Experience on Underwater Artefact Search Using Underwater Walking Robot Crabster CR200

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***Abstract*— In April 2015, the 4th underwater test of Crabster CR200 was conducted to investigate the mission capability for search and recovery of underwater artefacts. The experiment was conducted from 16th April 2015 to 15th May 2015 off the Mado Island in West Korea. In the experiment, we searched and found artefact specimens successfully in turbid water using imaging sonar on CR200 and iron pots buried under bottom using metal detect optionally installed on CR200. One of potteries was successfully recovered from seabed by CR200. The artefacts used in the experiment were imitations of potteries and iron pots made and sunken by marine archeologist about one year ago. We verified the exploration ability of CR200 in turbid water and the applicability to the survey and recovery of underwater artefacts. In this paper, we present the results of experiment and share the experience on the experiment.**

Keywords—Crabster CR200; underwater artefact; underwater walking robot; turbid water; marine archeology

I. INTRODUCTION

Ancient artefacts were found in more than 250 areas off the coast of Korean Peninsula. However, the excavations were carried out in just about 20 areas due to the limitations for human divers to access the site. Underwater archeology is very time consuming work and even dangerous for human divers. Underwater robot can be a solution for this problem. Several underwater robotic vehicles have been used for underwater archaeology [1][2]. The main constraint of marine archaeology of the previous works is water depth. The robotic vehicles were used to explore in more than 30 meters water depth that diver cannot work. High tidal current and very turbid water are another severe constraints to the both human and robots in the Yellow Sea.

The Yellow Sea is located between China and Korea. The water depth is less than 100 meters. The relatively shallow water and very complicated coast line of western coast in Korea cause high water current when tide is changing. The high current mostly goes with turbid water. Traditional underwater vehicles driven by propellers were not efficient to explore the shipwreck in off the western coast of Korea. The water current makes hard for vehicles to keep underwater position stably. The turbid water makes hard for the vehicles to capture clear images of shipwreck on seabed. Marine archaeologists have difficulties to use conventional underwater vehicles such as HOVs, ROVs and AUVs in the severe conditions of Korea. The Crabster CR200 has been developed to explore these kinds of severe area. The CR200 is a new type of remotely operated vehicle crawling on seabed with six legs[3-7]. The CR200 is equipped with acoustic imaging systems in addition to the optical cameras to search an identify target efficiently in turbid water[6][7].

The scientist of Korea Research Institute of Ships and Ocean Engineering (KRISO) conducted experiments to explore underwater artefacts using CR200 in Anheungnyang of Taean Peninsula cooperating with marine archaeologists of National Research Institute of Maritime Heritage (NRIMCH). The Taean Peninsula shown in Fig. 1 is a prominent area of the Yellow Sea coast, and located in the major point of the Korea Yellow Sea's coastal route. Anheungnyang of the Taean Peninsula is considered as one of the most dangerous sea areas including Uldolmok in Jindo, Sondolmok in Kanghwa Island, and Indangsu in Seohae Province. Four cargo ships of Middle Ages were excavated from Taean area of Korea during 2007 and 2011. The experiment was conducted in the Mado Shipwreck No.2 area.

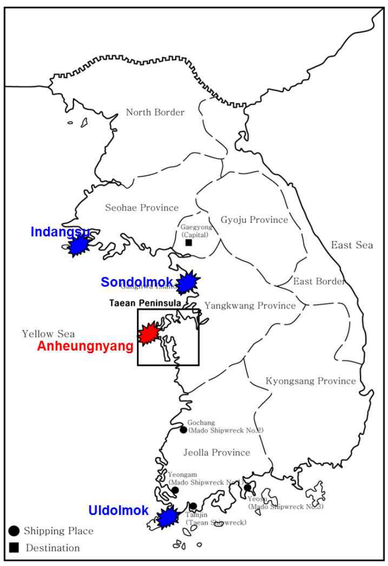

Fig. 1. The Anheungnyang of Taean Peninsua where four shipwrecks of Middle Ages were excavated.

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The experimental results and experiences on the underwater artefacts exploration using CR200 are reported in this paper.

II. Experimental Setup

A. Platform: Crabster CR200

The Crabster CR200 has six legs and two robotic arms in forward two legs. It is designed to be able to keep precise underwater position and stable attitude in water current by mechanically contact on seabed with legs. The stable posture enables CR200 to get clear acoustic images in turbid water. The brief specifications of CR200 is listed in table I. The outer view of CR200 during deploy is shown in Fig. 2. Default sensors are a scanning sonar, an acoustic camera, eight optical cameras and a CTD sensor. As CR200 has enough space, redundant communication channels and sufficient electrical powers, special sensors are easily attached additionally. Fig. 3 shows a metal detector equipped CR200, which is a configuration to find metal object buried under bottom. After CR200 is launched, operators control CR200 in remote control van. All data from CR200 are displayed on the monitors and logged in hard disks. Inside of control van is showed in Fig. 4. A barge is used as base station for the experiment. The CR200 system including a remote control van, an winch/cable/crane system and a hangar van was installed on the barge. The CR200 system on the barge is shown in Fig. 5.

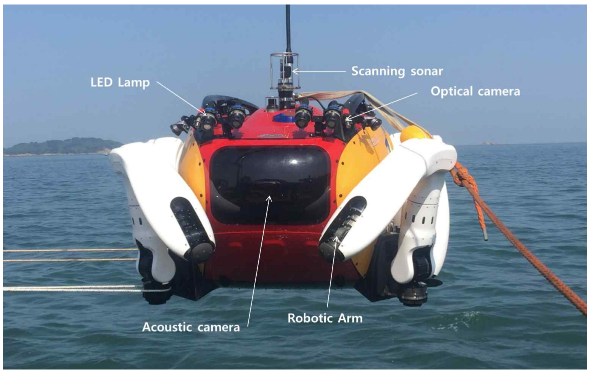


Fig. 2. The Crabster CR200 is being deployed in Anheungnyang.

TABLE I. SPECIFICATIONS OF CR200

Items	Value	Unit	Remarks
Dimension	2.5 X 2 X 1.3(2.0)	m	sit(stand)
Weight	600(200)	kg	air(water)
Max. depth	200	M	
Max. power	20	kW	
Num. of legs(arms)	6(2)	EA	
Max. walking speed	0.5	m/s	
Equipment	acoustic camera, scanning sonar, ADCP, CTD, AHRS, USBL, alt. sonar, tool sled, pan/tilt optical HD camera, analog cameras		

This work is a part of the research results of the ‘development of a multi-legged walking and flying subsea robot’ (PMS3000, PES1930).

Fig. 3. The Crabster CR200 with metal detector.

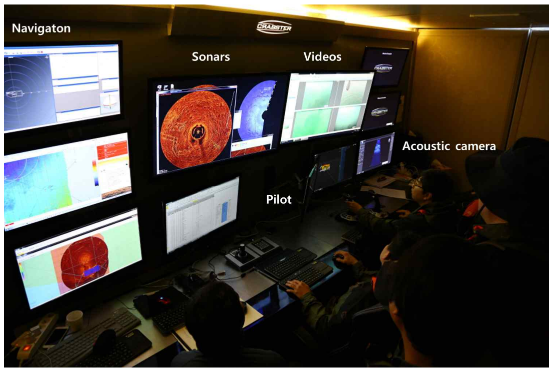


Fig. 4. Remote control system of Crabster CR200

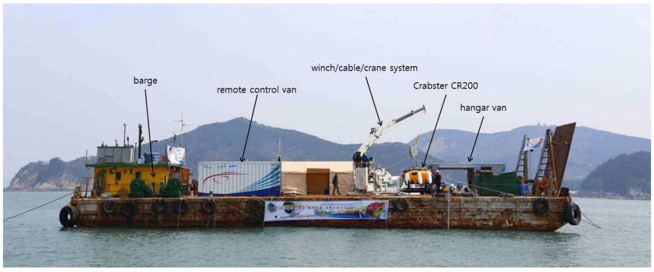


Fig. 5. Crabster CR200 system set on barge

B. Artefacts Setup on the Site

The CR200 experiment was conducted in the excavation area of Mado Shipwreck No.2 shown in Fig. 6. Water depth of the area is about 4 meters. Water current and visibility depend on the tide. Current speed was usually about 0.5~1 knots and visibility was 0.5~1 meters. After the excavation of Mado Shipwreck No.2 was completed, marine archaeologists made and installed new artefact imitations on the site on May 2014. The installed imitations are used as a target of a newly developed underwater searching device or strategies for underwater archaeology. Three kinds of artefacts were made; iron pot, pottery, and bronze cannon. Fig. 7 shows the artefacts imitations made by marine archaeologies of NRIMCH. A part of them were buried 1 meter under bottom and a part of them were buried 2 meters under bottom and the others were simply paced on the seabed. An iron pot and bundles of iron pots were buried separately at a given position in Fig. 8.

Fig. 6. Excavation area of Mado Shipwreck No.2. was chosen as experimental area.

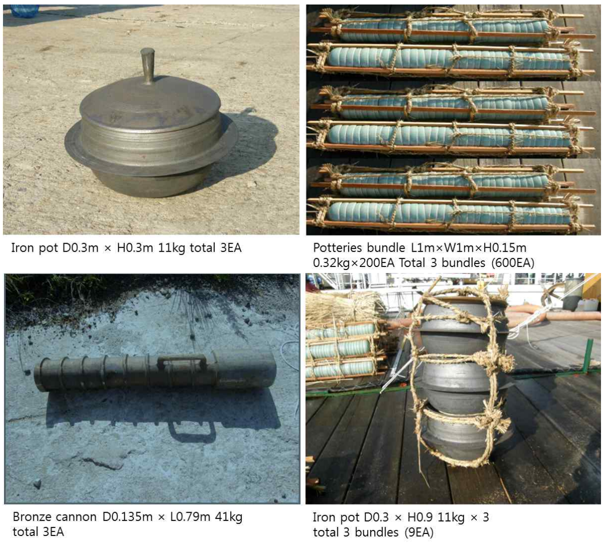


Fig. 7. Artefact imitations were made by archaeologist of NRIMCH.

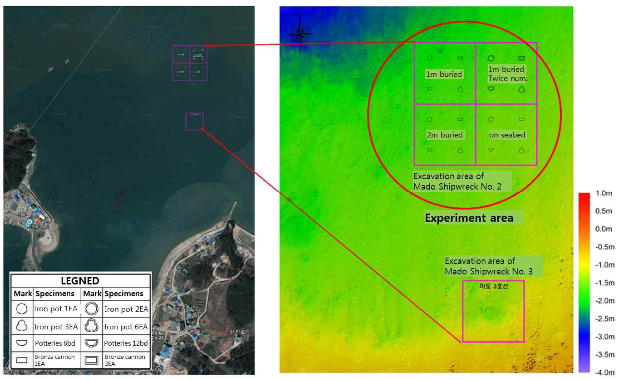


Fig. 8. Experiment area and installation of artefact specimens.

III. Artefacts Survey in Turbid Water

Though the water current is not strong, the experimental area was very turbid and shallow water area. Three types of equipment on CR200 were used to search underwater artefacts in the area. Scanning sonar seached 50m~100m radius circle at every scan. Acoustic camera searched and identifed underwater objects within about 10 meters ahead. Optical cameras used to identify objects within 1 meter ahead when the visibility is available.

A. Scanning Sonar Survey

CR200 is equipped with MS1000 scanning sonar on the top of the body shown as Fig. 2. It searches up to 100 meters surroundings of CR200. During the scanning operation, CR200 is able to provide stable platform by keeping its position and attitude even in tidal current environment. We could find several abnormal spots in the scanning image of experiment area. Some of them were identified as artefact specimens deployed a years ago. A scanning image of experimental area is shown in Fig. 9. The fixed objects in the scanned images can be used as reference points of local navigation after the image is overlapped on the bathymetric map. Two scanned images, barge are overlapped on the bathymetric map as Fig. 10.

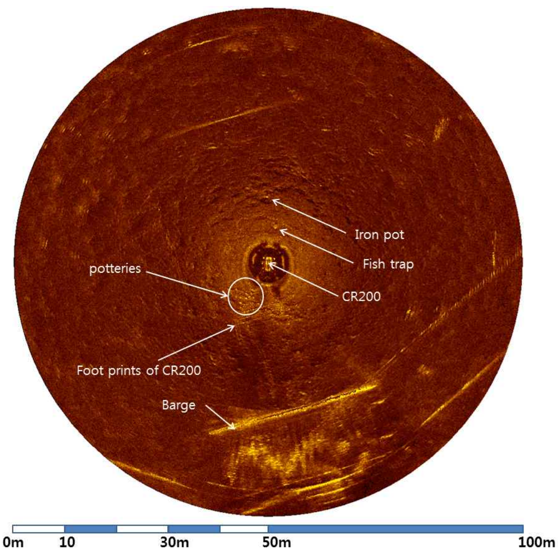


Fig. 9. Sanning sonar image of the experiment site.

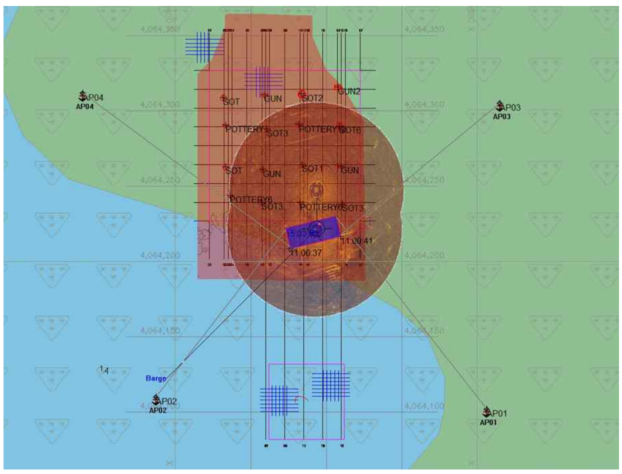


Fig. 10. Scanning sonar images overlapped on the bathymetric map.

B. *Acoustic Camera Surey*

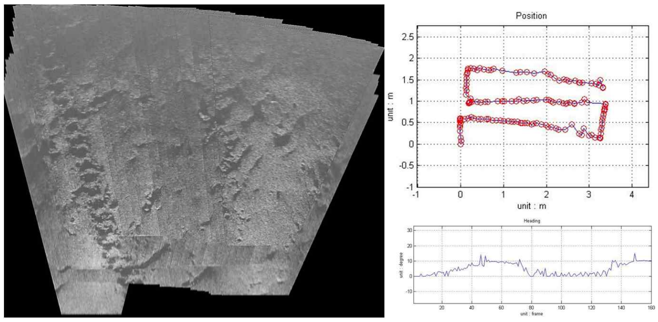
Acoustic camera is very useful instrument in turbid water. It provides high resolution acoustic images in real-time. CR200 is equipped with an acoustic camera ARIS explorer 300. CR200 moves and approaches to the interesting spots found in scanning image and features the objects using acoustic camera. Acoustic camera is used to identify objects within 10 meters ahead. CR200 identified underwater artefacts using acoustic camera successfully. Fig. 11 (a) shows three iron pots tied to a bundle which is an artefact specimen deployed a year ago for the experiment. The iron pots are identified also by optical camera after CR200 approached closely to 1 meter. The optical image of the pots is shown in Fig. 11 (b) and the image of original pots is found in Fig. 7. Fig. 12 (a) shows potteries featured by acoustic camera. The potteries shown in Fig. 7. were scattered on seafloor and covered with sediment. Optical image of pottery is shown in Fig. 12 (b). Capturing the acoustic images, we can make mosaicked image. Fig. 13 (a) shows a mosaicking example using scale-invariant feature transformation (SIFT) algorithm. Fig. 13 (b) is an estimated position and heading of CR200 extracted from pattern matching, which will be used to estimate slip between feet and seafloor.

(a) acoustic image (b) optical image

Fig. 11. A bundle(3 pots) of iron pots are identified by acoustic camera in 2 m distance and optical camera in 1 m distance.

(a) acoustic image (b) optical image

Fig. 12. Potteries scattered on seabed were identified by acoustic and optical cameras.



(a) (b)

Fig. 13. Mosaicking of acoustic images and extraction of position information from pattern matching (a) mosaicking of acoustic image (b) position and heading extracted from pattern matching.

C. *Optical Camera and manipulation*

The optical cameras cannot give much information in turbid water. However they still useful for final identification of objects because human are familiar better to optical image than acoustic image. The turbidity of experimental area depended on the tide time. The visibility was less than 1 meter, however, visibility was better to 1~2 meters at high tide in neap tide. We tried underwater manipulation when the visibility was more than 1 meters. We could recover a pottery with left arm of CR200 as shown in Fig. 14. Since iron pot was too large to handle with an arm, we lifted and moved it by cooperating both arms. Fig. 15 shows optical and acoustic images during CR200 handles the pots using both manipulators. CR200 manipulators can controlled in both joint space and work space.

Fig. 14. Pottery recovery using manipulator.

(a) optical image (b) acoustic image

Fig. 15. Manipulation of iron pot using both arms.

IV. SUMMARY AND CONCLUSIONS

In this paper, we introduced an underwater artefact searching experiment using Crabster CR200 which is an underwater walking robot. The experiment was conducted off the western coast of Korea where exist tidal current and is too turbid for divers to search with ease. CR200 successfully found artefacts with its scanning sonar, and identified the types of artefacts using acoustic camera after it approaches to the objects. CR200 handled underwater artefacts with its manipulators and recovered a sample of artefact. We verified with this experiment, Crabster CR200 is very effective system in tide and turbid area. The Crabster CR200 will be more effective in deeper area.

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