Multi-legged ROV Crabster and an acoustic camera for survey of underwater cultural heritages

Preliminary performance experiments in sea

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Abstract—**In west coast of Korea peninsula, there are some offshore sites where ancient sunken shipwrecks have been discovered. These ships are supposed to carry an amount of artifacts what show lifestyle and culture of the day. In these areas, however, because of fast ocean currents and low visibility, underwater survey and excavation by divers are strictly restricted. Especially, optical cameras and human's visual inspection become defective. To overcome these conditions, use of unmanned underwater vehicles such like a ROV(Remotely Operated Vehicle) which is equipped with acoustic imaging devices has been raised. This paper describes preliminary performance experiments for survey of underwater cultural heritages using a ROV whose name is Crabster driven by six artificial legs with a high-resolution acoustic camera in sea. The Crabster uses the six articulated legs actuated by BLDC motors as its thrusters. Therefore, it moves on the sea floor without disturbances by propellers which are widely used as thrusters of any other general ROVs. In addition, The robot is expected to minimize shadow areas of acoustic imaging sensors by controlling its body posture precisely using the legs. In this paper, we introduce operations of Crabster and the acoustic imaging devices when we conducted from April to May in 2015. Using acoustic imaging devices, we could find dispersed potteries and iron caldrons. Mosaicked image to show surround of the robot is also included.**

Keywords—Crabster, Underwater cultural heritage, Acoustic camera, Low visibility

I. INTRODUCTION

In west coast of Korea peninsula, there are several sites known as lodgments of ancient trade ships. But, because the coastal areas have the large tide difference, rocks and fast currents, the sailings were not always safe. As a results, many ships had been sunk. These ships are supposed to trade artifacts such like kettle, cup, pottery, caldron including food and grain. These properties and the shipwrecks themselves are valuable as cultural legacies.

Traditional underwater excavation has been conducted by human divers. If there are fast flow and low visibility, the human activities become very restricted. It is also very limited to perform marine archaeology under 50m water depth. Then,to overcome these restrictions, use of ROVs or AUV (Autonomous Underwater Vehicle)s has been raised. [1]

A multi-legged walking ROV whose name is Crabster has been developed by Korea Research Institute of Ships & Ocean Engineering. It has six artificial legs driven by BLDC motors. The name of Crabster is a combination of Crab and Lobster because the robot's behavior imitates those of the two creatures. The robot walks on the sea floor minimizing environmental disturbances which can be caused by thrusters such as propellers. It is also equipped with optical camera, LED lights, USBL transponder, ADCP(Acoustic Doppler Current Profiler), single-beam scanning sonar, acoustic camera and etc. Maximum operation depth is 200m.

The preliminary performance experiments described in this paper were accomplished to verify usefulness of the Crabster for survey of underwater cultural heritages. The acoustic imaging devices such as scanning sonar and acoustic camera takes the core role for inspection against turbidity. And the Crabster adjusts these imaging devices' posture to minimizing acoustic shadow zones, noise, shaking caused by water flow or tidal currents and provides the best positioning to the imaging devices. Therefore, the robot functions as an actively adaptable mobile observatory for imaging devices.

The experiments were conducted from April to May in 2015 in cooperation with National Research Institute of Maritime Cultural Heritage of South Korea. We located the site of interest for these experiments near the find-spots of Mado shipwreck No. 1~No. 3. [2, 3] Figure 1 shows the wreckage and divers' activity. The place is also close to the excavation of Mado shipwreck No. 4. Maximum depth of that site was 4~5m. Average speed of tide current was about 0.4kts. [2]

Section 2 introduces the Crabster system and survey installation. And section 3 depicts how to acquire acoustic images using the Crabster. Section 4 includes conclusion and future works.

II. CRABSTER AND ITS SURVEY INSTALLATION

The Crabster is a kind on ROVs. It is connected to the mothership with a tether cable which supplies power and communication. The biggest difference is that it used six legs of four degrees of freedom to walk on the sea floor and to control its posture. Although it leaves its footprints on the sea floor, much less sediment disturbance to surroundings occurs than when propellers are used. Launch of the robot is shown in Fig. 2.

The scanning sonar which in installed on the back of the Crabster uses single-beam of 625kHz. It images the surroundings out to 150m. The acoustic camera uses dual frequency modes. At identification mode using 3MHz, it images out to 5m with resolution of 3mm. Using these two acoustic imaging devices, the Crabster is able to inspect objects of interest in the turbid water where general optical cameras suffer from low visibility. Figure 3 shows the Crabster and its equipment.

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Fig. 1 Wreckages and diver’s excavation activity [2]

Fig. 2 Launch of the Crabster ROV

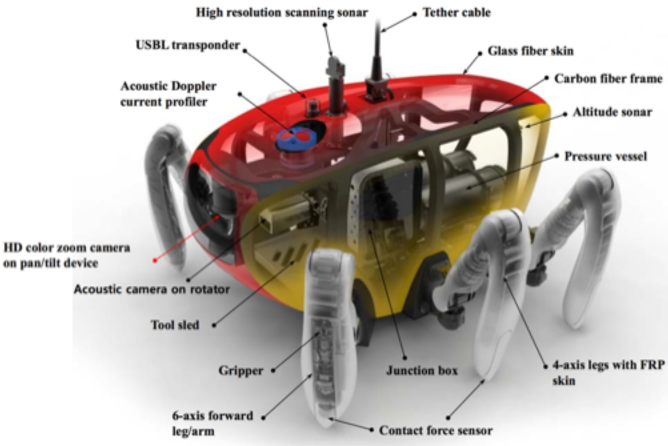

Fig. 3 Equipment of the Crabster

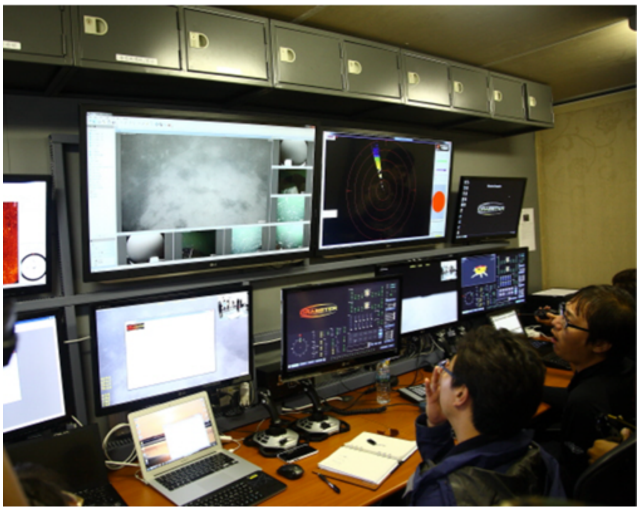

Fig. 4 Inside of the remote control van

We used a barge vessel and installed Crabster operation system on it. The Crabster operation system consists of a remote control van, a transportable hangar and a winch-crane. The remote control van includes a DC power suppler, USBL monitoring system, an agent computer, sensor monitoring system and etc. The transportable hangar provides space for storage for the robot while being transported and space for maintenance. Figure 4 and Fig. 5 shows inside of the remote control van and the transportable hangar, respectively. The winch-crane consists of 500m tether cable, its winch drum and a 133kNm-class crane. It is shown in Fig. 6. The winch drum and the tether cable are connected via a fiber-optic rotary joint. A turning plate was used for the crane and winch drum.

Figure 7 shows arrangement of the remote control van, the transportable hangar and the winch-crane on the barge vessel. A power generator is also installed. A tug boat was deployed for moving.

Fig. 5 Transportable hangar

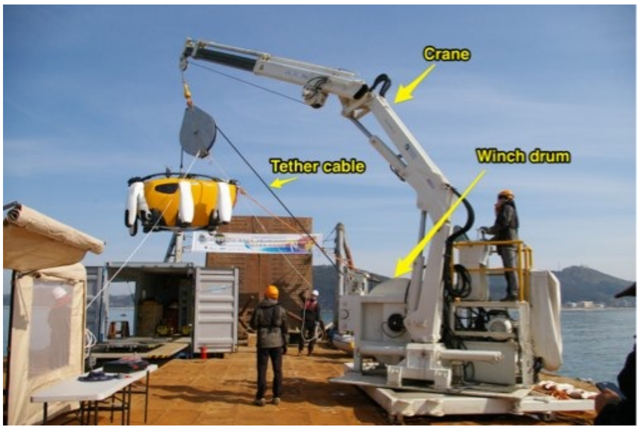

Fig. 6 Winch and crane

Fig. 7 Arrangement of the Crabster survey sysmte

III. ACQUIREMENT OF ACOUSTIC IMAGES

As principle for two-dimensional acoustic camera of how to generate images using acoustic beams is different with those for optical cameras, images of any objects placed in front of the acoustic camera and optical camera are different. [4] Therefore, we need to examine the way things appear in acoustic images. Figure 8 shows a side-view showing arrangement of optical HD camera and the acoustic camera installed on the Crabster and their viewing field. The viewing field of the optical HD camera is colored as yellow, on the other hand, those of the acoustic camera is colored as blue. Two viewing fields become almost overlapped. However, images of each device are completely different as shown in Fig. 9. This is a case of that a long iron drum was in the front of the Crabster. The image of the optical camera shows a front view of the object, whereas the image of the acoustic camera shows a top view of the object. In this secession, how to acquire acoustic images of underwater objects or specimen will be described.

A. Looking around

After when the Crabster reaches the bottom, the robot takes a look around using optical cameras, single-beam scanning sonar and acoustic camera. Figure 10 shows an image of the scanning sonar. It shows trace of footprints and surroundings. In Fig. 11, scattered potteries and trace of footprints in the acoustic camera's images are shown.

B. Approaching and inspecting

If we detected something interest, the Crabster walked toward it. Figure 12 consists of two sequence shots showing the robot's approaching to the object of interest. After that the object is closer than 5m, we operated the acoustic camera at high frequency to get higher resolution and rolled the camera to get a side-view of the object as shown in Fig. 13. One of major advantages of the Crabster is that it can adjust its body posture in place. It can be conducted by changing positions of the six feet or by just rotate its body fixing the feet shown in Fig. 14. In this way, the Crabster is able to extend its viewing field of the cameras minimizing environmental disturbance of sediment blowing. For rotation, a conventional ROV need to activate propellers and as a result, it disperses sediment and increase turbidity dramatically. In addition, it is not easy for the propeller-driven ROV to correct its posture and precise positioning after rotation because the rotation accompanies floating and re-landing. Figure 15 shows that the Crabster is inspecting a long flange pipe with changing its heading without any disturbance.

C. Manipulating

Two manipulators are planted inside the two front legs. Using these manipulators, the Crabster is able to conduct sampling tasks. Figure 16 shows that the manipulator touches a iron caldron. At this moment, the turbidity was not so high. Then, the optical camera could show its performance.

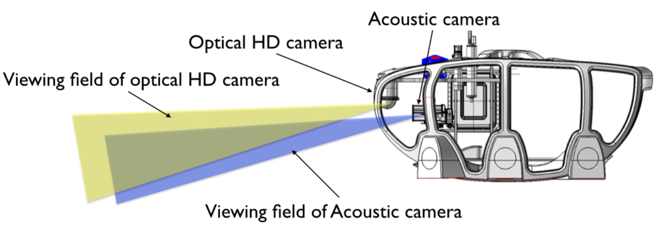

Fig. 8 Viewing fields of optical HD camera and acoustic camera

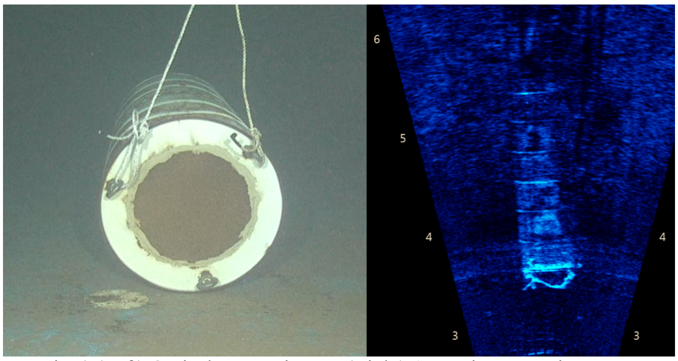

Fig. 9 (Left) Optical camera image, (Right) Acoustic camera image

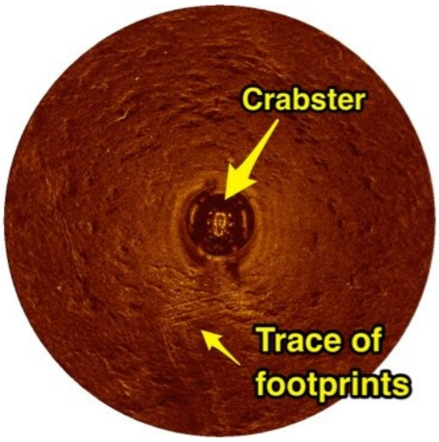

Fig. 10 Scanning sonar image showing surroundings of the Crabster

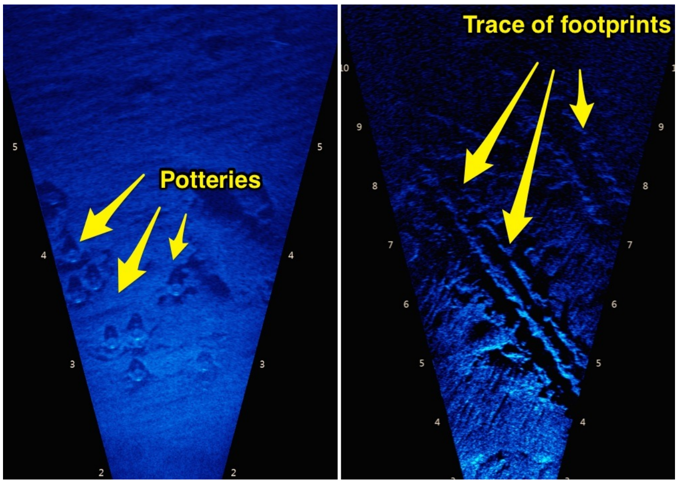

Fig. 11 Scattered potteries and trace of footprints

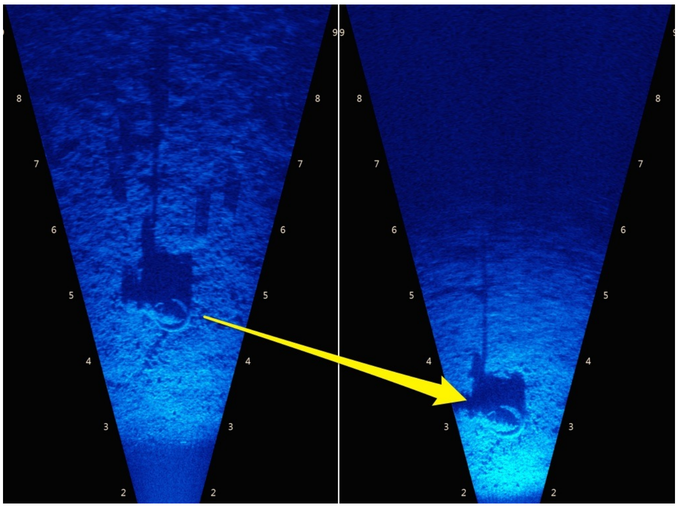

Fig. 12 Walking approach to the object of interest

D. Post processing

We mosaicked several images which were consecutively grabbed while the Crabster was rotating. As a result, we could obtain a circular-shaped image showing surroundings of the Crabster as shown in Fig. 17. This mosaicked image is analogous to those of the scanning sonar. But, the mosaicked image shows higher resolution even if it shows shorter range.

IV. CONCLUSIONS

We introduced preliminary experiments of the Crabster to verify its performance in sea and how to useful for survey of underwater cultural heritages. The Crabster walked on the seabed floor and approached objects of interest successfully. Using acoustic imaging devices, the robot was able to discover objects such as potteries, iron caldron, abandoned tire, etc in the turbid water where conventional optical cameras become defective. As controlling and changing its body precisely, it could extend viewing fields of imaging devices without disturbance to external environment. As a result, these experiments showed capability of the Crabster as an actively adaptable underwater mobile observatory.

In the future, research on extraction of navigational clues from acoustic images will be achieved.

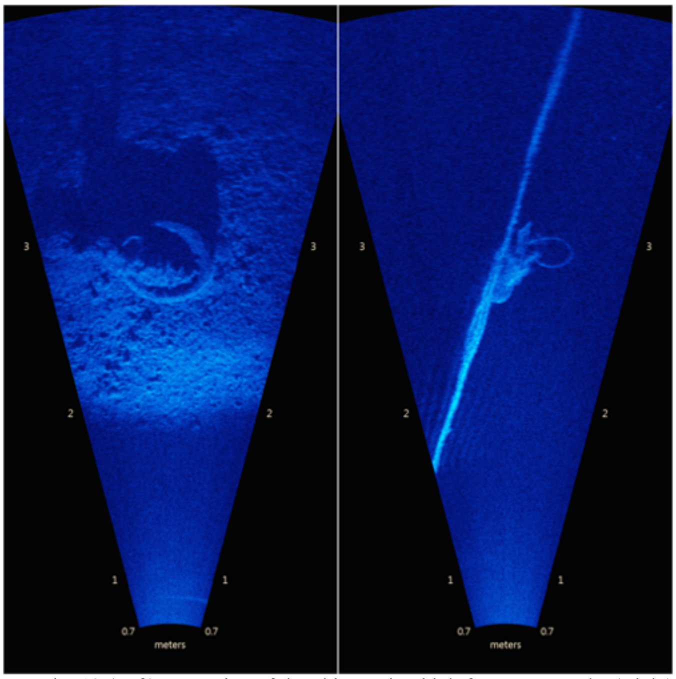

Fig. 13 (Left) Inspection of the object using high frequency mode, (Right) Side-view image obtained by rolling the camera

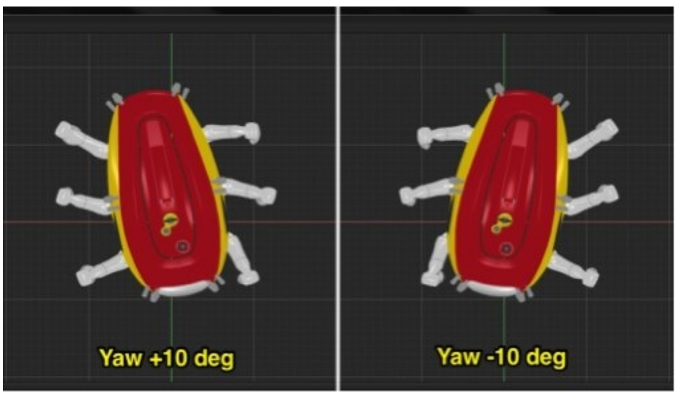

Fig. 14 Yawing motion fixing the six feet to extend viewing field

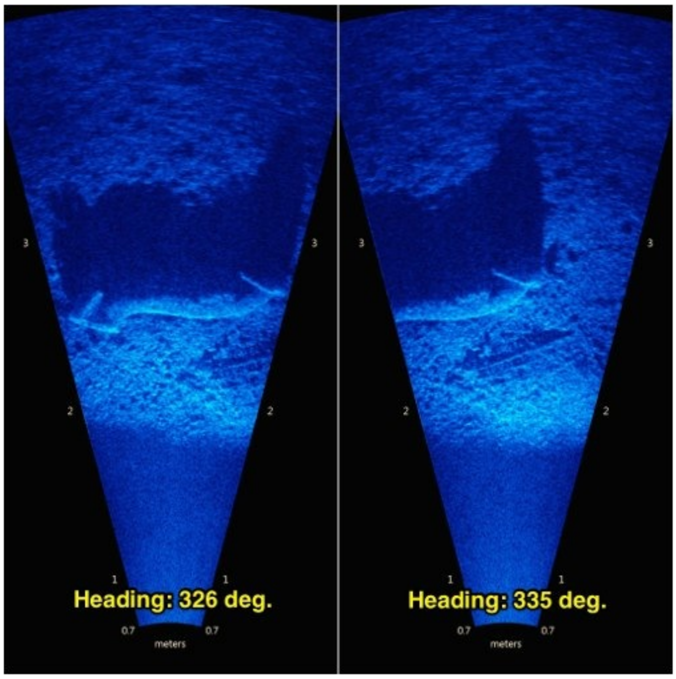

Fig. 15 Inspecting the long pipe without any disturbance into environment

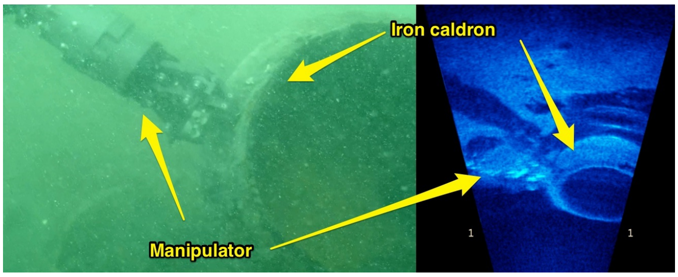

Fig. 16 Manipulation task - Touching an iron caldron

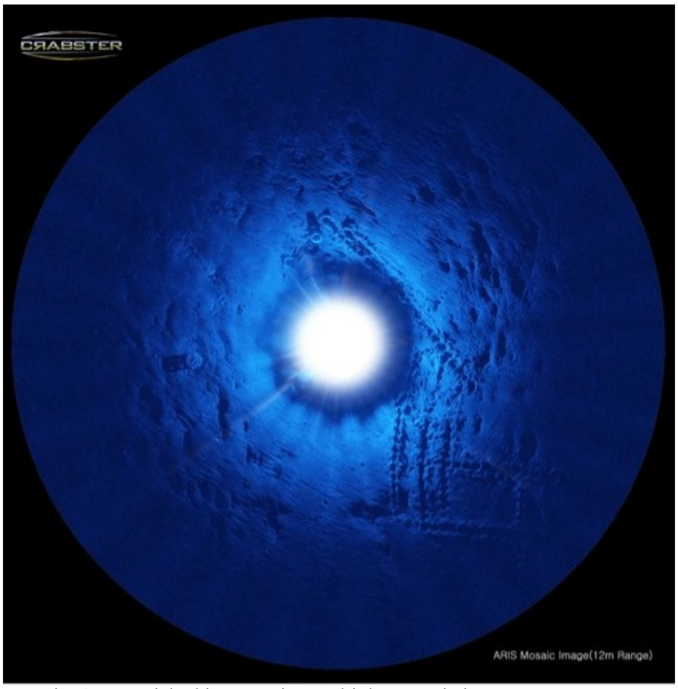

Fig. 17 Mosaicked image using multiple acoustic images

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REFERENCES

1. N. Gracias, P. Ridao, R. Garcia, J. Escartín, M. L'Hour, F. Cibecchini, R. Campos, M. Carreras, D. Ribas, N. Palomeras, L. Magi, A. Palomer, T. Nicosevici, R. Prados, R. Hegedüs, L. Neumann, F. de Fillippo, A. Mallios, "Mapping the Moon: Using a lightweight AUV to survey the site of the 17th century ship 'La Lune'," OCEANS - Bergen, 2013 MTS/IEEE
2. National Research Institute of Maritime Cultural Heritage, "Taean Mado Shipwreck No. 2 - Underwater Excavation," Series of Research Report of National Research Institute of Maritime Cultural Heritage No. 27, 2012 (*In Korean*)
3. National Research Institute of Maritime Cultural Heritage, "Taean Mado Shipwreck No. 3 - Underwater Excavation," Series of Research Report of National Research Institute of Maritime Cultural Heritage No. 27, 2012 (*In Korean*)
4. S. Yu, T. Kim, A. Asada, S. Weatherwx, B. Collins, J. Yuh, "Development of High-Resolution Acoustic Camera based Real-Time Object Recognition System by using Autonomous Underwater Vehicles," OCEANS - Boston, 2006