Experimentation for development of Underwater Acoustic Video Camera: in experiment dock

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Abstract- **Ocean resources exploration and underwater works using Remotely Operated Vehicle and Autonomous Underwater Vehicle increase interest, and a techniques of underwater image with acoustic has become a significant concern. Therefore, a development of new underwater acoustic device adapted to ocean resources exploration and underwater works. In this study, we experiment with the use of acoustic video camera for development of a new acoustic video camera and software to meet ocean resources exploration and underwater works needs. The experiment was performed by means of an acoustic video camera, underwater teleoperated excavator, underwater crawler, and simulated chimney. High spatial imaging and software were developed for this experiment and they were used to generate 3D views, to display an operation views and measurement distance of targets. Our results will be necessary for the ocean resources exploration and underwater works.**

Keywords—Real-time 3D imaging, Ocean resurces exploration, Underwater works

I. INTRODUCTION

In recent years, ocean resources exploration and underwater works using Remotely Operated Vehicle (ROV) and Autonomous Underwater Vehicle (AUV) increased interest, and a techniques of underwater image with acoustic has become a significant concern [1]. We developed the Underwater Acoustic Video Camera as a simultaneous real-time 3D imaging and measurement for operation and maintenance of port and breakwater in the past time[2]. However, Underwater Acoustic Video Camera for exploration with ROV needs improvement in weight saving, downsizing and acoustic performance such as resolution, view angle and visual range [3]. In this study, we experiment with the use of acoustic video camera for development of a new acoustic video camera and software to meet ocean resources exploration and underwater works needs.

II. FIELD EXPERIMENT MATERIALS

A. Experiment site

The field experiment was conducted from February 23th, 2015 to March 3th, 2015 at the Yamanouchi dock owned by The Kanto Regional Development Bureau. Panoramic view of the dock is show in Fig.1. The dock size is 100 m in length, 30 m in width and 6 m in depth of sea water.

Figure 1. Panoramic view of the experiment area. The experiment area was conducted at the Yamanouchi dock. The dock size is 100 m in length, 30 m in width and 6 m in depth of sea water.

B. Underwater Acoustic Video Camera

The Four-dimensional Wide-angle Imaging and Surveying SONAR (4-DWISS) developed by Port and Airport Research Institute was a type of imaging sonar, simultaneously visualizes and measures wide area three-dimensional space in real time. 4-DWISS used for operation and maintenance of port and breakwater [2].

The Underwater Acoustic Video Camera which was used in this experiment is show in Fig. 2. This acoustic camera developed through 4-DWISS for obstacle avoidance by Hitachi, Ltd. Specifications of the underwater acoustic camera show in Table. 1. This underwater acoustic camera transmits 500 kHz (low frequency) to 1 MHz (high frequency), and provide 64 degree (horizontal angle) and 34 degree (vertical angle) field of view. Visual distance of underwater acoustic camera is 30 m, and frame rate is 20 Volumes / s. Acoustic camera was reduction in size and weight by adopting Luneberg lens [4].

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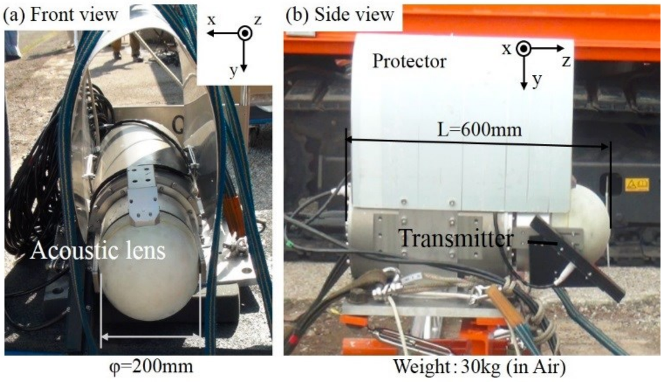

Figure. 2 Front view (a) and side view (b) of underwater acoustic camera.

Table. 1 Specifications of underwater acoustic camera

	This study
Frequency [kHz]	500 - 1000
Beam number	64(H) x 34(V)
Range [m]	5 -30
Range resolution [m]	0.256
Update rate [frame/s]	20 (Max.)
Field of view [deg]	64(H) x 34(V)
Beam width [deg]	1 x 1 0.35m*
Pixel size at object plane [m]	0.35m*
Size [m]	0.60 x 0.2Φ
Weight [kg]	30
Capacity to resist pressure [m]	-100

*: Visual distance is 20 m.

C. Remotely Operated Vehicle

The experiment was conducted using 2 types ROV, were underwater teleoperated excavator (ROV-1) and deep sea crawler type robot (Deep Crawler, ROV-2). ROV-1 is shown in Fig. 3. ROV-1 was reconstruction of 0.1 m^3 class mini excavator attaching proportional-type electric control valves for hydraulic power, valve drivers, potential maters for joint angles and reaction force sensor [5]. ROV-1 was operated by electric signal at onshore controller. Behavior of ROV-1 were displayed on onshore controller at these sensor information. ROV-2 is shown in Fig. 4. ROV-2 developed for ocean resources exploration by Toa Corporation, and equips capability of working in the deep sea 3,000m depth and narrow places.

D. Targets

As shown in Fig. 5, targets of experiment were ROV-1, simulated chimney and acoustics refractor for correcting 3D images of quasi ocean resources exploration. Simulated chimney was constructed from three drums which were covered by gravel for restricting specular reflection from surface (Fig. 5(a) and Fig. 5(b)). Size of simulated chimney was 2.7 m of height and 0.6 m of diameter. An acoustic marker is shown in Fig. 5(c). Acoustic marker was corner cube type, and size was 0.5 m height and width.

Figure. 3 The underwater teleoperated excavator (ROV-1).

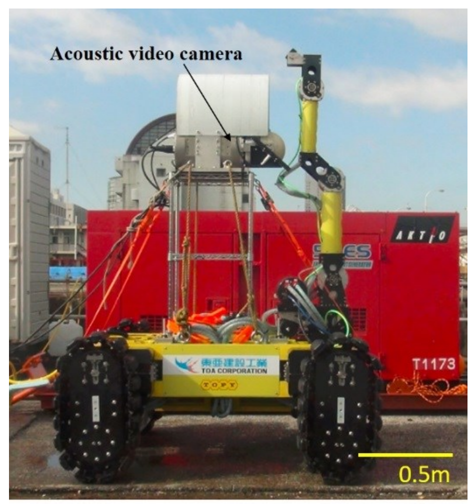

Figure 4. The deep sea crawler type robot. The acoustic camera unit was mounted on the underwater crawler and it was horizontally angled with horizontal surface.

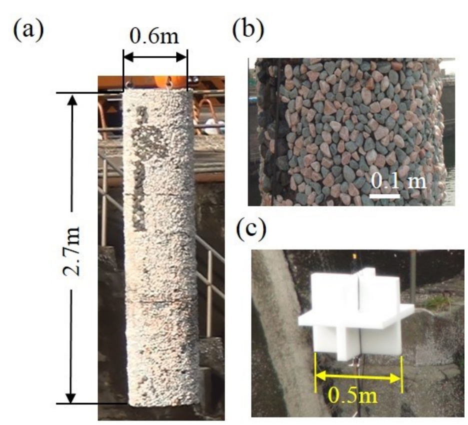

Figure 5. Targets for acoustic imaging. (a) The simulated chimney. (b) Surface of simulated chimney. (c) An acoustic marker.

E. Experimental setting and experimental methods

As shown in Fig. 6, simulated chimney, acoustic marker, ROV-1 and ROV-2 with mounted acoustic video camera set into the dock. Simulated chimney was positioned at 10 m from dock wall, and acoustic marker was strung at 2 m from simulated chimney. After positioned target, ROV-2 has been into the dock, and has guided to the simulated chimney and acoustic marker in view by visual contact. After fixed shooting position, ROV-1 has guided to view of acoustic video camera. At this time, arm of ROV-1 has uplifted for surface and swivel 60 degrees from direction of movement. Captured 3D images of this experiment was run 3 types moving of ROV-1, were approached simulated chimney, moving arm, swivel body. The data were collected at a maximum range of 30 m from acoustic video camera and 20 volume rate. Continuous volume images were captured while mobbing ROV-1 and about 5000 volumes were captured during this experiment.

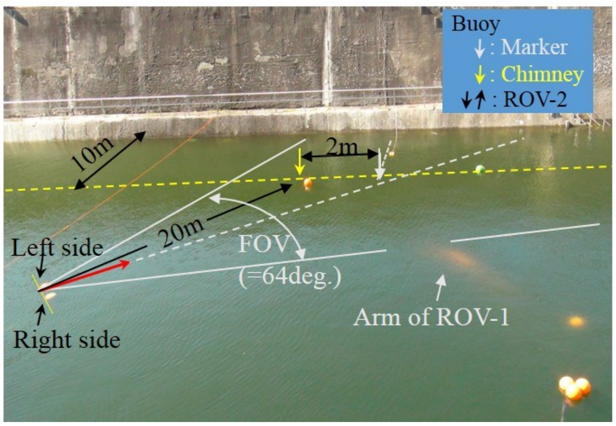

Figure. 6 The experimental setup. A position of ROV-2 and acoustic camera are located under the two black arrows. An acoustic marker and simulated chimney positon are located under the white arrow and yellow arrow.

III. IMAGE PROCESSING AND DATA ANALYSIS

A typical 3D image of reconstructing acoustics data is shown in Fig. 7. The simulated chimney, ROV-1 and an acoustic marker are visible. We developed software for 3D images such as Fig. 7. This software was highly suitable for this examination to reconstruct 3D images view, displaying operation view and measure distance of target from Rov-1.

A. 3D visualization

Detailed flow on reconstructing 3D image method is shown in Fig. 8(a). The data always represents the backscatter echo information from targets in 3D space. The raw data was constructed three data of strong backscatter echo position into each acoustic beam data. At the first, a voxel with an intensity below the noise threshold was treated as noise and set to zero level (voxel color is black), whereas other voxel were normalized an intensity. The threshold was determined based on the background noise level via a GUI and noise was eliminated from the raw data. At the next, coordinate transformation from the raw data to 3D space was performed by view angles and voxel expansion. Finally, color was added to the voxel with intensity rate and a 3D view was generated.

B. Operation view and measure distance of target

In the ocean resources exploration and underwater works, operator of ROV guides to destination and works in low visibility. Far filed visualization and into the low visibility fields become quite important an acoustic images. Therefore, we developed a representation methods for guiding ROV. The representation methods have accomplished by redirection of viewing point and measurement distance of target. The flow of operation view and measuring distance are show in Fig. 8 (b) and (c). Generation of operation view was identical with flow of 3D visualization from color printing. Operation view is view from predetermined view angles and is coordinate transformation from 3D to 2D space. In this experiment, we generated 2 types operation view of front view and birds-eye view. Measuring distance was identical with flow of operation view from 2D coordinate transformation. After 2D coordinate transformation, a pixel was treated as zero intensity to zero, whereas other pixels were set to 255, and a black and white binary image was obtained. The erosion and dilation were performed using 3 × 3 mask at binary image. Isolated pixels were eliminated and separate pixels were connected. Finally, we discerned targets using labeling method and measured distance using labeling information.

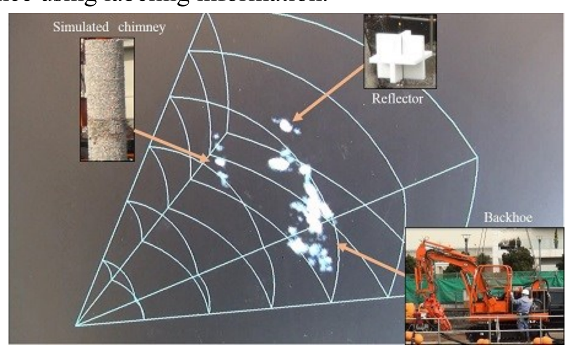

Figure. 7 Typical 3D view. The color was shaded black to white by voxel intensity. Wireframes are separated 5 m distance.

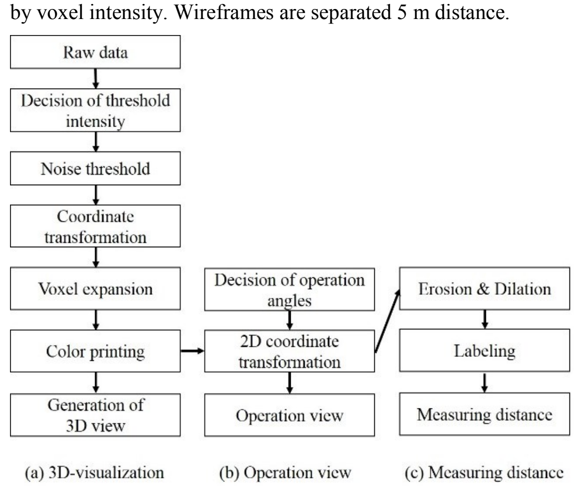

Figure. 8 Schematic diagrams of the image processing and data analysis. (a) Steps with the generation of 3D views. (b) Steps with operation views. (c) Steps of the measurement distance.

IV. RESULT AND DISCUSSION

Typical 3D views of targets were show in Fig.9. The color was automatically set to blue from black using intensity rate. Fig. 9 (a) was seen of ROV-1 approaching to chimney and Fig. 9 (b) was seen of moving arm of ROV-1. Targets are visible and targets distance from acoustic camera proved about 20 – 25 m of 3D views. These figure captured the entire picture, however detail shape of targets were difficult to capture. This is because the real-time 3D image was reconstructed from low resolution data, where the resolution affected the image quality. An acoustic camera was captured high resolution view of targets, because this 3D views were used to get for perceived as targets, works information and around information.

Operation view were shown in Fig. 10. Fig. 10(a) is front view and Fig.10 (b) is top-down view of operation view. The color of this figures were automatically set as Fig.10. A front view was generated at generally angle of acoustic camera. A distance of simulated chimney and ROV-1 was measured using this figure, a horizontal distance was 2.7 m. A top-down view was generated at view angle from surface. This view was received depth position of targets and swivel angles of ROV-1. Horizontal position and depth position was received from a front view and a top-down view and the correct relative position was received 2 types view.

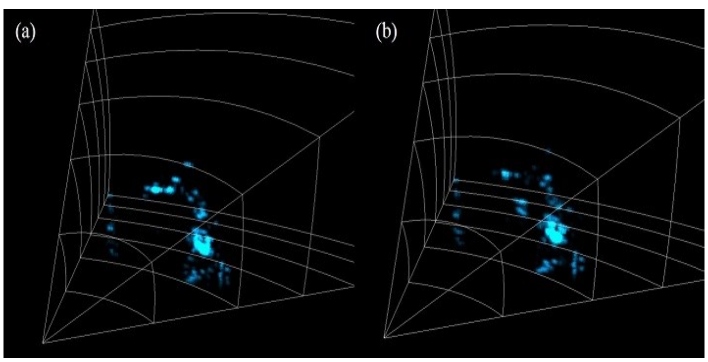

Figure. 9 Typical 3D views of targets. The color was automatically set to blue from black by voxel intensity. (a) A seen of ROV-1 approaching to chimney. (b) A seen of moving arm of ROV-1.

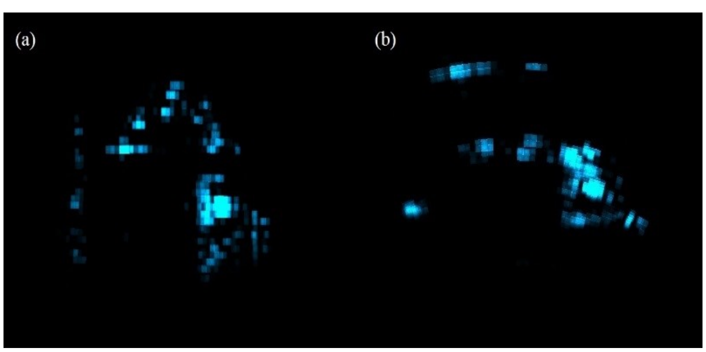

Figure. 10 Operation view. (a) A front view from the acoustic camera. (b) A top-down view at view angle from surface. The color was he color was automatically set to blue from black by voxel intensity.

In this result, we focused on 3D and 2D imaging methods and viewing, however an acoustic video camera had improved points, they are low resolution, narrow angle of view, and reduction in size and weight. In this future, we will develop a new acoustic video camera based on knowledge of this experiment for ocean resources exploration and underwater works.

V. CONCLUSION

In this study, we experiment with the use of acoustic video camera for development of a new acoustic video camera and software to meet ocean resources exploration and underwater works needs. High spatial imaging and software were developed for this experiment and they were used to generate 3D views, to display an operation views and measurement distance of targets. Our results will be necessary for the ocean resources exploration and underwater works. We focused on 3D and 2D imaging, however the acoustic video camera was estimated low resolution and narrow angle view in this experiment. In the future, we will develop the new acoustic video camera based on knowledge of this experiment.

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