

Sea trials for benthos sampling using autonomous underwater vehicle

著者	Nishida Yuya, Yasukawa Shinsuke, Sonoda Takashi, Watanabe Keisuke, Ishii Kazuo
journal or publication title	Proceedings of International Conference on Artificial Life & Robotics (ICAROB2020)
volume	25
page range	167-170
year	2020-01-13
その他のタイトル	Sea Trials for Benthos Sampling Using Autonomous Underwater Vehicle
URL	http://hdl.handle.net/10228/00008222

doi: <https://doi.org/10.5954/ICAROB.2020.OS23-1>

Sea trials for benthos sampling using autonomous underwater vehicle

Yuya Nishida

Khushu Institute of Technology, 2-4 Hibikino, Wakamatsu, Kitakyushu, Fukuoka 808-0196, Japan

Shinsuke Yasukawa

Khushu Institute of Technology, 2-4 Hibikino, Wakamatsu, Kitakyushu, Fukuoka 808-0196, Japan

Takashi Sonoda

Nishinippon Institute of Technology, 1-11 Aratsu, Kanda, Miyako, Fukuoka 800-0394, Japan

Keisuke Watanabe

School of Marine Science and Technology, Tokai Univ., 3-20-1 Orido Shimizu-ku, Shizuoka, 424-8610, Japan

Kazuo Ishii

Khushu Institute of Technology, 2-4 Hibikino, Wakamatsu, Kitakyushu, Fukuoka 808-0196, Japan

E-mail: ynishida@lsse.kyutech.ac.jp, ishii@brain.kyutech.ac.jp

Abstract

For enhancement of oceanic engineering technology and researchers, underwater robot competition has been held since 2016. Seventh competition in this year consists AUV league that university's vehicles automatically cruise at field and junior league that underwater craft is made. The paper reports competition regulations of AUV and junior league and results of the competition held in October 2019.

Keywords: Autonomous Underwater Vehicle, Benthos sampling, suction device

1. Introduction

Autonomous underwater vehicles (AUVs) without umbilical cable cruise a wide area and is often used for bio-resource survey [1-2]. In the survey, AUVs take seafloor images for measurement of benthos biomass and distribution using a mounted camera and strobe. However, bio-resource survey by AUVs is difficult to obtain the sample useful for scientists. Previous AUVs can capture the specific benthos that its developer decided the target before resource survey, but scientists on the ship can't chose sampling target during survey. To realize an efficient bio-resources survey by AUVs, the authors developed the AUV Tuna-Sand2 with an epochal sampling method that previous problem is solved, as shown in Fig.1 [3-4]. The AUV succeeded to capture a shell on the seafloor of 100 m depth that the operator selected as sampling target during observation in March 2018 [5], but the AUV was able to only sample one time



Fig.1 The AUV Tuna-Sand2

because its suction device may drop with suction more than twice. The paper explains the system of the AUV Tuna-Sand2 and new suction device developed for continuous sampling, results of experiments performed with the AUV in the ocean are shown.

Table 1 The specification of the AUV Tuna-Sand2

Category	Value
Dimension	(L)1.4 m x (W)1.2 m x (H)1.3 m
Weight	390 kg
Max. speed	1.2 kt (0.6 m/s)
Max. depth	2,000 m
Duration	8.0 h
Actuators	Horizontal thrusters x 4, Vertical thrusters x 2 Ballast releaser x 2 The arm with a suction device x 1
Battery	Li-Ion 5,000 Wh
Communications	Wireless LAN, Acoustic modem for command link Acoustic modem for image data
Sensors	INS, DVL, Depth sensor, Transponder for SSBL positioning
Payloads	LED array x 2 LED strobe x 2 Scanning sonar x 1 3D mapping device x 1 Camera for benthos sampling x 1

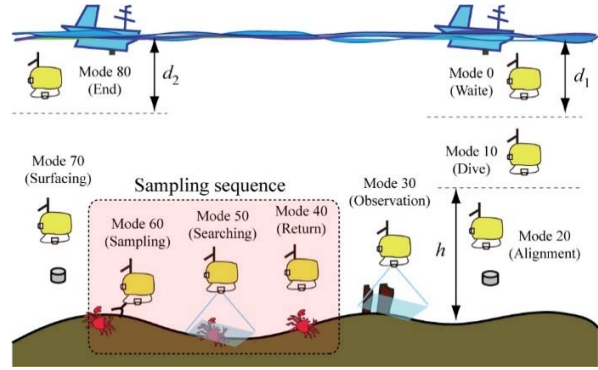


Fig.2 Survey procedure based on the state flow

2. The hovering type AUV Tuna-Sand2

2.1. System

Hovering type AUV Tuna-Sand2 can dive up to 2,000 m depth and operate for up to 8 hours using a mounted Li-ion battery. Table 1 shows the specification of the AUV Tuna-Sand2. The AUV estimates self-position based on altitude and ground velocity from doppler velocity log (DVL), attitude and heading from inertial navigation system (INS) and depth sensor data. The transponder is installed on the top of the AUV, and the operator on the support ship can measure the global position of the AUV under the ocean using a positioning device based on super short base line (SSBL). The obstacle is detected by scanning sonar mounted on the front of the AUV, and the AUV increases altitude if the sonar detects the obstacle which 5 m. As observation device, the AUV has a mapping device for 3D reconstruction of the seafloor and a camera for benthos sampling.

2.2. Survey procedure

The AUV Tuna-Sand2 acts sequentially based on the state flow as shown in Fig.2. After deployment in the ocean, the AUV which has two ballasts dives by its

weight to the seafloor (Mode 0). During the dive, mounted sensors and payloads is turned on for navigation and observation (Mode 10). The AUV becomes neutral buoyancy by releasing a ballast and camera parameters are adjusted while taking a seafloor image, when it closes to the ocean (Mode 20). Three minutes after reaching the seafloor, the AUV navigates at a constant velocity and altitude along preset waypoints and takes image of the seafloor using a camera and two LED arrays every five seconds (Mode 30). Then, the benthos candidate is searched by saliency map that is the same as human attention model from the seafloor image enhanced by the Retinex method. If the candidate is detected, reference image of the candidate is made for tracking, and the candidate and its surrounding images which data size reduced are transmitted to the support ship using a special acoustic modem. The operator on the ship selects sampling target from received images and instructs the image number to the AUV by acoustic modem for command link. After received operation instruction, the AUV returns to the points where the image of the instructed number was taken. Sampling target is searched and tracked by pattern marching method based on the reference image of the candidate. If the target is found, the AUV approaches and captures the target by mounted suction device. After the sampling sequence, the AUV waits a few minutes for next instruction from the operator while keeping the safe altitude. Then, if the instruction is received, the AUV runs the sampling sequence again. If there is no instruction or there is an instruction of mission abort, the AUV becomes positive buoyancy by releasing a ballast and goes up to the surface.

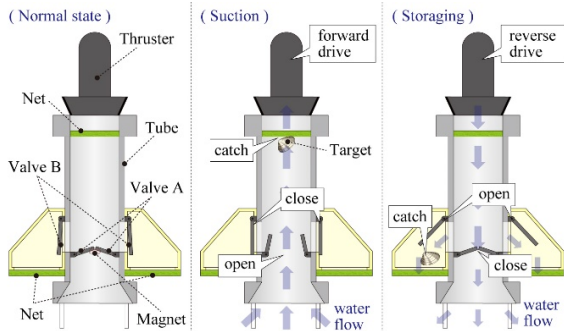


Fig. 3 Suction device for continuous sampling

2.3. Suction device

Previous suction device consists of a tube with check valves and a thruster, and it may drop captured benthos with suction more than twice because there is no canister. To solve the problem, a suction device which has two canisters and two valves with different functions was developed as shown in Fig.3. If the benthos is wanted to catch, the device sucks the target with the water by a forward drive of the thruster. Then, the valve A opens by the water flow, and the net near the thruster catches the target. The valve A closes by its weight and the force of the magnet when the thruster is stopped, the target puts on the valve A. After that, the valve B opens by a reverse drive of the thruster still with the valve A closed, and the target moves into the canister. Because the valve B closes during suction, the device continuously sucks the sampling target without dropping out.

3. Sampling experiments

To experiment for continuously sampling, the AUV Tuna-Sand2 with a developed suction device was deployed at 120 m depth in the Suruga Bay in December 2019. Figure 4 shows the trajectory of the AUV during cruising, and time series data of the AUV position during the sampling sequence is shown in Fig.5. The AUV cruised at 2.0 m/s velocity to 1st waypoint and observed the seafloor of about 120 m² by the camera while keeping 1.0 m/s velocity and 1.5 m altitude. Then, 85 benthos candidates were detected by image processing from taken seafloor image and were transmitted to the support ship by using the acoustic modem. The operator on the ship received only half of the transmitted images, and three sampling targets were selected by the operator from the images. The AUV tried

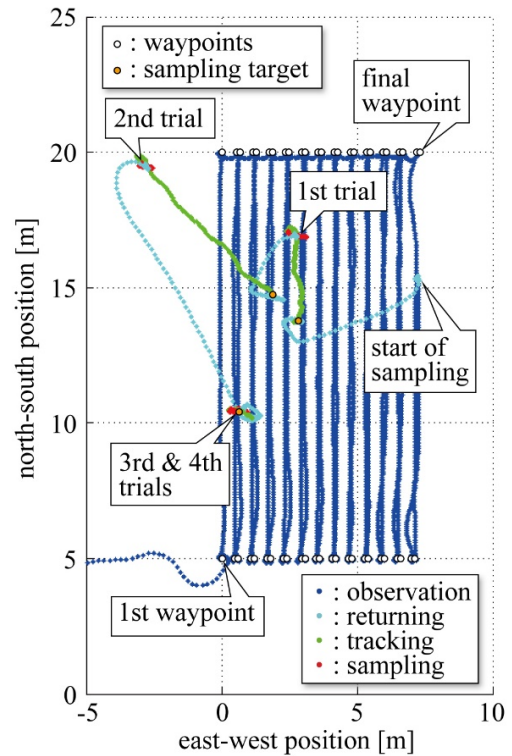


Fig.4 The trajectory of the AUV during cruising

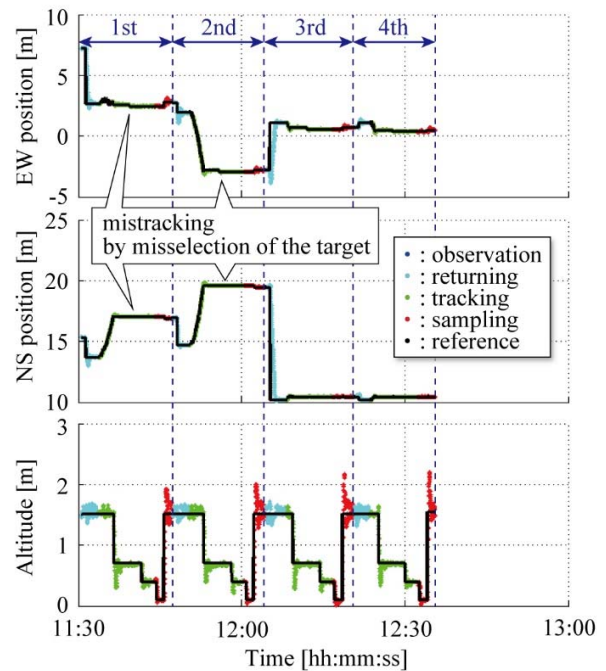


Fig.5 The position data during the sampling sequence



Fig. 6 Referenced images in the first and second trials

capturing different targets for the first and second trials, but the AUV couldn't search the targets and tracked the wrong targets. The cause is that the targets instructed by the operator were marine snows shown in Fig.6. Because the received images were the images with low resolution and color depth, the operator was difficult to search from the benthos candidates. In third and fourth trials, the AUV tried to capture the same benthos that stuck the seafloor like the sea anemone and didn't sample the benthos because the suction force of the device wasn't so high. The AUV controlled the position with high accuracy of ± 0.05 m error from the references and tracked the sampling target in third and fourth trials.

4. Conclusions

To solve the problem of the previous method, the authors developed the benthos sampling method by the AUV with the suction device that is able to suck several times. In the sea trial using the method, the AUV could try to sample four times according to the instruction of the operator on the ship, but the benthos couldn't be captured due to the mis-selection of the sampling target and weak force of the suction device. In future work, the authors will develop user-friendly image transmission method and the device which can suck the benthos sticking to the seafloor.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Number 18K04585. The authors are deeply grateful to the crews of Tokai University's research vessel HOKUTO and the students of Watanabe laboratory who helped with the sea trials.

References

1. Yuya Nishida, et al., Resource investigation for kichiji rockfish by autonomous underwater vehicle in Kitayama bank off Northern Japan, *ROBOMECH Journal*, Vol.1, pp.1-6, 2014
2. Blair Thornton, et al., Biometric assessment of sea vent megabenthic communities using multi-resolution 3D image reconstructions, *Deep Sea Research Part I: Oceanographic Research Papers*, Vol.116, pp.200-219, 2016
3. Yuya Nishida, et al., Underwater Platform for intelligent robotics and its application in two visual tracking systems, *Journal of Robotics and Mechatronics*, Vol.30, No.2 pp.238-247, 2018
4. Shinsuke Yasukawa, et al., Vision system for an autonomous underwater vehicle with a benthos sampling function, *Journal of Robotics and Mechatronics*, Vol.30, No.2 pp.248-256, 2018
5. Yuya Nishida, et al., Benthos sampling by autonomous underwater vehicle equipped with a manipulator with suction device, *Proc. of IEEE Underwater Technology*, DOI: 10.1109/UT.2019.8734330, Taiwan, 2019