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Three Dimensional Measurement of Fish Movement Using Stereo Vision

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Abstract: Recently, the technology of cultivation has been and continuous to be developed in the fisheries and the studies for a high production efficiency are widely conducted. The reaction of fishes under the sound should be studied in order to develop the fish tank with less factors of stress. In this paper, three-dimensional measurement system of the fish motion has been presented in order to study the relation of the fishes under the stimulating sound. Three kinds of fishes are used to detect the reaction against the sounds. Frequency analysis is executed by using the three- dimensional position data.

Keywords: Image processing, Three dimensional measurement, Stereo vision, Fish behavior

I. INTRODUCTION

In recent years, the fishing industry has made considerable advances in aquaculture technology and there has been substantial research to help increase production efficiency. Some of the land-based aquaculture research has addressed the problem of underwater noise, such as that from pumps or the surrounding environment. Underwater noise is considered a source of stress for fish, leading to lower yields and production efficiency. Low-noise type water tanks for use in land-based aquaculture are being developed to eliminate underwater noise as a source of stress. The tiger globefish (torafugu), bluefish, and sea bream are classified as high-class cultured fishes with a premium market value, and offers potentially high profits for the land-based aquaculture industry. It is also known that stress makes tiger globefish susceptible to cannibalism, which can lower yields. Therefore, eliminating sources of stress for these fishes is a pressing problem to be solved.

This paper addresses the relationship between fish behavior and underwater noise as one of the source of stress. To evaluate quantitatively stress experienced by fish, a system was constructed for motion-analysis of fish behavior within the water tank, consisting of an imaging system to measure behavior and an underwater acoustic system to introduce acoustic stimuli into the water tank. The imaging system incorporated a stereo measurement system using two charged-couple device (CCD) cameras.

Three species of fish were used. Based on coordinates of time-series data for fish behavior measurements, frequency analysis of fish behavior was conducted at regular intervals to evaluate changes in their behavior cycle with and without the effect of acoustic stimuli.

The results of the experiment are described below.

II. MEASURING SYSTEM

For this research, measuring system using two-CCD cameras was created in order to conduct three-dimensional analysis of fish behavior. The advantage of an image processing method is that measurements could be taken without making any contact with the fish directly. An algorithm was created to evaluate stress levels related to changes in fish behavior with and without the effect of acoustic stimuli. The schematic diagram of this measurement system is shown in Fig.1.

As shown in Fig.1, a system of two cameras and lighting was set-up in the upper area of the water tank, and three-dimensional measurements of fish behavior were recorded. The two CCD cameras are synchronized and the sampling frequency is 60Hz. The signal from the CCD camera is sent to the frame grabber and digitized as 512*512 pixel intensities. The digitized data is used for the following computer analysis.

From the results of these measurements, in order to evaluate behavior-cycle time variants, time-series motion analysis was conducted and the behavior-cycle of the fish was evaluated.

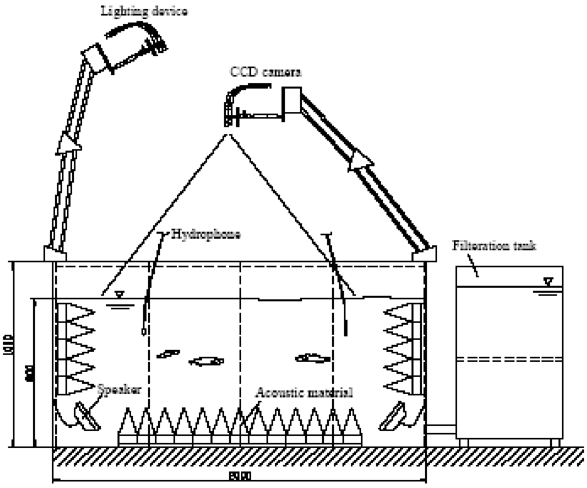


Fig.1 Schematic diagram of measuring system

For this experiment, a running spectrum analysis method was adopted, with the analysis range being shifted sequentially during the course of the analysis.

III. THEORY OF STEREO VISION

The stereo method uses the principle of triangulation, to calculate the depth map of a scene using two-dimensional images from two CCD cameras[1].

The configuration between two CCD cameras and the measuring target is shown in Fig.2.

When the camera's coordinates are (u, v), the lens focal distance is f, and the spatial three-dimensional positions are (x, y, z), the relationship between these variables can be shown using the following formula:

$$\lambda(u \quad v \quad f) = A(x \quad y \quad z) \tag{1}$$

λ : Coefficient, A : Coefficient

which can be displayed as a determinant as:

$$\lambda\begin{pmatrix} u \\ v \\ 1 \end{pmatrix} = \begin{pmatrix} h_{11} & h_{12} & h_{13} & h_{14} \\ h_{21} & h_{22} & h_{23} & h_{24} \\ h_{31} & h_{32} & h_{33} & h_{34} \end{pmatrix}\begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix} \tag{2}$$

Developing this relationship, when λ is excluded, the formulae become:

$$h_{11}x+h_{12}y+h_{13}z+h_{14}-uxh_{31} -uyh_{32}-uzh_{33}-uh_{34}=0 \tag{3}$$

$$h_{21}x+h_{22}y+h_{23}z+h_{24}-uxh_{31} -vyh_{32}-vzh_{33}-vh_{34}=0 \tag{4}$$

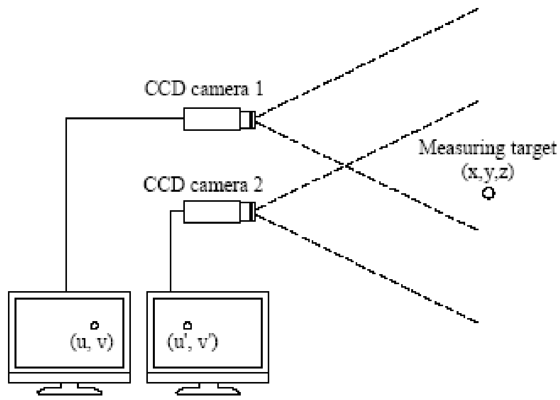


Fig.2 Configuration of the CCD camera system

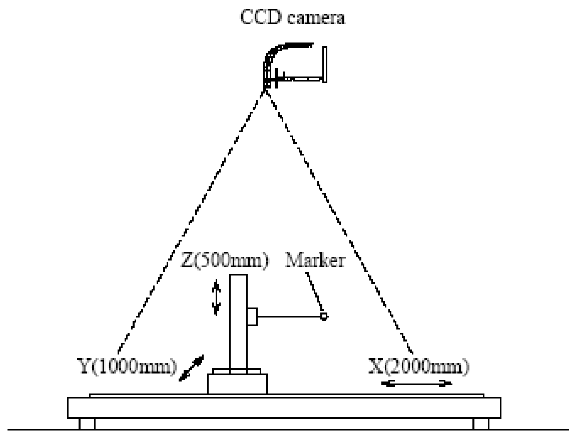


Fig.3 Schematic diagram of calibrating system

When the coordinates for the second camera's time series are (u', v'), equivalent to formulae (3) and (4), the relationship becomes:

$$h'_{11}x+h'_{12}y+h'_{13}z+h'_{14}-uxh'_{31} -u'yh'_{32}-u'zh'_{33}-u'h'_{34}=0 \tag{5}$$

$$h'_{21}x+h'_{22}y+h'_{23}z+h'_{24}-uxh'_{31} -v'yh'_{32}-v'zh'_{33}-v'h'_{34}=0 \tag{6}$$

Camera position calibration is conducted to establish the simultaneous equation parameters h_{11} to h_{34}, and the relationship between (u, v) (u', v') and (x, y, z) is established.

As h_{11} to h_{34} and also h'_{11} to h'_{34} in the above formula are already known, using formulae (3) to (6), the spatial three-dimensional position, (x, y, z), can be established from the two pairs of (u, v) (u', v').

IV. EXPERIMENT

1. Experiment to verify the accuracy of positional measurements

To calibrate the camera position, a three-dimensional traverse device enabling accurate positioning calibration within the water tank was used. The system to calibrate the camera's position is shown in Fig. 3.

A computer program was used for the camera position calibration. A marker attached to the three-dimensional traverse device was moved, the camera images were captured by computer, and the coordinates for the position of the marker attached to the traverse device were entered via mouse and keyboard.

Simultaneously the same traverse device was used, and the arbitrary movements of the position of the marker enabled the accuracy of the measurements to be verified. The results demonstrate that the accuracy of the measurements in the water tank could be achieved to within ±5 mm error at the position of 300mm depth.

2. Behavior measurements

The experiment allowed the fish to move freely in the low-noise water tank while sound collected from within the ocean was played. Fig.4 shows an image of the experiment. Three species of fish were used for these experiments (tiger globefish, blue fish, and sea bream), and the correlation between fish behavior and the effect of acoustic stimuli was analyzed.

The running spectrum method was used for the analysis[4][5]. The analysis is executed upon sliding the interrogation window on time series. The spectrum analysis using the time history data x(t) is expressed as follows.

$$\tilde{x}(t) = \frac{X_0}{2} + \sum_{K=1}^{N/2-1}[X_k \cos(2\pi f_k t + \phi_k)] + \frac{X_{N/2}}{2}\cos(2\pi f_{N/2} t) \quad (7)$$

f : Frequency, X : Amplitude

The response evaluation is executed by the result of the spectrum analysis.

Fig.5 shows measurements of fish behavior when acoustic stimuli of 315 Hz frequency and 10-second duration were introduced. Taking the wall of the water tank as the starting point, Fig. 6 plots the distances the fish moved relative to this starting point. Fig. 7 shows the results of the analysis of the fish behavior cycle.

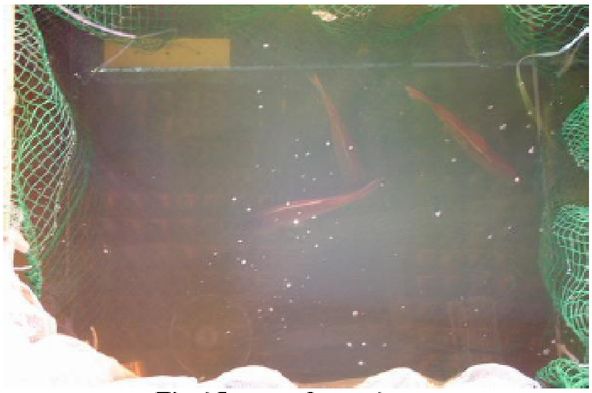
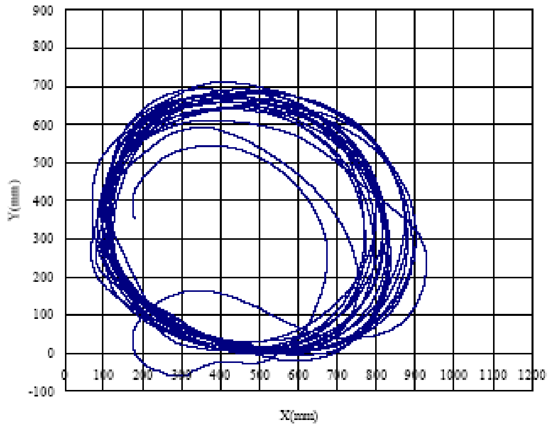
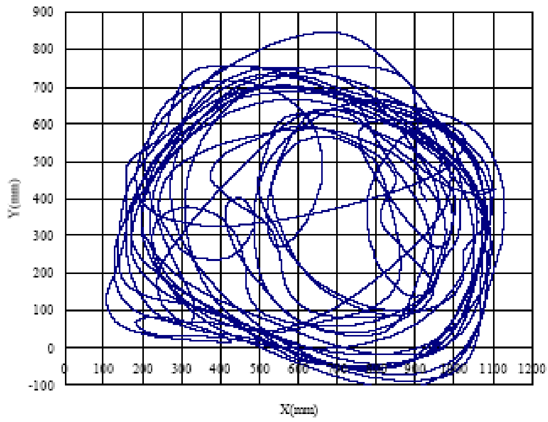


Fig.4 Image of experiment



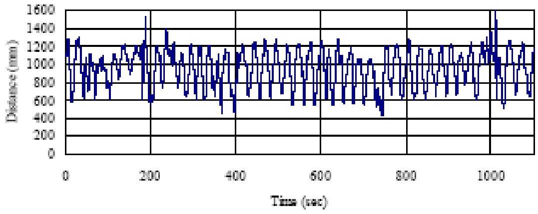
(Bluefish, 315Hz, 500sec)



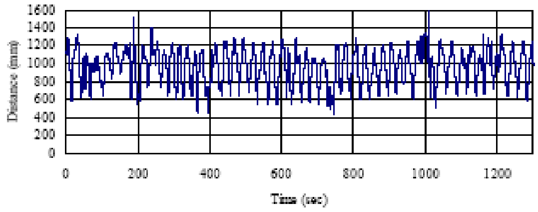
(Sea bream, 315Hz, 500sec)

Fig.5 Measuring result of the motion of fishes

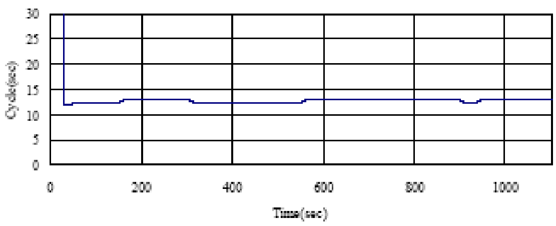
The experiment was unable to determine continuous tiger globefish behavior patterns in the water tank, and a correlation could not be established between behavior and the effect of acoustic stimuli.



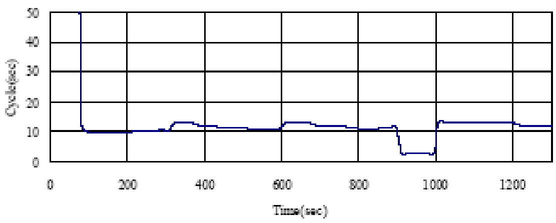
(Bluefish, 315Hz)



(Sea bream, 315Hz)
Fig.6 Moving distance from the wall



(Bluefish, f=315Hz)



(Sea bream, f=315Hz)
Fig.7 Result of the analysis of moving period

Studies of the ecology of the tiger globefish have found that it belongs to the bottom-dwelling family of fish that has developed the so called 'lateral line' friction drive sense organs over auditory senses. Fish with developed lateral line sense organs are said to exhibit a large response to low frequency noise[7][8]. However, observations of the movements of tiger globefish indicate that it belongs to a class of the family of fish that moves slowly. We can therefore infer that tiger globefish belongs to a class of fish which does not exhibit significant behavioral response to external noise. Conversely, it was established that the behavior patterns of striped jack and red sea bream frequently altered in response to acoustic stimuli. They exhibited evasive behavior in response acoustic stimuli, which acted as a stressor to the fish.

V. CONCLUSION

For the purpose of this research, a system was constructed for three-dimensional measurements via computer vision to analyze fish behavior within a water tank for use in land-based aquaculture. Accuracy of positional measurements within the water tank was achieved to within ±5 mm. A frequency analysis of fish behavior was conducted based on the measurements of fish behavior, which made it possible to record any changes in the fish behavior cycle in response to acoustic stimuli.

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