Data Acquisition of Obstacle Shapes for Fish Robots

SEUNG Y. NA, DAEJUNG SHIN, JIN Y. KIM, SEONG-JOON BAEK

Dept. of Electronics and Computer Engineering
Chonnam National University
300 Yongbong-dong, Buk-gu, Gwangju 500-757
SOUTH KOREA

Abstract: - It is important to get information about obstacles to avoid collision for a natural and smooth movement for fish robots. In this paper, we propose an IR sensor-based measurement system which gets information about obstacles for underwater fish robots. Due to complexity and space restriction, IR distance sensors are installed instead of cameras or sonar systems. Much importance is given to the nearby obstacles than those in the distance. A scanning IR sensor and two fixed IR sensors are used in our proposed system to get the pattern information of the obstacles in water. By analyzing the IR sensor data, the estimated shapes of obstacles are recognized. Trajectory control for underwater robots should be designed based on the estimated results of the shapes. Our experimental results show that fish robots, which use our proposed sensor system, make successful movement avoiding collision through channels.

Key-Words: - Fish Robot, Obstacle Shapes, Collision Avoidance, IR Distance Sensor

1 Introduction

The most basic task for fish robots is to detect obstacles and to avoid collision to make smooth and natural movements. The fish robots need to detect the obstacles in advance and move without collision. Successive collisions were prevented utilizing acceleration data when collision occurred in [1].

Fish robots make appropriate direction changes to avoid collision based on the IR distance sensor data. Analyzing image data of the target areas to recognize possible obstacles is the basic method in the water. Despite advantages of image systems, such as cameras and sonar, there are many kinds of situations where image data cannot be properly applied. The common reasons for this restriction are the limited capabilities of processors, ranges of short distances, transmission time and adverse underwater conditions to get sufficient image data.

For small-scale fish robots, it is necessary to apply cost-effective and basic sensors such as IR distance sensors rather than image sensor systems. IR sensors need small amount of information; thus, a quick and effective detection can be made. But the difficulties of the use of simple distance sensors are to recognize the shapes of obstacles correctly. In addition to a variety of shape patterns of the obstacles, shift distance and rotation angle of the robot relative to the obstacle make it hard to estimate shape patterns. In our proposed shape estimating system, a scanning IR sensor at the center with two fixed IR sensors at each side is used to get the pattern information of the obstacles in water. By analyzing the IR sensor data which has difficulties due to shift, rotation, and the speed of the robot, the estimated shapes of obstacles are reconstructed.

Path planning or control for fish robots should be designed based on the estimated results of obstacle shapes. Our experimental results show that fish robots, which use our proposed sensor system, successfully make their movement avoiding collision through the various types of channels.

2 IR Distance Scanning System for Fish Robots

The fish robot system in our lab uses IR distance sensors to measure the distance from the robots to obstacles in water. Due to structural limits, a resolution level depends on the distance and is also affected by noise. The underwater environment causes a much higher level of noise to IR distance sensors; moreover, the range of underwater measurement gets more shortened than that of the measurement in the air. Since data can be obtained only for one point at one time, it makes the system insufficient for shape recognition. To deal with these disadvantages of IR sensors for shape recognition, a proper scanning method should be used. In this paper we use a scanning IR sensor with a servo motor at the center, with two fixed IR sensors at each side, to get the pattern information of the obstacles in water. Also, a potentiometer is used to measure the rotation angle of the motor.

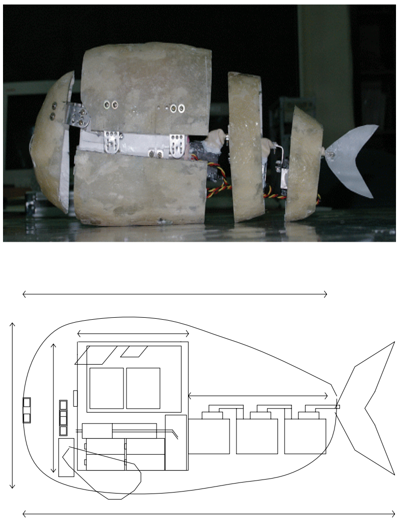


Fig. 1. A fish robot used in experiments

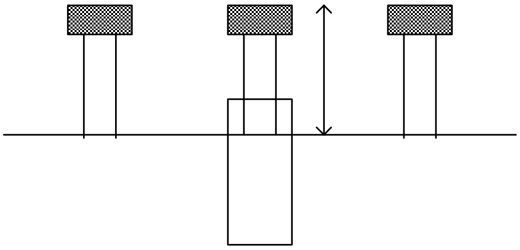


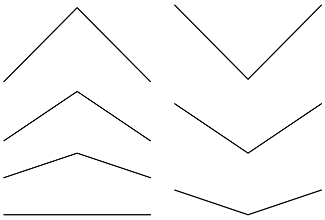
Fig. 2. Infrared distance sensor scanner

The fixed sensors, which are located on each side of IR distance scanner, are used to compensate the distance to the obstacle. They are also used as a primary data for a quick measurement or collision avoidance in the emergencies that no accurate object recognition is available. The shape measurement system is shown as in Figure. 2.

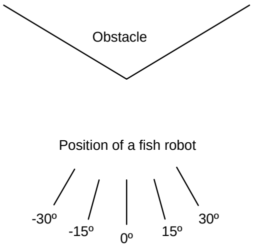
The IR distance sensor, which is used in this experiment, is a GP2D12 by Sharp Co. The range of measurement in the air is 10-80 cm, but the valid range in water is much reduced to 10-25 cm due to noise. The noise level becomes higher as the distance gets longer. The device of a sensor module is treated water-proof to be used in water. A film is attached to the lenses so that direct exposure to water as well as reduction of effective distance range can be prevented.

3 Recognition of Obstacles

The underwater robot which was constructed in our lab is 26.5×13.5×12.5 cm, length, width, and height, respectively. The robot moves in the tank with the size of 120 × 120 × 180 cm. Obstacle models, which consist of two planes, range from 90 to 270 degrees in the water tank as shown in Figure 3(a). Fish robots can approach obstacles with different angles relative to the center of obstacles as shown in (b).



(a) plane angles of obstacles



(b) rotation of obstacle

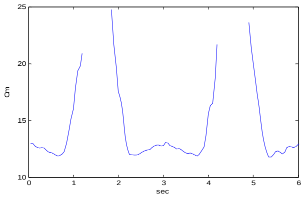
Fig. 3. Various shapes and positions of obstacles

Figure 4 shows a typical example of data processing which geometrically reconstructs an original obstacle shape using angular and distance information obtained within the measurement range in static condition.

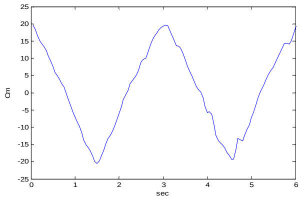
37 Cm

13 Cm

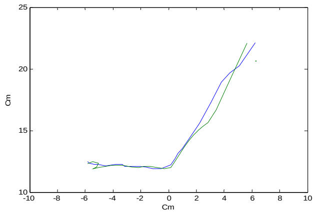
MSF430 MSF430



(a) distance raw data



(b) angle raw data



(c) reconstructed obstacle shape

Fig. 4. Typical example of an obstacle shape reconstruction in static condition

3.1 Simple Recognition

When the obstacle is located too close from the robot or there is not enough time to obtain sufficient data for the obstacle, a quick and simple method is utilized to avoid collision. The location data for the shape of the obstacle is calculated using the absolute coordinate values measured by all sensors.

The three points measured by the scanning sensor S_S and two fixed sensors S_L and S_R , which are located on each side, are P_S , P_L and P_R , and the coordinates are $(-5, L+4)$, (x_S, y_S) and $(+5, R+4)$, respectively. L and R are measured distances from the left and from the right fixed sensors, respectively, and S is the value by the scanning sensor. If the angle of the scanning sensor is α, then

$$x_S = (S+4)\sin\alpha \, , \; y_S = (S+4)\cos\alpha$$

The measurement frequency of the sensors is 20Hz. For the scanning sensor it moves sideways by a servo motor with a constant speed within the range of -20 ~ +20 degrees. Scanning frequency is 1/3Hz. The three basic values from three sensors are obtained almost at the same time. Rules for collision avoidance in the emergency, when a robot is too close to an obstacle or some sensors do not provide distance data for obstacle shape reconstruction, are as shown in Table 1. Zero and 1 refer to beyond the measurement range and within the range, respectively. We assume that the rules in Table 1 are applied only when all sensor values are less than 16 cm from the center.

Table 1. Simple avoidance rules of fish robots

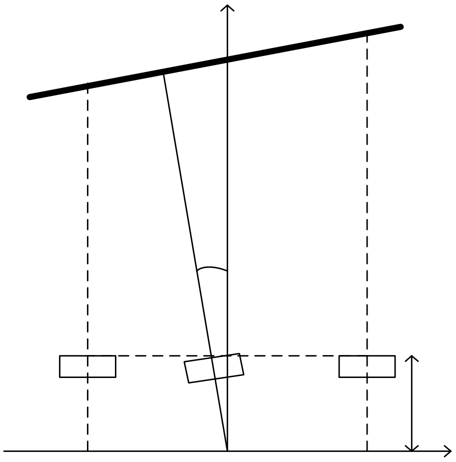
Case	P_L	P_S	P_R	Commands
C1	0	0	0	Move Forward
C2	0	0	1	Turn Left
C3	0	1	0	If α >0, Then Turn Left Else If α <0, Then Turn Right
C4	0	1	1	If θ_R >0, Then Turn Right Else If θ_R <0, Then Turn Left
C5	1	0	0	Turn Right
C6	1	0	1	If $P_L > P_R$, Then Turn Left Else If $P_L < P_R$, Then Turn Right
C7	1	1	0	If θ_L >0, Then Turn Right Else If θ_L <0, Then Turn Left
C8	1	1	1	When α <0, If θ_L >0, Turn Right, Else If θ_L <0, Turn Left When α >0, If θ_R >0, Turn Right, Else If θ_R <0, Turn Left

3.2 Accurate Recognition

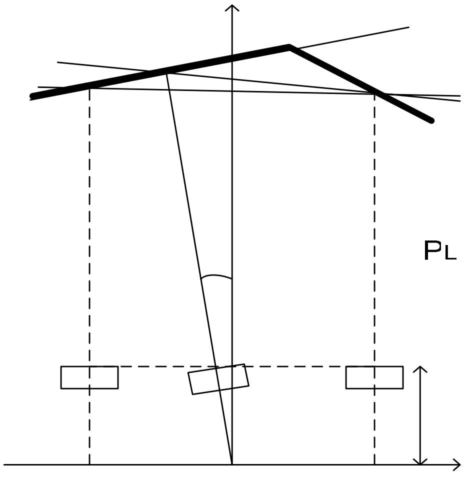
Since shapes vary from obstacle to obstacle, we assume, at first, that the model consists of two planes. Therefore, the reconstructed obstacles always have two ending points and they have one corner point unless it is single sided. This is geometrically calculated from the absolute coordinate values of the reconstructed obstacles. But all the data about the obstacle's structure and approaching angles should be available for a reasonable approximation to obstacle shapes. Figure 5 shows geometric relationships of sensor data for an example of the obstacle.

Let the lines passing through P_L and P_R be **L**, P_L and P_S be **L**L, P_S and P_R be **L**R, and the slopes of the lines be m , m_L , m_R , respectively, The estimations of the plane angle of an obstacle and rotation of an obstacle, distance to an obstacle are made from the measurements of the three IR sensors. The methods such as log-polar map or fft which require vast amount of calculation are not appropriate for a microprocessor located inside a small fish robot.

While a robot is moving there is a considerable level of noise due to waves, vibration of the actuators or the scanning motor itself. Therefore the discrepancy of the scanning sensor data should be compensated using the distance data of the fixed sensors at both ends. We propose a method that transforms the raw shape data from the scanning sensor to the real obstacle shape irrelevant to the rotation and shift of the obstacle using the distance data of the fixed sensors.



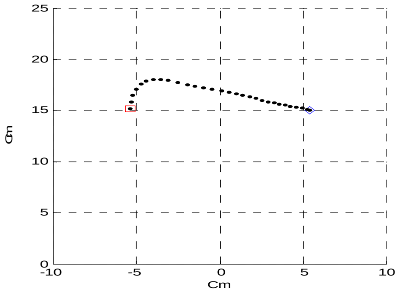
(a) Obstacle without corner



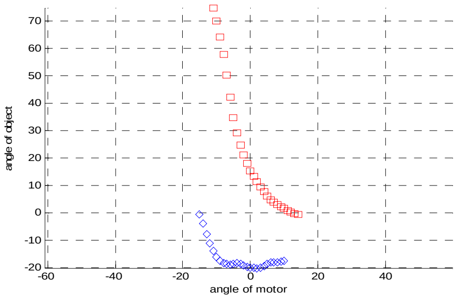
(b) Obstacle with a corner

Fig. 5. Geometry of sensor system for real obstacles

In Figure 6(a), scanned data for an obstacle which has a 90 degree corner is shown in a dotted line. Estimated angles from the far left measurement are denoted by a line made up of squares, and the estimated angles from the far right measurement are denoted by a line made up of diamonds as shown in Figure 6(b). The data denoted in a line of diamonds shows almost constant -20° as the motor angle changes from +11° to -8°. We assume this constant angle to be m_R . The line of squares indicates +74° at the motor angle of -11° and then it drops sharply. We assume the average of the first three angles to be m_L . Therefore, the estimated obstacle angle is about 89°, and the corner point is measured at the average of -11° and -8°.



(a) Scanned data



(b) Estimated angles from left and right end points

Fig. 6. Angles of an obstacle from two left and right points to each scanned point

Figure 7 shows reconstructed results when the obstacle which has 120° is rotated in five different ways.

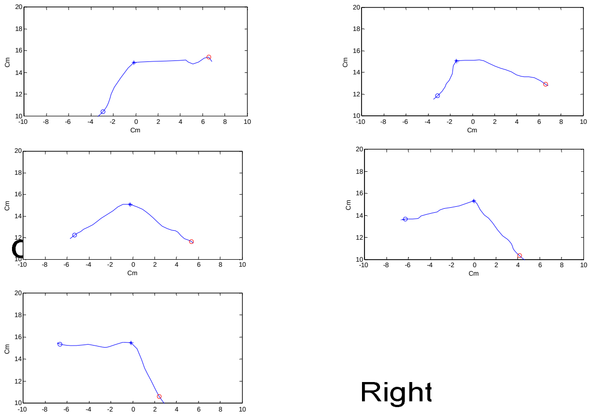


Fig. 7. Reconstruction and feature points of the same angle obstacle in five positions

Y
L
Obstacle
PR
Ps
PL
C
Left
Sensor
SL
Scanning
Sensor
Right
Sensor
SR
Ss
4Cm
-5Cm
0
5Cm
x

In Table 2, estimated reconstructions are obtained for the cases such as the distance of 15cm, the zero degree of rotation, and the degrees of the obstacles are 90°, 120°, 150°, 180°, 210°, 240°, and 270°, respectively. Also, it shows the estimations, in terms of average and standard deviation, of obstacle angles in the first row, and rotation estimation in the second row, for the obstacles with each degree given.

Table 2. Estimation results for various angles of an obstacle (distance is 15cm, rotation angle is 0° and shift distance is 0 cm)

Angle / Error		90°	120°	150°	180°	210°	240°	270°
Angle [°]	mean	0.29	-1.11	3.79	-3.24	-0.57	2.21	4.92
	std	1.85	1.52	1.98	2.65	2.04	1.23	2.83
Rotation [°]	mean	2.54	1.59	-0.12	-4.58	3.33	0.76	1.64
	std	1.04	0.75	0.76	1.12	4.43	1.15	3.38

Table 3. Estimation results of 120° obstacle for various rotation angles (maximum distance is 15cm and shift distance is 0cm)

Angle / Error		30°	15°	0°	-15°	-30°
Angle [°]	mean	-0.51	3.12	1.80	2.48	-2.11
	std	4.99	4.83	2.10	2.00	4.15
Rotation [°]	mean	-0.41	1.31	1.88	1.84	0.74
	std	1.45	2.17	0.81	0.41	0.85

Table 4. Estimation results of 240° obstacle for various rotation angles (minimum distance is 12cm and shift distance is 0cm)

Angle / Error		30°	15°	0°	-15°	-30°
Angle [°]	mean	0.84	0.81	2.59	8.31	8.23
	std	2.73	2.53	1.30	2.74	2.90
Rotation [°]	mean	7.03	4.40	5.51	8.48	4.90
	std	2.54	2.30	0.99	2.98	4.60

Table 3 is the estimation results for various rotation angles when the test obstacle has 120° obstacle angle and maximum distance is 15cm. Table 4 is the estimation results for various rotation angles when the test obstacle has 240° obstacle angle, minimum distance is 12cm.

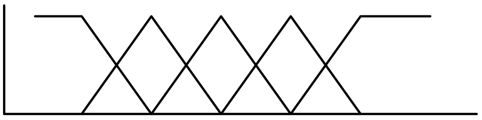


Fig. 8. Membership functions of m_R and m_L

The rules for obstacle avoidance use two slopes, m_R and m_L, and the membership functions are as shown in Figure 8, and the fuzzy rules are described in Table 5. In Table 5, B, F, and S represent Backward, Forward, and Stop of the left and right motors, respectively.

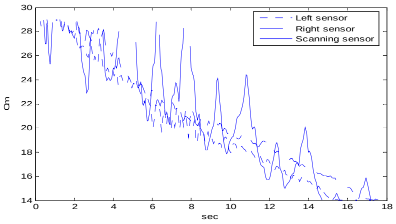
Table 5. Fuzzy rules for obstacle avoidance using m_R and m_L

m_R / m_L	NB	NS	ZERO	PS	PB
NB	Left Small (S,F)	Left Small (S,F)	Left Small (S,F)	Left Small (S,F)	Right Small (F,S)
NS	Left Small (S,F)	Left Small (S,F)	Left Small (S,F)	Right Small (F,S)	Right Small (F,S)
ZERO	Left Big (B,F)	Left Small (S,F)	Right Small (F,S)	Right Small (F,S)	Right Small (F,S)
PS	Left Big (B,F)	Right Small (F,S)	Right Small (F,S)	Right Small (F,S)	Right Small (F,S)
PB	Backward (B,B)	Right Big (F,B)	Right Big (F,B)	Right Small (F,S)	Right Small (F,S)

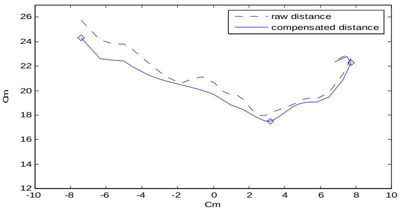
4 Compensation of Robot's Movement

Based on the distance and angle data measured by a scanning sensor when the robot is not in motion, the original shapes of obstacles are reconstructed and their characteristics are analyzed. Robots are moving in real situations; thus, the effect of distance changes during a half cycle should be compensated for the primary data obtained in the static condition. Since the fixed sensors have more reliable data, the average value of each side fixed sensor data is used to compensate the scanned shape data.

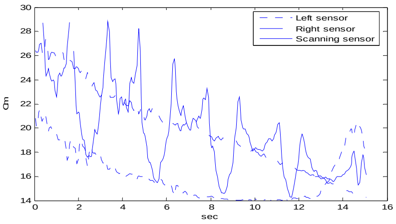
The compensation begins when the minimum distance during a half cycle measurement becomes between 16cm and 20cm. The real-time distance data and the reconstructed shapes of obstacles which have different angles are shown in Figure 9. Figure 10 shows a typical example of applying the proposed method to the underwater robot's passage along the given path in a water tank.



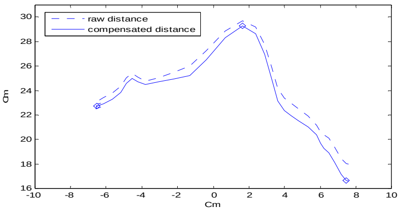
(a) Data of two fixed and a scanning IR sensors



(b) Obstacle shapes in case of (a)



(c) Data of two fixed and a scanning IR sensors



(d) Obstacle shapes in case of (c)

Fig. 9. Distance data and compensation of obstacle shapes for movements

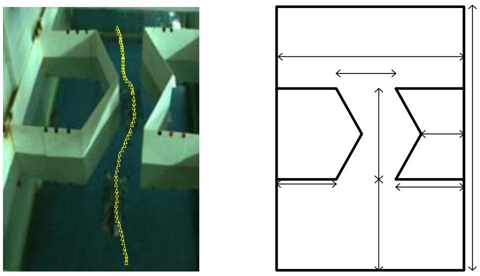


Fig. 10. Example of obstacle avoidance

5 Conclusion

A shape estimating IR distance sensor system, which consists of a scanning IR sensor at the center with two fixed IR sensors at each side is proposed for fish robots. Using this sensor system instead of cameras or sonar proves to be effective in getting the shape pattern information of the obstacles in water for small robots. By analyzing the IR sensor data which has difficulties due to rotation and the speed of the robot, the estimated shapes of obstacles can be reconstructed. Path control for fish robots should be designed based on the estimated results of obstacle shapes. Our experimental results show that fish robots successfully make their movement avoiding collision through the various types of channels.

Acknowledgements

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