c_K^i x_K \qquad (3)$$

where x_k is fuzzy input for half cycle photo transistor output, z^i is fuzzy output for change of direction, and F_k^i is a fuzzy membership function.
i = 1, 2,…, I, k = 1, 2,…, K
I : number of fuzzy rules,
K : number of fuzzy inputs,
c^i : linear value of fuzzy output

Fuzzy output is given by

$$z^* = \frac{\sum_{i=1}^{I}\prod_{k=1}^{K} F_k^i(x_k) z^i}{\sum_{i=1}^{I}\prod_{k=1}^{K} F_k^i(x_k)} \qquad (4)$$

Various autonomous tracking results are shown in Fig. 7.

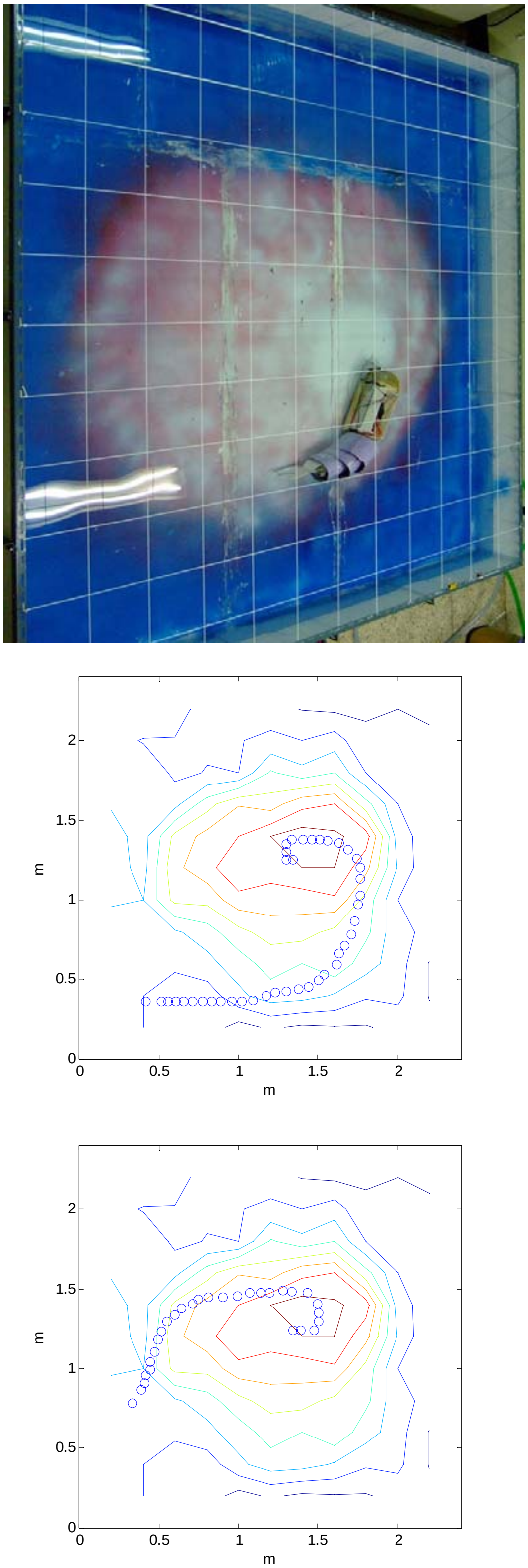

Fig.6. Examples of autonomous tracking results

5 Conclusion

We presented new water pollution tracking system using a fish robot and showed simulation results to pursue higher intensity of infrared. We imitated diffusion of water pollution source using infrared LED and photo transistor in small water pool with different color map. We checked the possibility which a fish robot pursues the pollution source and its effectiveness. We will develop real water pollution tracking system.

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