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Recognition of Sizes and Angles of Obstacles Using Distance Sensors for Fish Robots

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Abstract: - Obstacle detection and recognition to avoid collision for a natural and smooth movement are the most important concerns for a fish robot. Walls, rocks, water plants and other nearby robots are common obstacles for a group of small scale fish robots and submersibles that have been constructed in our lab. A distance measuring sensor for general purpose use rather than a camera is mounted on a motor shaft to scan a certain range of foreground from the head of a fish robot. The fish robot's ability to recognize the location, size, and the approaching angles to an obstacle is improved to avoid collision based on the scanned information. Evident features of obstacles' sizes and angles are obtained through a neural network training algorithm from the scanned data by a simple distance sensor. Experimental results show the successful path control of a fish robot to go through a passage without hitting obstacles.

Key-Words: - Fish Robot, Obstacles, IR Distance Sensor, Recognition

1 Introduction

Several types of small scale fish robots and submersibles have been constructed in our lab. They have been tested in a tank of 120 x 120 x 180cm dimension for collision avoidance, maneuverability, control performance, posture maintenance, path design, and data communication. Depth control using strain gauges, acceleration sensors, illumination, and the control of motors for fins or screws are processed based on the MSP430F149 by TI. User commands, sensor data and images are transmitted by Bluetooth modules of class 1 between robots and a host notebook PC while fish robots are operated within a 10cm depth. RF modules are used when the depth is larger than 10cm. They are operated in autonomous and manual modes in calm water. Manual operations are by remote control commands in various Bluetooth protocol ranges depending on antenna configurations.

The use of a simpler IR type distance sensor rather than a camera or a sonar module for fish robot's eyes is proposed. A distance measuring sensor for general purpose use is mounted on a motor shaft to scan a certain range of foreground from the head of a fish robot. Simple plane obstacles with various sizes and approaching angles are considered for experiments. Sonar sensors are not used to make the robot structure simple and compact. All circuits, sensors, motors and a processor card are contained in a chassis of 25 x 12 x 16cm dimension.

Successive direction changes of the propulsion are necessary to avoid collision with obstacles. Direction changes of the fish robot are determined on the base of the location, sizes, and approaching angles to an obstacle. The set of information is obtained by a distance sensor that is scanning foreground from the head of a fish robot. From the raw data of the sensor output voltage, a sufficient amount of information can be deduced for obstacle avoidance. Estimated values of the location, sizes, and approaching angles to an obstacle are calculated using a general ANN algorithm. Experimental results show the successful path trajectories of a fish robot to go through between obstacles avoiding collision.

2 Structure of a Fish Robot

The use of a scanning distance sensor instead of a camera module or a sonar system is addressed in this presentation to measure sufficient data about obstacles to avoid collision. A neural network algorithm to estimate important data for direction changes is used. Although the proposed scanning sensor and an ANN algorithm are applied to a simple small scale fish robot, there are many components necessary to do trajectory control, collision avoidance, posture maintenance and communication. Propellers rather than fins are used for a simple structure. One propeller is mounted at the tail for propulsion and a symmetrical pair of propellers is used instead of pectoral fins for horizontal direction control as well as propulsion. Acceleration sensors are installed to measure force changes as well as the posture of the fish body. Schematic diagram and photograph of the fish robot are shown in Figure 1.

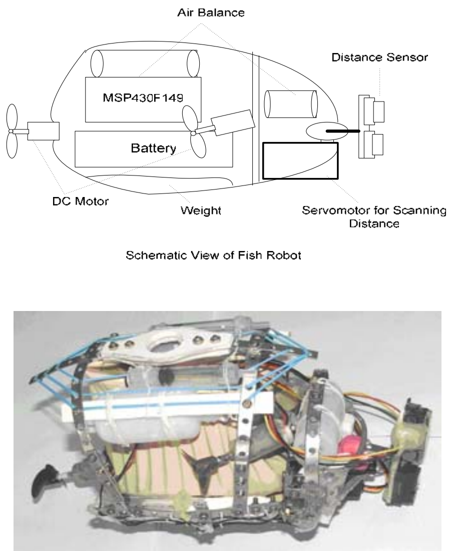

Fig. 1. Structure of the fish robot

2.1 Microcontroller MSP430F149

MSP430F149 is chosen for the microcontroller of the small scale structure with many components to be interfaced since it requires a single 3.3V source while two 16 bit timers, eight channels of 12 bit A/D converters, two USART ports are provided internally. Data from two scanning distance sensors of different ranges, a pressure sensor, two acceleration sensors, control signals to four motors; three for propellers and one for scanning, are processed conveniently using this processor.

2.2 Distance Sensors

One of the most important sensors for the purpose of collision avoidance for a fish robot is a distance measuring sensor to get data from the front tip of a fish robot to nearby obstacles. Distance data are measured continuously at 200 Hz rate by the sensors mounted on the shaft of a motor located at the head of a fish robot. The distance ranges of 4 – 150cm in the air are reduced seriously in the water. Two of short and long range sensors GP2D1xx by Sharp Co. are used. The scanning range of the motor is between -30° and +30° symmetrically. Schematic diagram and photograph of the scanning distance sensor module are shown in Figure 2.

By reading its output voltages while scanning the foreground of a fish robot, detection of location, sizes, and approaching angles of obstacles can be recognized. Signal conditioning and processing are necessary due to time adjustment and serious noises.

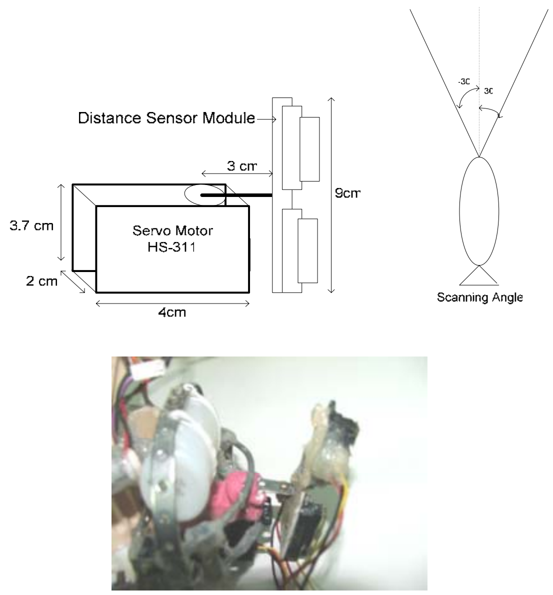

Fig. 2. Scanning distance sensor module

3 Obstacle Recognition

Collision avoidance is the basic problem in control of the fish robots. Thus it is necessary to get enough information about obstacles in front of the trajectory. Based on the analysis of measured data about the closest obstacle, a set of control commands is applied to make direction changes. The most important data are location, size, and approaching angle to a flat

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obstacle. A scanning distance sensor module at the front tip of a fish robot is used to obtain this set of information.

3.1 Obstacle Sizes
The strategy of path changes depends on the sizes of obstacles in front of the moving fish. Turning direction is determined according to the closest free space to swim. Then the direction change to the right side or left side is decided by reviewing the scanned distance data. Figure 3 shows a series of scanned distance data profiles for a flat obstacle at 20cm and 90 degrees away with the width of 5, 10, 15, 20, 25, 30cm respectively. It is straightforward to determine the location of an obstacle and free space from the distance profiles in Figure 3. Scanning starts at -30°, up to +30°, and then back to -30°.

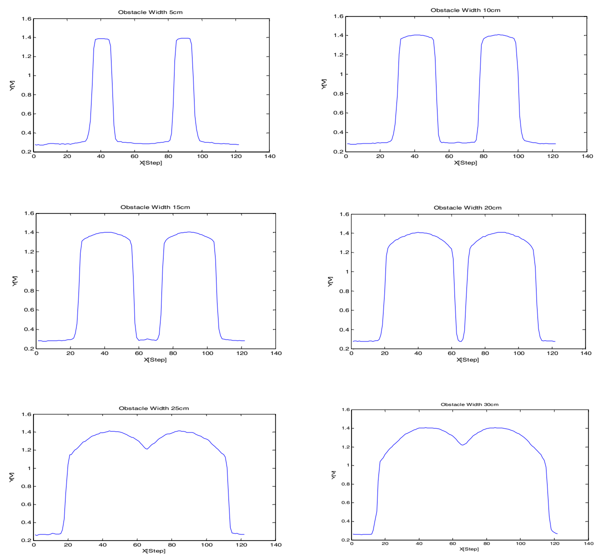

Fig. 3. Scanned distance data profiles for an obstacle (width of 5, 10, 15, 20, 25, 30cm)

3.2 Approaching Angles to an Object
At a fixed velocity, the degree of required turning amount depends on the approaching angles of a fish robot to an object. Thus the estimation of the approaching angles of a fish robot to an obstacle is important to change the propulsion direction properly so that swimming trajectory is modified and a successive collision does not occur.

For the reference of the angle estimation, scanned data about a set of approaching angles to a flat obstacle are established as in Figure 4. Each curve is made with LPF and averaging over several cycles. One cycle of each scan is from -30° to 30°, and then back to -30°. The general shapes of the scanned output voltages as well as the voltage ratios of the values at -30° and 30° reveal the angles to a flat obstacle easily.

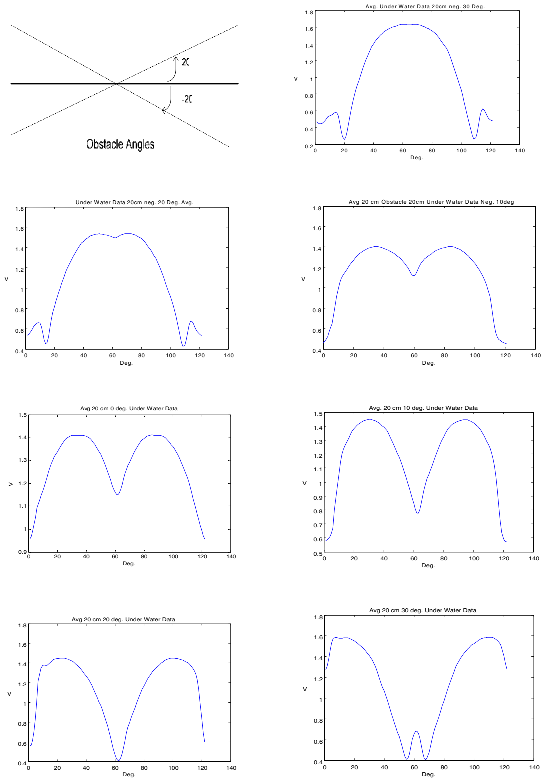

Fig. 4. Scanned voltage profiles with varying angles (-30, -20, -10, 0, +10, +20 and +30°, respectively)

4 Estimation of Sizes and Angles of Obstacles
Both relationship between obstacle sizes and the corresponding scanned data of the distance sensor and the one between obstacle angles and the matching scanned data profiles are evident as in Figures 3 and 4. But, real measurement has a considerable amount of noise. Moreover, voltage magnitudes vary noticeably in the water from time to time. The high noise level and time-varying property of the distance sensor make the estimation not so simple. Therefore, ANN based estimator is used for the size and angle information of an obstacle.

Sets of scanned data, shown in Figure 5, for angles of -30° and 30° as in Figure 4 are used for reference data for conventional neural networks. The estimations of approaching angles are tested for the scanned data of -27°, -23°, -17°, -7°, 7°, 17°, 23°, 27° as shown in Figure 6.

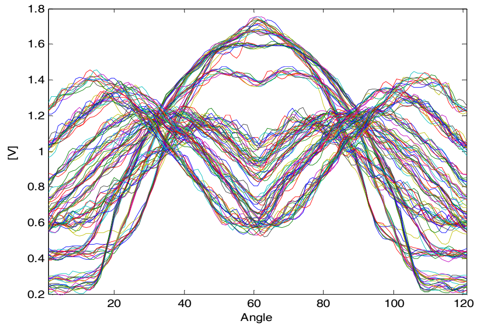

Fig. 5. Reference data for training (-30, -20, -10, 0, +10, +20 and +30°, respectively)

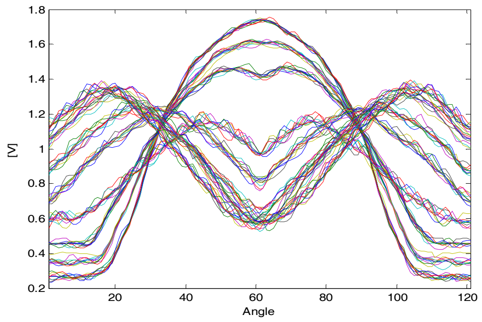

Fig. 6. Test data for neural networks (-27, -23, -17, -7, +7, +17, +23 and +27°, respectively)

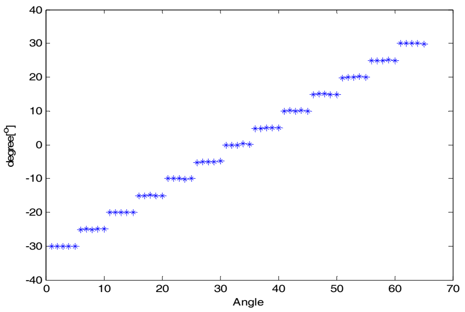

Fig. 7. Estimation results of training data (-30, -20, -10, 0, +10, +20 and +30°, respectively)

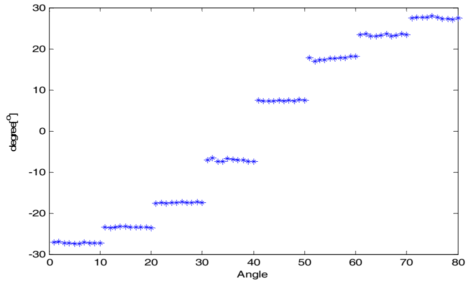

Fig. 8. Estimation results of test data (-27, -23, -17, -7, +7, +17, +23 and +27°, respectively)

The successful results of both sets of data are summarized in Figures 7 and 8. The maximum error and standard deviation for the whole set of training and test data are less than 1° and 0.35.

5 Experiments on Trajectory Control and Results

Experiments of the autonomous path control by a fish robot have been done to show the effectiveness of the proposed scanning distance sensor module to recognize obstacles. It is to find obstacles and a passage between them for a fish robot autonomously based on the proposed algorithms about the presence, sizes, and approaching angles to the closest obstacle. According to the results of the recognition, the fish robot makes its own trajectory control so that it can pass through the way where there is no obstacle without collision.

Simple strategies for the path control of a fish robot are as follows.

1) No detection of obstacles in the scanned range: go straight.
2) Detection of an obstacle and a free space: turn to the direction of the free space.
3) Detection of an obstacle and no free space in the scanned range: turn to the direction of the obstacle according to the approaching angles.

These three rules are basic guidelines of the direction change of a fish robot. The amount of turning direction can be obtained by the ratio of the obstacle range and free space range.

The following trajectories in Figure 9 have been produced from the successively recorded image files for typical examples of passages. The width of the passage is twice of that of fish robot. Figure 10 shows two obstacles in a tank, through which a fish robot should swim autonomously without hitting them.

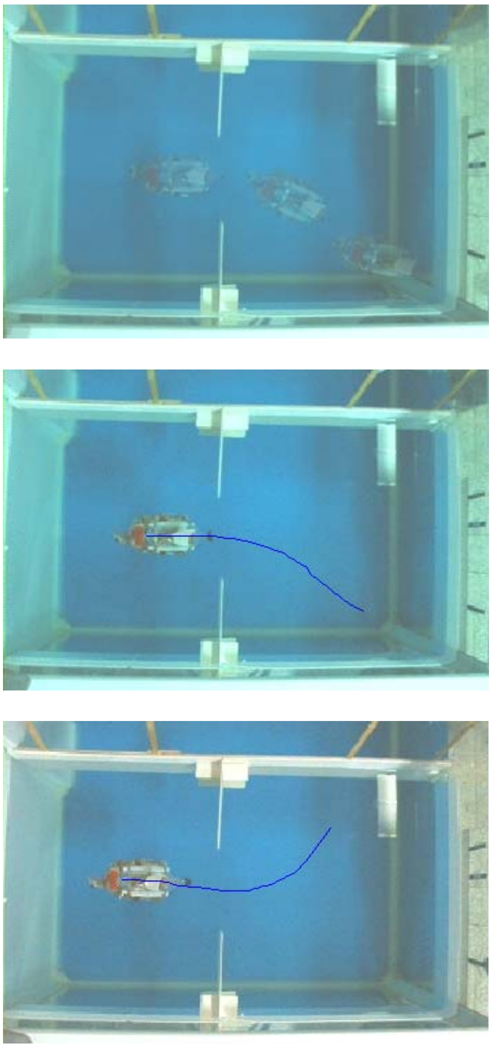

Fig. 9. Obstacles and trajectories of changed paths

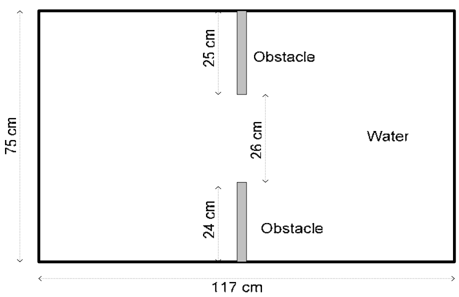

Fig. 10. Obstacles and a passage in a tank

6 Conclusion

A distance measuring sensor is mounted on a motor shaft to scan a range of foreground from the head of a fish robot. The fish robot's ability to recognize the location, size, and the approaching angles to an obstacle is improved to avoid collision based on the scanned information. The features of obstacles' sizes and angles are obtained through a neural network training algorithm from the scanned data by a simple distance sensor. Experimental results show the successful path control of a fish robot to go through between obstacles.

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