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New method of fish classification by using high-resolution acoustic video camera-ARIS and local invariant feature descriptor

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1. Introduction

In recent decades, fish classification increasingly received attention by not only fish producers but also lots of scientific researchers, because it provides fish farmers with better marketing in polyculture fish farming system, feeding strategies and stock assessment, and it is helpful to fish disease diagnosis. [1] Compared with traditional method, acoustic system is efficient and noninvasive, and it is able to penetrate the aquatic environment over long distance, which is suitable to the fish observation in turbid water.

Acoustic video camera uses higher frequencies and more sub-beams than common hydro-acoustic tools, which improves the image resolution and then enables observation of fish morphology and swimming behavior. [2] Nowadays, fish classification by acoustic video camera is mainly carried out in some indirect ways, such as by fish's acoustic shadow or frequency of fish's caudal fin.

2. Proposed Observation Method

By conventional observation method, ARIS provides 30° x 14° field-of-view for observation. However, in this case, it is hard to get high-quality acoustic images. In this condition, a new observation method was proposed. That is, ARIS was rotated by 90°, and mounted with a 3° concentrator lens. In proposed observation method, ARIS offers 3° x 30° field-of-view beam for observation, which matches well with fish's shape. And then, by proposed observation method, high-quality acoustic image of fish could be obtained. Fig. 1 is comparison of sonar images obtained by conventional method and proposed method.

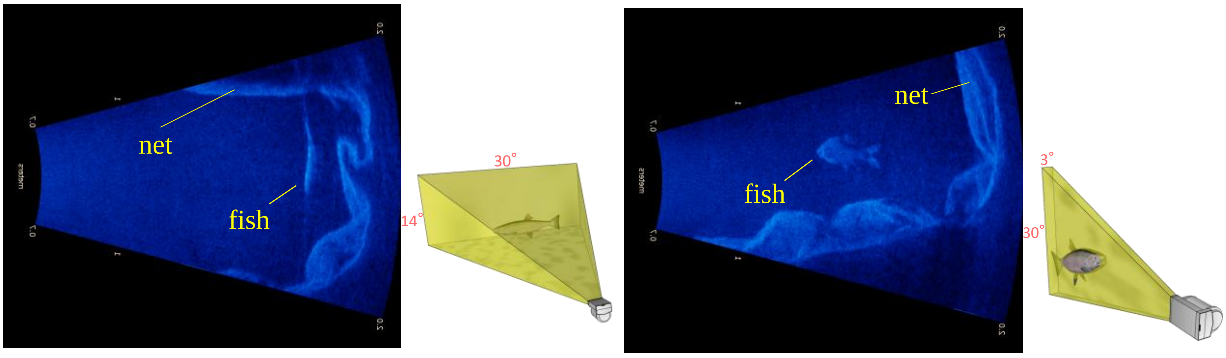

Fig. 1 Comparison of sonar images obtained by conventional method and proposed method

3. Field Experiment I

3.1 Experiment site and settings

ARIS was put into fish tank and set up by proposed observation method. The observation frequency of ARIS was set as 3.0 MHz, and the observation range was about 1.8 m from the imaging sonar. The two-dimensional frame consisted of 128 horizontal beams and 432 range samples. The frame rate was 8 fps.

As Fig. 2 shows, the site of field experiment was a small eutrophic pond adjacent to Izunuma Lake, where latitude is 38.722 degrees north and longitude is 141.092 degrees east, and the water depth was 0.7 meter. The environmental conditions in the pond were similar to those in Izunuma Lake and the observation equipment was easy to set there.

Fig. 2 Experiment site- a small pond fish-tank

3.2 Data processing

4 species of fish were prepared for experiment I. The alive fish samples were measured and then put into fish-tank respectively for observation by proposed method for about ten minutes. Fig. 3 shows the comparison of optical

images of fish samples and acoustic images with proposed observation method by ARIS.

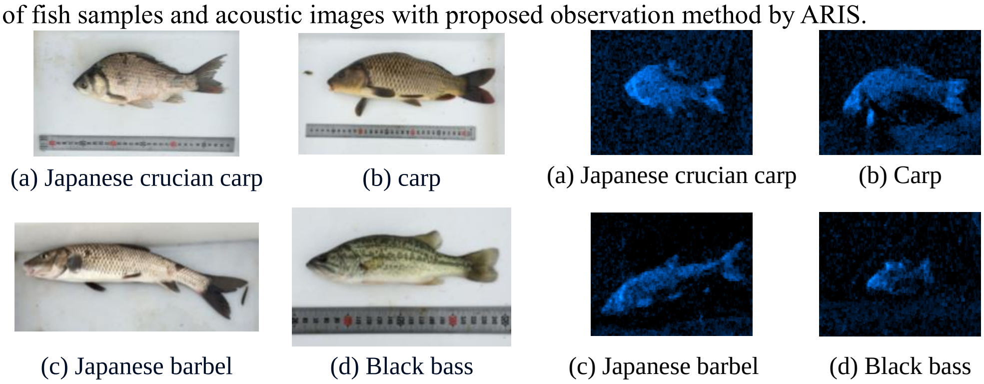

Fig. 3 Comparison of optical images and acoustic images of fish samples

The complete and clear sonar images were taken as the template images to match with the object images afterwards. After that, 10 frames of fish images were chosen as object images for matching. For the raw data, after bilinear pixel interpolation and background subtraction, every pixel whose intensity is below threshold will be treated as noise and set to zero. And then the image of fish will be cut from processed image which is used for template matching, and then NCC and SIFT methods were used for template matching.

3.2.1 NCC method

NCC (Normalized cross correlation) method on fish's template matching has been researched by Asada lab. [3] This method is usually used on template matching for detection or recognition of target in image. The result of NCC (R_{NCC}) is represented as degree of similarity R_{NCC}.

3.2.2 SIFT method

SIFT [4] (Scale-Invariant Feature Transform) method has been developed for optical images' matching for many years. This algorithm has the advantages of being robust to pattern's scale and angle change, which is suitable to template matching between fish. SIFT method mainly includes 4 steps as follows, scaling and detection of key point, localization of key point, calculation of orientation at key point and description of feature at key point.

Position matching between each key point was calculated by using Euclidean distance. As shown in Fig. 4, template of Japanese barbel and object images were matched by SIFT method.

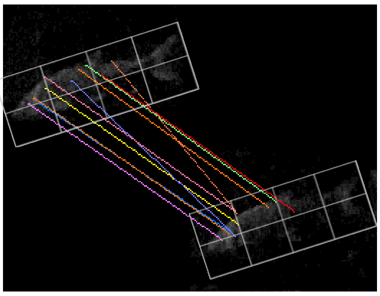

Fig. 4 Template matching of Japanese barbell

3.3 Result and discussion

All matching rates are shown in Fig. 5. For same species, the matching rate of NCC method is 0.70±0.04 and that of SIFT method is 0.80±0.06; for different species, the matching rate of NCC method is 0.55±0.05 and that of SIFT is 0.22±0.08. From the comparison, we can know that the difference of matching rate between correct and other ones on NCC method is 0.15, and that on SIFT method is 0.58. Matching rate's difference between correct and other ones was clearly improved by using SIFT-based algorithm, and therefore it is easier to distinguish same species of fish from others by SIFT method.

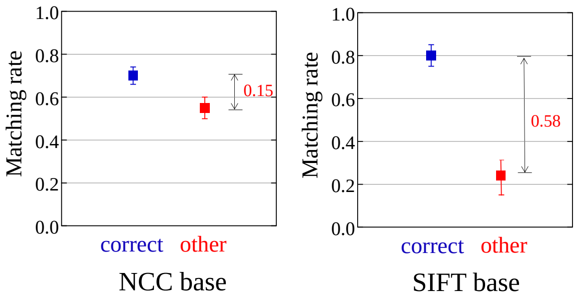

Fig. 5 Matching rate comparison of NCC and SIFT

And then, the matching rate of NCC method and SIFT method were compared when there are scale and angle changes in object images. As Fig. 6 shows, SIFT method is more robust to scale and angle change than NCC method.

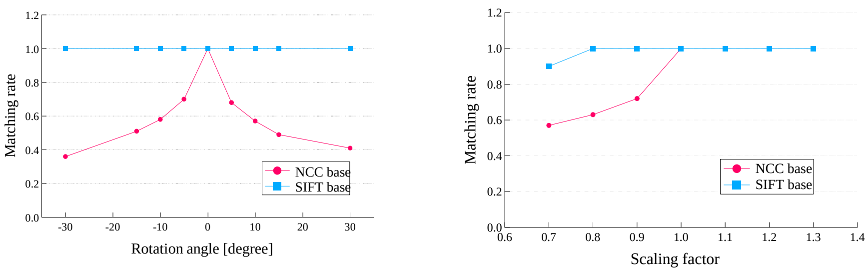

Fig. 6 Matching rate change of NCC and SIFT when scale or angle vary

4. Field Experiment II

4.1 Experiment site and settings

The experiment can be divided into two parts. As Fig. 7 shows, the first part of it was carried out in a fish tank about 200 cm x 80 cm x 60 cm. Optical digital camera was put above the tank to observe the angle between fish and sonar' center beam. Five species of fish were prepared for observation and every fish was observed for about 30 mins, which are Japanese crucian carp, Japanese barbel, snakehead mullet, carp and black bass.

The second part aims to obtain optical images of fish samples in good shape (frozen fish), and observe the fish samples underwater from different angles by ARIS.

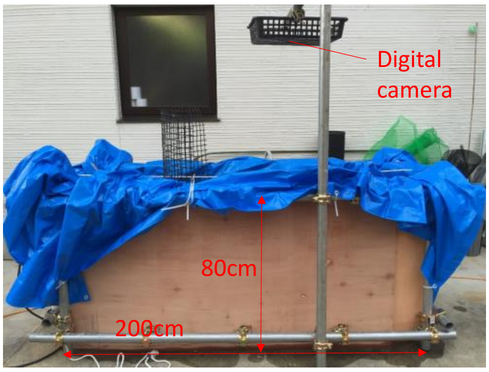

Fig. 7 Fish tank for experiment II

4.2 Result and discussion

Complete and clear images of fish were chosen as template images, 10 object images were chosen at every angle where data were obtained. After that, template matching at those angles were carried out by SIFT method. Fig. 8 shows the Matching rate of different fish individuals on certain angels. After that, the template image of every individual was matched with each other and calculated the matching rate to help consider the effect that individual difference causes in fish classification by SIFT method.

From the result, it can be concluded that except for the matching rate between Japanese crucian carp1 and 6, the matching rate between template images of individuals of same species is higher than 0.60. which means that individual difference will actually affect the matching rate of SIFT method, because even individuals of same species have their own sizes, density, hardness of body and so on.

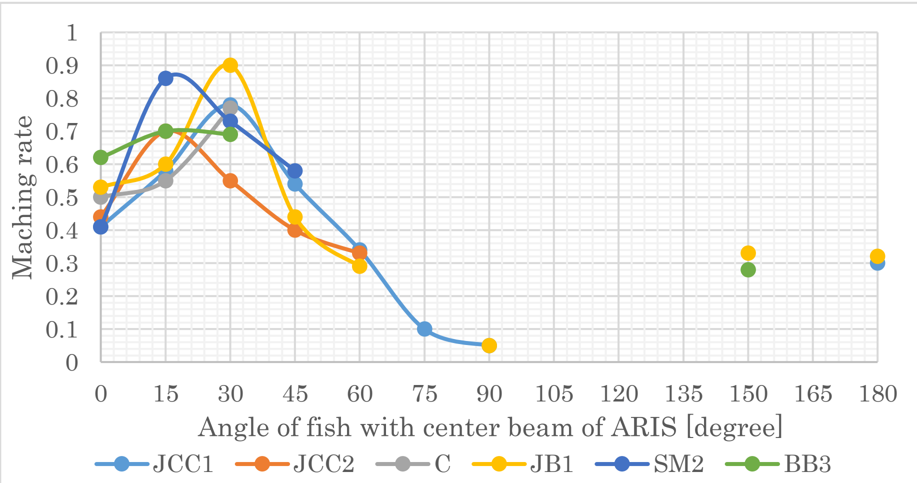

Fig. 8 Matching rate of different fish individuals on certain angels.

5. Simulation

5.1. Theory introduction and parameter settings

Firstly, fish will be considered as a 3-D model of closed curved surface constituted by multiple polygon triangle meshes, which will be fixed in the origin of coordinate system. Acoustic video camera will be consider as a point, which can emit straight lines of every space angle. In this condition, the straight lines emitted by acoustic video camera will cross with the triangle meshes of 3-D fish model. Assuming that straight lines will cross the meshes in the barycenter, through calculating the backscattering strength of every mesh of fish surface, the backscattering strength will be displayed by brightness.

5.2. Construction of 3-D fish model

In the second part of experiment II, optical digital pictures of the fish samples from multiple space angles were taken by digital camera. And then through the software of PHOTOSCAN, dense cloud points' model of fish was constructed. The coordinates of all dense cloud points was exported as .txt file. And then the .txt file was imported by the software of MESHLAB, after the mesh processing, a 3-D model of fish which was constituted by triangle meshes was obtained. Fig. 9 shows dense points cloud model made by PHOTOSCAN, and Fig. 10 shows the mesh model made by MESHLAB.

Fig. 9 Dense cloud points model made by PHOTOSCAN

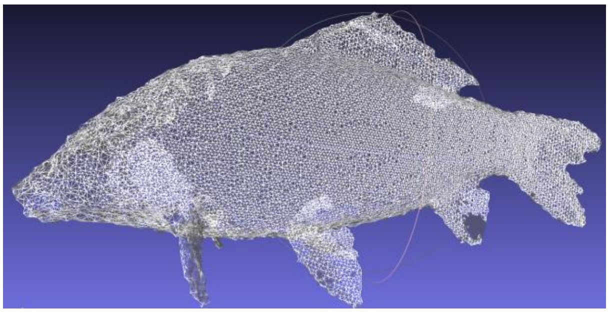

Fig. 10 Mesh model made by MESHLAB

5.3. Backscattering strength

Through parallel move and rotation, the fish model will be taken the origin of coordinate system for convenient operation. And its meshes will cross with straight lines of acoustic sonar at barycenter. Through Formula (3), backscatter of every mesh of fish surface will be calculated. [5] And then simulated images were compared with sonar images. Fig. 11 is a sample comparison of simulated image and sonar image.

$$S_B = 10\log\mu + 10\log(\cos\delta)^2 \qquad \text{Formula (3)}$$

Here S_B is backscattering strength, μ is ratio constant, δ is the angle of mesh's normal vector and the vector from mesh's barycenter to acoustic video camera.

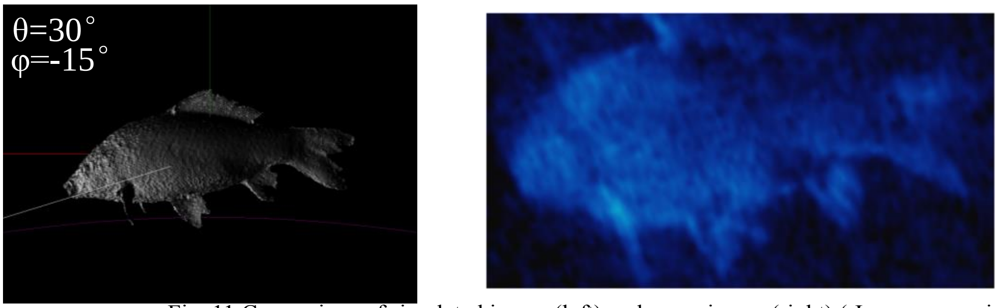

Fig. 11 Comparison of simulated image (left) and sonar image (right) (Japanese crucian carp)

6. Conclusion and Future work

This study researched on fish classification by using high-resolution video camera ARIS and local invariant feature descriptor. In experiment I, SIFT algorithm was applied into acoustic image processing for the first time. High-quality images were obtained by high-resolution acoustic video camera with proposed observation method. And it is known to us that SIFT based image processing method is more robust to angle and scale changes than NCC method, and it is easier for SIFT method than NCC to distinguish fish of same species from others.

In experiment II, corresponding connection between sonar images of fish and its angle with ARIS's center beam were observed, which supports a good hint to the fish classification by acoustic video camera in the future. From the result of matching rate, it is found that the sonar images of fish will be affected by the angle between fish and acoustic video camera's center beam and the extent how much fish's body is inside sonar's beam.

Simulation was done in order to produce simulated images at different angles as template images and to compare with sonar images. As a result, simulated images match well with sonar images in most occasions. However, the simulation does not take the factors of ARIS's narrow beam and fish's acoustic impedance into consideration, and it is still difficult to compared 2-D sonar images with 3-D fish model, quantitative results has not been obtained.

In the future, simulation should be able to generate 2-D sonar images considering the fundamental theory with which acoustic video camera forms images, considering narrow beam of ARIS and acoustic impedance of fish.

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