Development of the three-dimensional visualization method for the inner structure of small size fish using 25 MHz acoustic profile measurement

Masaru Nagaso, Katsunori Mizuno, Akira Asada
Institute of Industrial Science, Tokyo University
Dw-501 4-6-1 Komaba, Meguro-ku, Tokyo, Japan

Kazuto Kobayashi
Honda Electronics Co., LTD
20 Oyamazuka, Oiwa-cho, Toyohashi, Aichi, Japan

Mami Matsukawa
Doshisha university
1-3, Tatara Miyakodani, Kyoutanabe, Kyoto, Japan

***Abstract*—Visualization method using ultrasonic acoustic profile measurement was introduced and inner structures of small size fishes were examined. Detection of external and internal body surface were executed. Two kinds of fishes are chosen in this experiment and measured by using 25 MHz medical probe. Then signal processing and visualization of three-dimensional structure including inner part of the body, abstraction of the skin and organ boundary surface and mapping of reflection signal strength on their surfaces with corrections for surface gradient acoustical loss and scattering attenuation by referring the reflection strength change rate data, relating on the gradient and distance from the probe to target surface. Data for correction was taken from cylindrical silicon model are carried out. Three-dimensional acoustic images are obtained and the result shows that the detection of organs is possible even if these are small size organs of small size fishes. Then the reflection signals from the boundary surface of organs could also be seen clearly. Surface abstraction and reflection strength mapping shows points which has strong hardness and has great change of acoustic impedance. Application for fish species classification by reflection signal amplitude on body surface were tried and its capability was confirmed.**

Keywords—fish species classification; fish; acoustic imaging; ultrasonic; acoustic focused probe;

I. INTRODUCTION

Identification of sex is one of the most important procedures in almost all fish cultural industries, especially if its object fish has high value commercially. Currently, this procedure is carried out with hands of fish farmers, depending on their skills and experiments, especially it becomes difficult when it comes to fluvial salmonids that barely have external sexual characteristics. As described above, sex determination becomes the most significant bottleneck by taking personal cost and the time cost in its productivity improvement. A number of methods by immunological technique [1], [2] were examined. Palpation method [3] was introduced as a simple way which can avoid cumbersome procedures. The ultrasound method has been used for gonadal assessment [4], [5]. But these methods can applicable only after attaining sexual maturity. The sooner sexing is better for optimizing the efficiency. So the methods which can identify a immature gonad or other benchmark are needed. On the other side, driving fishes into a narrow space and touching their bodies, which are needed in these methods, give them heavy stress and cause quality losses [6].

In the field of nature observation and evaluation of natural resources, fish species classification method is needed. For instance, optical methods are adopted [7]. But the methods using optical video camera have problems if the water turbidity is high. Acoustic methods are used for this aim using fish detecting sonar. But it is still difficult to distinguish the slight difference, especially if objects are small size fishes, because of the low frequency sound that instrument's emit that gives low resolution image.

For these reasons, visualization of the shape of fish, organs figures and structure of it by using non-contact acoustic profile measurement was examined. To see the small structure, we used high frequency ultrasonic. Body surface and boundary surface of organs extraction and mapping of reflection signal strength was examined to detect the difference between the sex and species of fish. In this study, immature Char and Seema are chosen for subject of this experiment as a main freshwater fish species that is farmed and stocked for environmental conservation and sport fishing purpose in entire states of Japan as a national policy.

II. EXPERIMENTAL CONDITION

A. *Fishes and experimetnal setting*

Char(Salvelinus:Fig. 1) and Seema(Oncorhychus masou masou:Fig. 2) are subjects of this experiment. Four of each fish species(Table. 1) were measured. Fig. 3 shows experimental set-up. Acoustic focused probe(20-mm focal length, Honda Electronics, Toyohashi, Japan), that transmits ultrasonic pulse with center frequency of 25 MHz, is hold by triaxial controller(Sigma Koki sgSP26-200) and scans for two horizontal axis directions at 1 mm interval. Acoustic wave is transmitted at each scanning spot, and after receiving the reflection wave, AD conversion and recording on PC, through a digital oscilloscope(Tektronix DPO-3054) are executed.

978-0-933957-40-4

Fig. 1. The appearance of Char in immature state.

Fig. 2. The appearance of Seema.

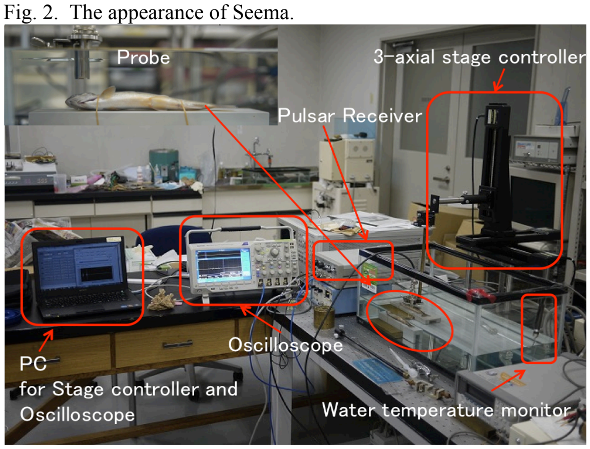

Fig. 3. Experimental set-up.

TABLE 1. List of measurement object fishes

species	***number***	***size (length, height) [mm]***	***condition***
Char	1	145 x 27	postmortem rigidity was recognized
	2	155 x 25	
	3	140 x 25	
	4	145 x 29	
Seema	1	120 x 23	
	2	140 x 26	
	3	116 x 23	
	4	115 x 23	

B. Signal processing flow

Signal processing, described in Fig. 4, is followed before visualizing the figure of fish. At first, offset correction is performed to avoid the effect of offset voltage. And then envelope is abstracted from the magnitude of analytic signal that can be obtained from recorded signal (called B-mode image). Then the entire figure of fish appears by plotting spots that have strong amplitude in reflected signals after a threshold processing, Alpha blending is implemented to see an inner part of the body.

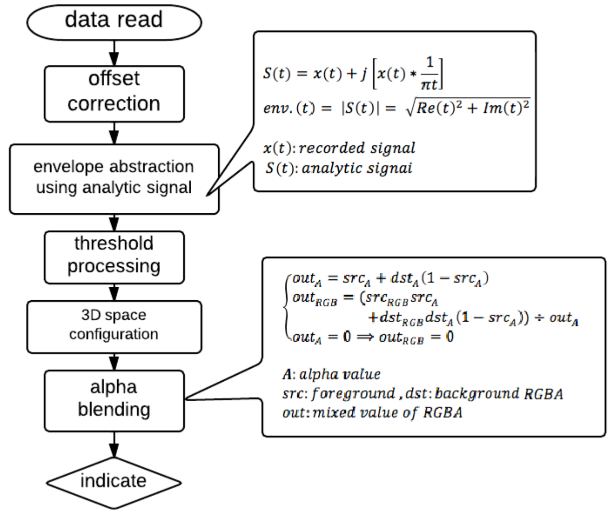

Fig. 4. Signal processing flow chart, and formulas of alpha blending and envelope abstraction.

C. Surface detection and generation surface patches

After three-dimensional reconstruction of acoustic image, the position of boundary surfaces can be abstracted by multipling underwater sound speed to waveform rise time. And reflection amplitude is calculated by integrating the reflection signal. Firstly, body surface extraction was performed. And then Delaunay triangulation(generating triangle surface patches: Fig. 5.) were applied to observe informations on object surface, not as points floating and having space between surrounding points, to see as surface information. So two-dimentional linear interpolation to position data and reflection amplitude is taken place by making triangle sides and drawing color of patches gradationally. Secondaly, boundary surfaces of organs can be extracted as second peak of reflection signal following to the reflection from body surface.The same procedure are examined to this surface.

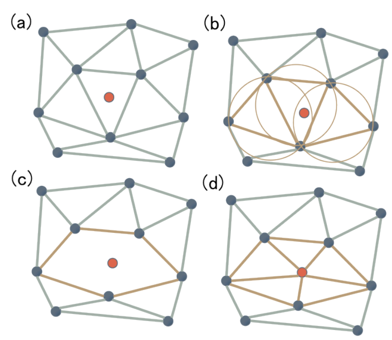

Fig. 5. Processes of Delaunay triangulation.
(a) Add a data point among other points that have already triangulated. (b) Choose all triangles whose circumcircle includes the added point. (c) Polygonal shape is made by them. (d) Make new sides from all vertexes. Continuing this point adding process till the whole data point being added makes entire triangulated surface.

D. Correction of reflection amplitude

Reflection amplitude data acquired in former process include scattering attenuation and effect from gradient of reflecting plane. To measure acoustic characteristics on surface and find differences among fish species or inner organs, these effects are needed to eliminate. For this requirement, correction function was set by measuring cylindrical silicon model with the same setting of fish measurement. Reflection data were recorded from the mid-point of the cylinder's arch (Fig. 6). Normalized values calculated by dividing each reflection amplitude value by the strongest reflection amplitude value are used for correction. Fig. 7 shows this correction function. Dividing data on fish body surface by this function becomes elimination of scattering attenuation and reflection surface gradient effect also should be vanished.

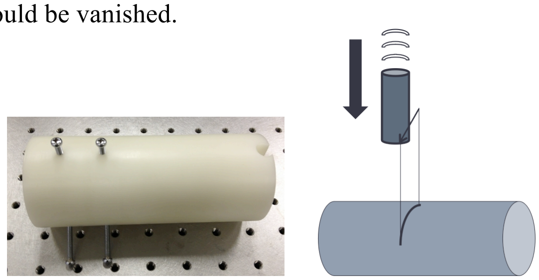

Fig.6. Cylindrical silicon model and measurement method of correction values.

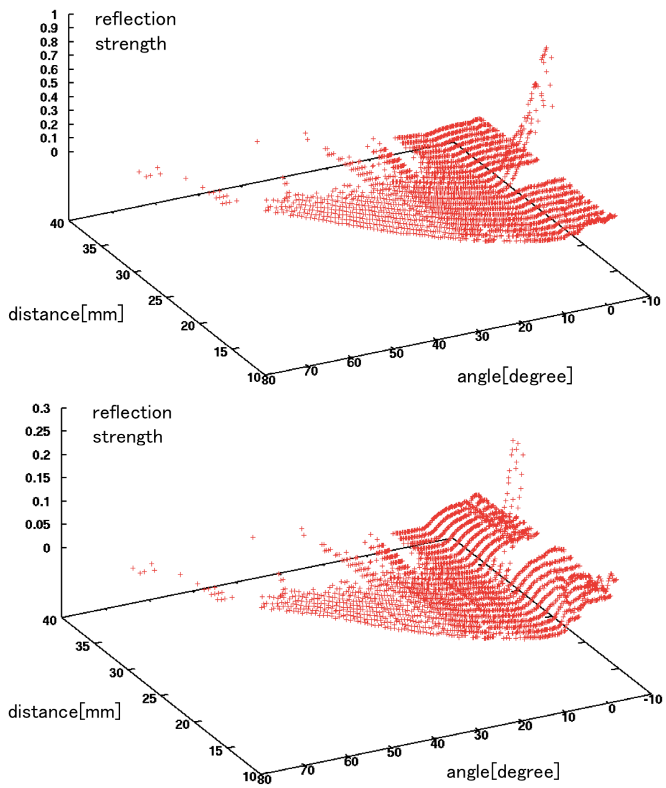

Fig. 7. Correction function plotted with distance from acoustic probe to the surface of object and angle of surface on horizontal axes and normalized reflection strength on vertical axis.

III. Result and Discussion

Fig. 8(a) is the result of B-mode image and (b) is a one of the raw reflection signals chosen from the place considered that multiple kind of organs stack. From the signal, reflections from 3 boundary surfaces are identifiable. Body surface reflects the first peak of signals. And second peak is considered the wall of stomach, and third peak is presumably from gonad or spinal cord. So the capability of this prove that can detect small inner structure was confirmed. Fig. 9 is images that alpha blending was applied partly to the body surface. Three-dimensional structure of organs can see obviously without dissecting their stomach. Spinal cord connecting the head and tail, stomach and air bladder are visible with their acoustic shadow.

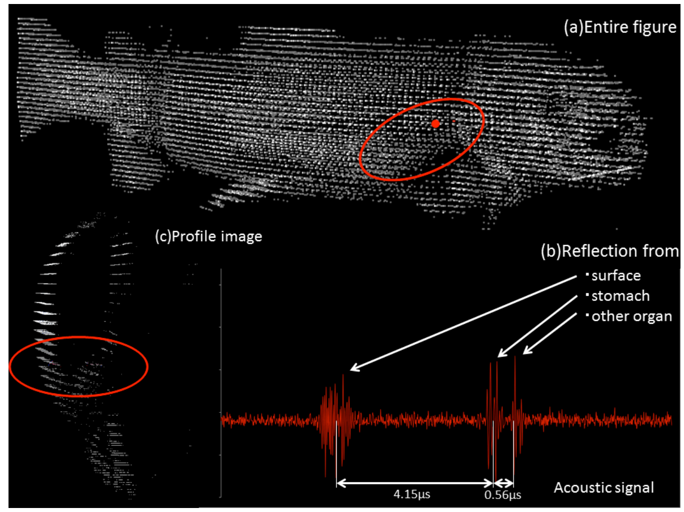

Fig. 8. Entire figure(a), acoustic signal at the red dotted point(b) and profile image(c) reconstructed by B-mode imaging.

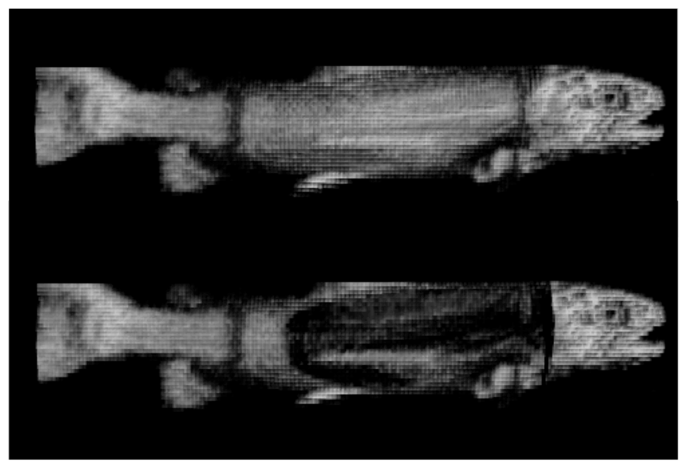

Fig. 9. Image of a Char applied Alpha-blending partly to the body surface.

After extraction of surface nodes (Fig. 10(a)), Delaunay triangulation is applied. There are few triangle patches which includes outlier as one of vertexes. To extract these outliers, threshold processing is done. Normal vector of each triangle patch, the smallest internal angle and length of sides are adopted for threshold values. After this extraction, the next peak point is examined with the same process. This procedure continues till the collect surface is found or the end of the signal time.

Fig. 10(b) is the appearance of the surface data after this process. Drawing these patches results Fig. 10(c) that shows acoustic surface image having three-dimensional coordinate data and reflection amplitude. By taking the same process to the next reflect points located posterior to the body surface, boundary of inner organs can be visible (Fig. 11). From the shape of the surface and reflection amplitude, air bladder appears as a part which returns the strongest reflection and stomach returning the second strongest reflection value.

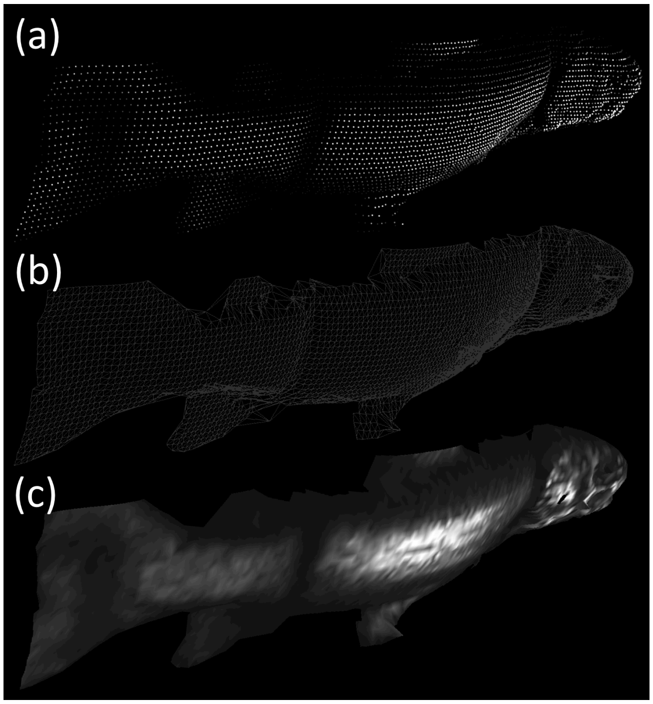

Fig. 10. (a)Extracted surface points. (b)Triangle patches after outliers removal. (c)Drawn surface depending on the reflection strength at each data point.

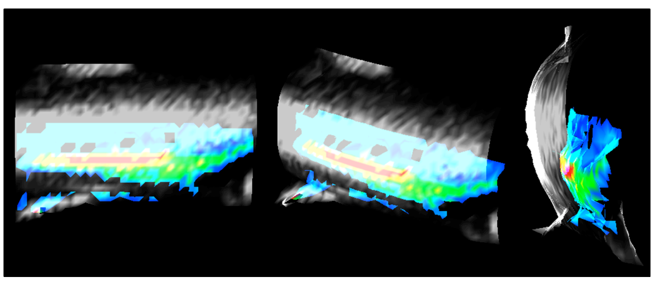

Fig. 11. Extracted boundary surface of organs which shows the characteristic forms and reflection strength of air bladder and stomach. Red part has the most strong reflection amplitude.

To verify the effectivity of this method in fish species classification, numerical comparing at the similer part of body surface for all sample fishs are tested. All reflection amplitude values of each point are summed and averaged at each fish. From the result of this comparison, the small difference of the reflection amplitude value between Chars and Seemas could be seen. The values of Seemas reflection are slightly stronger than Chars. In Fig. 12, correction applied values are plotted. Correction function are applied to the averaged value of distances and surface angles in selected part of the body surface. Correction function are linearly interpolated biaxially. From this result, the differences between Chars and Seemas can understand remarkably. So the classification ability of this method was confirmed.

The capability for sex identification couldn't be evaluated because of the immature state of fishes which don't have recognizable characteristics if it was tried by eye.

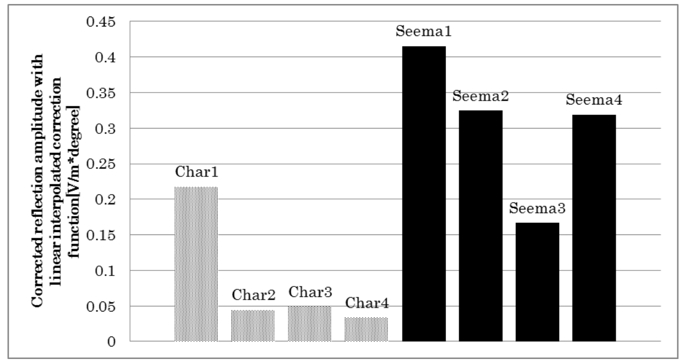

Fig. 12. Averaged reflection amplitude applied correction function.

IV. CONCLUSION

In this study, we introduced a new method for visualizing a three-dimensional structure of small fishes and evaluate its availability for sex identification and species classification. The correction for ultrasonic focal probe was examined by data measured from actual reflection amplitude and its surface information of the Cylindrical Silicon model. Sex identification was not examined because of the situation of tested fishes. The capability of fish species classification was confirmed by comparing the difference of reflection amplitude levels with distance and gradient correction.

For the future study, measurement for the matured fishes are needed to confirm the applicability to sex identification. Surface amplitude evaluation will be applied to inner organs surface to detect gonad or other characteristics by the difference of it.

REFERENCES

[1] David L. Berlinsky, Jennifer L. Specker, "Changes in gonadal hormones during oocyte development in the striped bass, Morone saxatilis", Fish Physiol. Biochem., vol. 9, pp. 51-62, March 1991.

[2] J. C. A. Craik, S. M. Harvey, "A biochemical method for distinguishing between the sexes of fishes by the presence of yolk protein in the blood", J. Fish Biol., vol. 25, issue 3, pp. 293-303, September 1984.

[3] Y.Kano, "Sexing fish by palpation: a simple method for gonadal assessment of fluvial salmonids", J. Fish Biol., vol. 66, pp.1735-1739, June 2005.

[4] Abbas Esmaeili Mola, Hrachya G. Hovannisyan, Rajab Mohammad Nazari, Mahmoudreza Ovissipour, "Early sex identification in cultured beluga (Huso huso) using plasma steroid hormones", African journal of biotechnology, vol. 10, issue 10, pp.1959-1965, March 2011.

[5] Robert E. Colomb,Paul S. Wills,James E. Garvey, "Use of Ultrasound Imaging to Determine Sex of Shovelnose Sturgeon", North American Journal of Fisheries Management, vol 24, issue 1, pp. 322-326, February 2004.

[6] Bruce A. Barton, George K. Zwama, "Physiological changes in fish from stress in aquaculture with emphasis on the response and effects of corticosteroids", Annu. Rev. Fish Dis., vol 1, pp. 3-26. 1991.

[7] Concetto Spampinato, Daniela Giordano, et al., "Automatic Fish Classification for Underwater Species Behavior Understanding", Proceedings of the first ACM international workshop on ARTEMIS, pp.45-50, 2010.