FISH DETECTOR AND FISH CLASSIFIER USING EMBEDDED ARTIFICIAL NEURAL NETWORK

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Abstract - Fish finder made by company has already been known and sold commercially. Sometimes fish finder made by company not suit for underwater robotic or submarine robot. The size and the price are not designed for research purposes. The goal of this research is to propose a low cost fish detector and classifier which suits enough to be applied to submarine robot using ping sensor which used to be a proximity sensor in mobile robot. With some precondition in hardware and using Artificial Neural Networks algorithm to detect and classify fish the design has been shown to be successful with maximum value of 100% detection and of 94% classification for two types of fish. Not only the existing and the type of fish can be known, the behavior in group can be revealed by statistically interpretations such as hovering passion and sparse swimming mode.

Kevword*: fish detection. classification. Artificial Neural Network. Ultrasound sensor*

.1. INTRODUCTION

Fish detection was not the new idea; many researches have been done to produces fish detection. They even expand the idea to locate the location of schooling fish [8]. Variety of techniques and algorithms have been tried and implemented, for example using ultrasound based fish finder combined with Global Positioning System. For a fish robot or a miniature submarine, which has limited area for equipments, a simple algorithm and small device has to be found which smart enough but has a light weight.

It is common for fisherman to find fish using fish finder device. Fish finder consists of ultrasonic transmitter and receiver which detect the existence of a group of fish. Certainly, fish finder detects only the fishes themselves. The schooling fish will reflects ultrasound wave from the fish finder and therefore the existence of a group of fish can be identified. Moreover, fish finder can be improved to classify the type of the fish, not just their existence, by adding pattern classification such as Hidden Markov Model, clustering, artificial neural network.

The problems of fish detection are the price and size of device itself. Even fish detection of fish finder is used in a fisher boat not suited for submarine robot which should be small and light enough to carry on. In this research fish detection is performed by detecting small fish type which have behavior to gather or school together.

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2. DESIGNING FISH DETECTION AND CLASSIFICATION

2.1. Fish Classification

There are various methods to classify pattern such as Hidden Markov Model has mentioned before. This method compares the output for interrelated input to state condition as comparing pattern. Some condition states are made before according clustering data. Other method which is easier to train is fuzzy min max neural network classification which combines the fuzzy logic as inferential tools with Artificial Neural Network (ANN) as classification method [1,2]. Input pattern representing the fish type is available as ultrasound echo signal.

The feature extraction tool also becomes the important step to produce successful classification. Some methods of feature extraction are based on time domain, while other methods are based on frequency domain. [5] proposes two type of such feature extraction. In time domain feature extraction some feature is examined such as shape of signal, present of peak, local maximum or minimum, average maximum amplitude and duration. In frequency domain, the feature is attained by firstly transformed time domain echo signal to frequency domain using Fast Fourier Transform. Range of maximum amplitude in frequency domain becomes an observation variable.

Fuzzy logic can also be used as classifier [3] by means of Fuzzy C-means and fuzzy nearest prototype. In this paper detection tool is carried out in time domain. All echo data from ultrasound is extracted to significant feature and then inserted to Artificial Neural Network (ANN)

2.2. Sensory system

Sensory system is made by modified ping ultrasound sensor Maxsonar EZ-1 which familiar in mobile robot as proximity sensor. To make the sensor becomes waterproof, it need protected layer which can transmit and receive ultrasound signal but hinder the water to not flows into sensor. We use a condom as waterproof media and it is quite useful.

The sensor output has three types of data i.e. analog, digital and pwm. Digital data in the form of serial data can be easily attached to other digital port like port microcontroller or port computer. For used with Basic Stamp microcontroller can be shown in Figure 1.

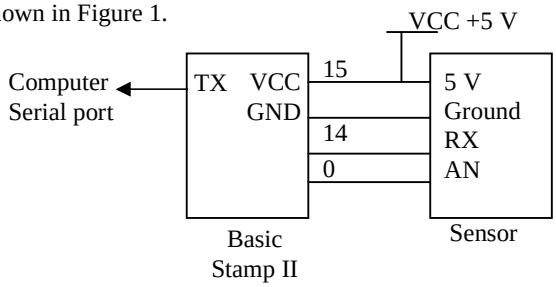

Figure 1. Sensor connection to microcontroller

This sensor is well enough to detect small fish from range 10 cm until 100 cm. It is shorter than used in air caused by uncoupling buffer in condom and water. The sensor will produce echo signal in serial data when any obstacle blocks the signal. A proximity sensor is used so the distance information inside the signal become interfering input to detection system. The problem for feature extraction algorithm described later is to distinguish between fish and other obstacles such as wall and other floating object and compensate the distance information.

2.3. Embedded Artificial Neural Network

Embedded Artificial Neural Network (EANN) is an artificial neural network algorithm which specially designed to suit to be downloaded into microcontroller. The method to apply artificial neural network which all continuous function is simply by making continuous function with discrete series function.

Continuous algorithm in ANN like back propagation algorithm with no hidden layer architecture can be rewritten as follows

$$\vec{y}_j = f\left(b_i + \sum x_i w_{ij}\right) \quad (1)$$

$$f(.) = \frac{1}{1+e^{-\alpha x}} \quad (2)$$

$$\Delta w_{ij} = \alpha \frac{df}{dx}(\vec{t} - \vec{y}) \quad (3)$$

In this case, exponential function in sigmoid function (equation 2) can be represented as follows:

$$e^x = 1 + x + \frac{1}{2!}x^2 + \frac{1}{3!}x^3 \quad (4)$$

III. EXPERIMENTAL PROCEDURES

3.1. General procedures

Experimental procedures were divided into three stages. The first stage consists of data acquisition and preparation of good feature extraction from raw sensory data and in the second stage is learning process which uses artificial neural network as offline supervised procedure using MATLAB toolbox.

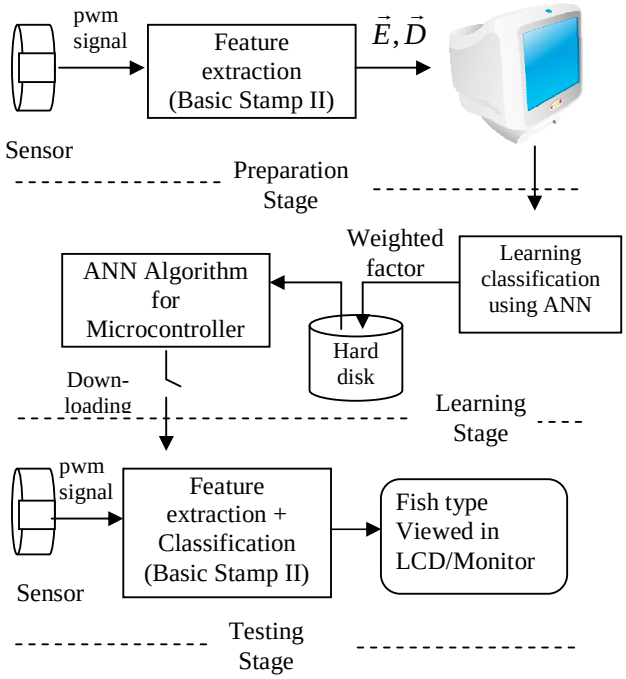

Figure 2. Schematic of fish detection and classification

Feature extraction and data acquisition is being done by microcontroller Basic Stamps II (Figure 2). Microcontroller in preparation stage have role to transfer echo signal sensor to computer. Simple visual basic program can be download freely in [8]. The last stage is testing the detection and classifier algorithm which has been downloaded in EEPROM microcontroller

The sensor remain in a board, rotating shaft allows the board to be rotated in its axes. The rotating mechanism is mounted on fixed thin plywood. Other plywood divides the water in two area, with fish and without fish. To make the fish exist or

not is simply done by rotating a shaft. (Figure 3). If the sensor faces to non fish area it will be conditioned as no fish.

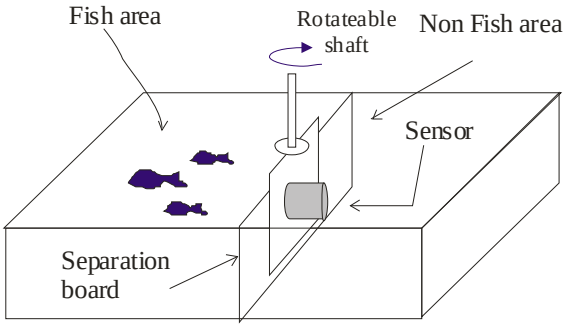

Figure 3. Experiment Setup

The objective of feature extraction is to locate any echo signal which represented the existing of fish i.e. the big amplitude and separated them from raw data as independent signal. Then it is processed by statistical tool like mean or maximum value. The last thing is inserted to Artificial Neural Network as learning tools with α is learning rate=0.1, σ=0.003, t is target vector, f(.) is activation function. The implementation of artificial neural network on microprocessor is done by representing some continuous non linear activation function into a linear-fraction of function.

3.2. Feature Extraction

Feature extraction procedure will process raw data, i.e. echo sensor signal *c(t)* (Figure 4), into some variables by which the existence of fish can be brightly represented and in other side the obstacle which is non fish can be eliminated too.

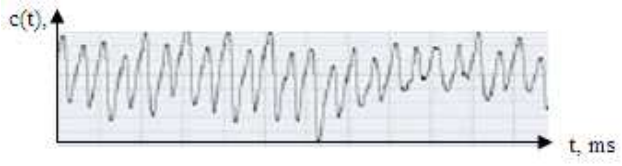

Figure 4. Echo sensor signal *c(t)* obtained by directly connecting ping sensor to computer serial port

Kulinchenko [5] uses the range of minimum to maximum of temporal data as a feature representing fish existence. The technique later called by shape parameter. The shape of the echo provides a great deal of information about the reflecting object. The slope of the echo's leading edge reveals how hard the reflecting surface is. The trailing edge reveals information about the absorption of the echo by the target and the target's resonant structure.

In this paper, the output of feature extraction process is existence vector with size [2x1] and directional vector with size [4x1], they are symbolized as $\vec{E}$ and $\vec{D}$ respectively:

$$\vec{E} = \left[\sum_{i=1}^{N} c_i \; ; \forall c \in [u_k, v_k) \right], \; k = 1 \text{ to } 3 \qquad (5)$$

$$\vec{D} = \begin{bmatrix} \min(\tau) \\ \max(\tau) \\ f_1(d) \\ f_2(d) \end{bmatrix} \qquad (6)$$

with $f_1(d) = \sum_{i=1}^{\frac{N}{2}} d_i \; ; \; f_2(d) = \sum_{i=\frac{N}{2}+1}^{N} d_i$

the value of τ represented the time distance between two neighbor amplitude and *d* is a distance amplitude between two neighbor amplitude, as shown in Figure 5.

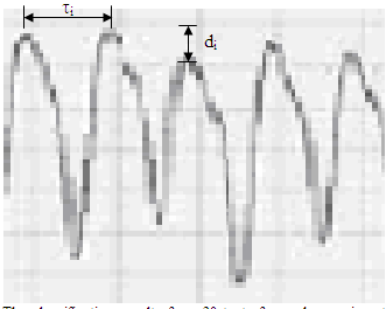

Figure 5. Calculation of τ and d value

3.3. Detection and Classification Procedure

The existence of fish is detected by checking the $\vec{E}$ vector and fish type is detected by inserting the $\vec{D}$ vector, produced by feature extraction, into artificial neural network algorithm. The whole process can be shown in the flowchart shown in Figure 6.

The amplitude value is obtained by recording echo amplitude in multi interval by ignoring fish-swimming direction. Using simple statistics every range is sorted into a table, and subsequently, the detection can be done by using table matching approaches.

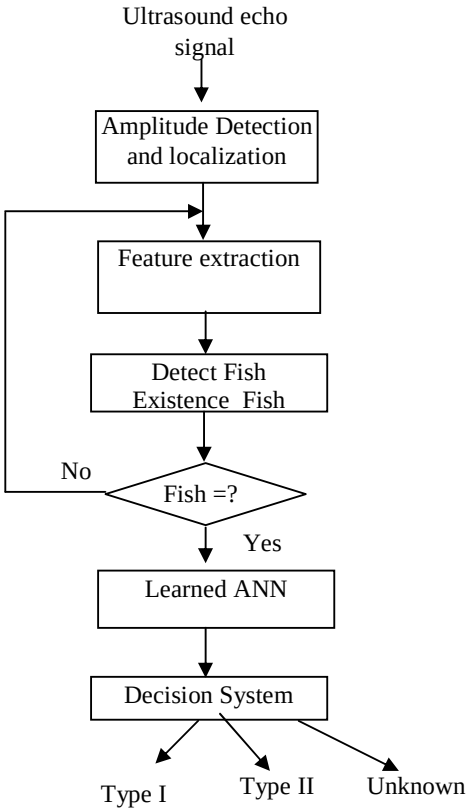

Figure 6. Detection and Classification Procedures

IV. RESULTS

The amplitude range classifier is based on observation about the amplitude range of temporal data which magnitude is being normally in the range of 0 to 1 (Table 1). It should be remembered that this range which represented by $\vec{E}$ vector is also contain information about distances of the fish as the ping ultrasound sensor itself is used to be a proximity sensor. So the amplitude of echo signal measured in this vector is truly represented the distance between sensor and the fish, however, this information is not useful and should not eliminate the main goal, i.e. the information of fish existence.

Table 1. Cumulative amplitude of echo signal

Class	Normally Amplitude range	Number of Amplitude $\vec{E}$
Fish Type I	[0.1 0.3]	10
	[0.3 0.6]	4
	[0.6 0.7]	12
Fish Type II	[0 0.2]	18
	[0.2 0.5]	8
	[0.5 0.9]	0

So the value τ and d in equation (5) are represented the interval time and amplitude difference which represented moving objects. The directional vector $\vec{D}$ can not exactly detect the real fish direction, it only expresses the changing direction caused by fish schooling pattern which approaches near or going far from the sensor.

The number of echo is counted for the same sampling time for each measurement in 1 minute. The range of maximum amplitude and number of (echo) amplitude is the tool to separation process. The range is defined simply by dividing the total range of amplitude into three equal part of percentile gain from 20 experiments. Signal disturbance comes from the edge of aquarium and the wall of aquarium can be eliminated by increasing the starting boundary value and decreasing the final boundary value, respectively

Then, Table 1 becomes a template or match table to detect the existence of fish. Actually the number of amplitude as mention before is represented the variety of distance obtained from schooling fish. These numbers can also represent the change of distance in some certain time which indirectly represents the motion parameter of fish in a group, such as school direction, mobility, randomness and agility.

Using 20 experiment data, the ANN supervised learning algorithm performed in MALTAB program has achieved successful optimization with MSE = 0.1. The weight variable as product of this process is inserted into ANN microcontroller algorithm. Results from 20 real-time tests are shown in Table 2. The successful criteria of the classification are represented in percentage of total test.

Table 2. The result of classification

Fish Type	Detection	Successful Classification from detection
I	90%	94%
II	100%	80%

From this result it can be said that using existence vector $\vec{E}$ and using cumulative amplitude pre-designed table, the designing of low cost fish detection has already been realized successfully. The classification of fish Type II is only 80% and less than that of Type I. It shows than the pattern of direction which is represented by directional vector $\vec{D}$ is more reliable in fish type I. The ANN is easily to have optimization value in tendentious similar pattern or in very non similar pattern. Hence, for the case of fish type II, the pattern of directional vector for each learning samples together do not have significant distinction.

If τ_i and d_i values are listed and variability is determined by using standard deviation, it can be that fish type II has greater values than fish type I.

Table 3. Statistical value of two fish type

Fish Type	Mean		Standard Deviation	
	τ	d	τ	D
I	0,36	0,45	0,001	0,002
II	0,02	0,41	0,3	0,15

As shown in Table 3 the mean value of *d* has almost the same value between two types. It indicates that the average of amplitude neighborhood distance in two types is the similar. In real it means that two groups of fish has tendency to gather in the steady location and has little passion to wander or making hovering swim. Fish type I has mean τ greater than type II it caused by the size of fish type I is bigger than type II so schooling fish type I is detected more often and it is also shown by smaller value of τ-standard deviation. The value of d-standard deviation represents the sparse group of fish. In a group schooling fish type II has sparse swimming mode and has more density (individual per area) than type I.

V. CONCLUSIONS

The result has shown that using existence and directional vector and with some precondition in ping sensor, low cost fish detector and classifier has been successfully designed and implemented. Although some noise has still interfered in echo signal. The experiment has shown 100% detection capability and 94% classification of two types of fish. Furthermore, not only the existing and the type of fish can be known, the behavior in group can be revealed by statistical interpretations such as hovering passion and sparse swimming mode.

In the future research, the variation of mobility and agility can be quantized by observing thoroughly to directional vector. Hence, it can become a good starting point to have complex classification of more than two types of fish. More aggressive fish which has more agility swim will also be detected.

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