FEASIBILITY STUDY OF POSITIONING FOR FREE-FALL TYPE UNDERWATER OBSERVATORY SYSTEM USING DYNAMIC IMAGE ANALYSIS

Kouki Noguchi [1], Yuta Sato [1], Takuya Matsumoto [1], Kenta Hata [2], Yoshikazu Koike [2], Hiroaki Morino [2], Etsuro Shimizu [3], Kunio Sakata [4], Shigeo Itoi [5], Yoshinari Kou[6], Itaru Kawakami [7], Kuniaki Kurihara [8], and Junich Muramoto [9]

[1] Graduate School of Engineering, Shibaura Institution of Technology,

[2] College of Engineering, Shibaura Institution of Technology,

[3] Tokyo University of Marine Science and Technology, [4] Mukoujima Tech Co., Ltd.,

[5] I2I Tech Inc., [6] Nest Egg Inc., [7] Fukan Laboratory, [8] Gyogyotto Camera Supporters,

[9] Gyogyotto Camera Supporters (K6KCo. Nakmura)

Contact E-mail Address:ma15062@shibaura-it.ac.jp

ABSTRACT

In the recent years, technologies on marine development and research are strongly required and has been actively developed. However, it costs large to operate the marine apparatus, for example ROV (remote operate vehicle) or AUV (autonomous unmanned vehicle) in general. Hence, it is difficult to increase the number of researchers or explores on the marine field. Therefore, it is necessary to develop a low cost and an easy operation system for underwater observation and exploration. For such a demand, the authors have developed the low cost and easily-handled underwater observatory system (UOS), we call "Gyogyotto camera". The developed system enable us to observe all round view of sea bed in real time through LAN and Wi-Fi. Additionally, the real time image video can be watched on the land in the case that the butler-matrix Wi-Fi antenna is employed. By the way, it is difficult to estimate the position of the UOS although the positioning of the UOS is also important.

In this report, the developed observatory system "Gyogyotto camera" is described. Also, feasibility of inertial mass systems (IMS) in the combination with a dynamic image analysis is investigated. The dynamic analysis for the positon estimation which is based on particle image velocimetry (PIV) is to measure the current flow around the UOS.

1. INTRODUCTION

In the recent years, the global covering ocean observation and investigation is strongly required in order to protect sea creatures and to explore sea resource and so on. A free-fall-type underwater observatory systems (UOS) is often employed in order to monitor sea bed, earthquake awareness and its occurrence. Also, sea resources and creatures are often observed using the UOS. We are developing a low cost underwater observatory system, we call it "Gyogyotto Camera", using glass spheres like Edokko No.1 [1]. The UOS we developed can monitor and record entire circumferential underwater image in real time.

For free-fall type UOS, the positioning is also required. However, a global navigation satellite system (GNSS) doesn’t work under the sea because radio wave, which is a positioning signal from the satellite, reflects at the sea surface and absorbs in the sea. Usually, inertial mass systems (IMS) or ultrasonic positioning systems like SSBL (super short baseline) are often employed. Nonetheless, SSBL takes high cost to set the ultrasonic transducer system and IMS requires a ring laser gyroscope of which cost is high and size is also large.

In this report, the authors propose new positioning system for the free-fall type UOS. The IMS is also installed in the system. However, high accurate positioning is not expected completely if the cost and the size of IMS sensor is limited. Therefore, most of IMS systems has another sensor to compensate the error, for example Doppler Velocity Logger (DVL) [2]. The current stream around the system are estimated using PIV (Particle Image Velocity) method in order to compensate the bias error and to estimate the orientation and the motion of the system. We tried to realize PIV measurement using dynamic image analysis of the whole circumferential image. The bubbles generated by electrolysis of the sea water are employed as a tracer of PIV. The authors discussed feasibility of the method.

2. DEVELOPMENT OF GYOGYOTTO CAMERA

2.1 Constitution of the Gyogyotto camera

Figure1 shows configuration of Gyogyotto Camera. And Table1 indicates the specification of the camera. The developed camera consists of two parts. The lower part is a glass sphere and the upper is a PVC cylindrical case. The glass sphere contains batteries, a power supply board, a Wi-Fi router, four cameras (SNC-CX600, SONY), and an IMS sensor built-in smartphone (ZenFone2, ASUStek computer inc.). An angle of view of cameras is 120 degree in the air. In the water, the angle of view becomes narrower due to curvature of glass sphere and difference of index between glass and water. Then, the original camera lens changes into wider lens. And also, the four network camera are employed in order to record the entire circumferential image. The PVC cylindrical case contains batteries, a power supply board, a Wi-Fi router, a LED control board. Figure2 describes the operation of the Gyogyotto camera. The camera connects with a buoy or a ship floating on the sea through a LAN or an optical fiber cable in order to deliver real time image of sea bed. The LED brightness controller using ethernet-serial converter is mounted on the power supply board. Due to the difficulty of the process against the glass, there is only one hole for depressurization on the glass sphere. For the glass sphere, the upper hemisphere and the lower hemisphere put together and covered the peripheral of the contact surface by butyl rubber and plastic tape in order to prevent from sinking. The LAN cable is put through the hole on the PVC cylindrical case.

Figure3 shows the diagram for delivering path of movie and data. The four network cameras, that is SNC-CX600, are connected to the Wi-Fi router1 in the glass sphere. As mentioned above, the Wi-Fi router2 in the PVC cylindrical case is connected to the Wi-Fi router3 on the buoy in the sea surface. The connection between the Wi-Fi router1 and the Wi-Fi router2 is also achieved by Wi-Fi in order to reduce the number of the process on the glass sphere and the PVC cylindrical case. As the dissipation of Wi-Fi signal becomes large, Wi-Fi is not available directly under the sea. Then, the Wi-Fi communication via dielectric rubber, which is described in [3], is employed. The dielectric rubber is installed into the contact part between the glass sphere and the PVC cylindrical case.

2.2 Underwater entire circumferential image

We conducted an experiment operation of the Gyogyotto camera at Shin-Enoshima aquarium [4]. A synthetic image from captured movie is shown in Figure4. The images are obtained from each movie recorded by each internal camera and are stitched manually. As shown in Figure4, the clear entire circumferential underwater image is obtained. The circumferential entire movie should help in the geomorphic investigation and creature research under the sea. For our future plan, the synthetic process is operated automatically.

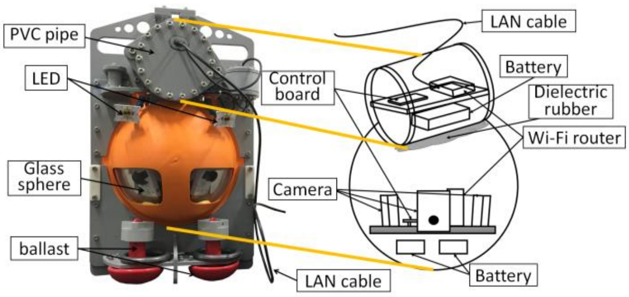


Fig.1 The configuration of Gyogyotto Camera.

Table.1 The specification of Gyogyotto Camera.

Size H × W × D [mm]	813 × 470 × 354
Weight [kg]	About 35
Drive time [hour]	About 4.4
Water depth[m]	About 300

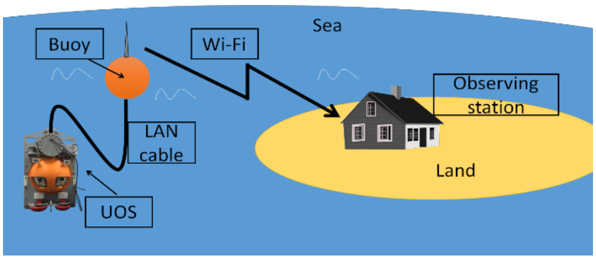


Fig.2 Schematic explanation of the operation of the Gyogyotto camera and the video delivery path.

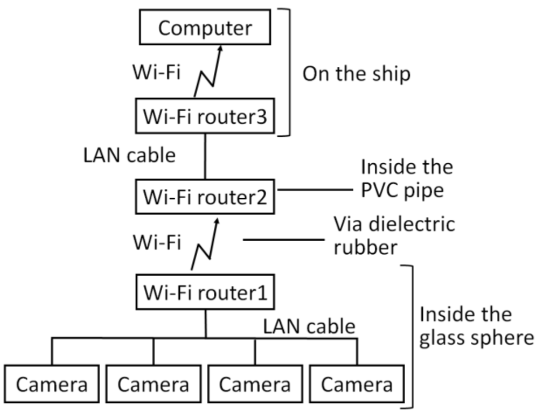


Fig.3 Diagram for delivering path of movie and data.

Fig.4 entire circumferential underwater image recorded by Gyogyotto Camera.

3. POSITION ESTIMATION OF THE UOS.

Using MEMS IMS sensor, that is accelerometer and gyroscope, built-in Zenfone2, the position of UOS is estimated. As well-known, an IMS unit produces a random walk signal. Generally, the precision of IMS sensor is characterized by the random walk signal [5]. Figure5 shows the position error by calculate the integration of the IMS sensor signal built-in the UOS when the UOS is stationary. Even if the UOS doesn't move at all, estimating position proceeds up to 8.1m dramatically due to the random walk signal.

The position estimation is also tried under the water. The pool as shown in Figure6 is employed at Tokyo university of Marine Science and Technology. Figure6 shows the estimation results indicated as blue line. On the experimentation, the UOS progress linearly by the crane in 8.1m of distance along the X direction. The real motion is also indicated as red line in Figure6. In positon estimation of the UOS, the bias error obtained by Figure5 is eliminated. Although the UOS only processed along X direction, the motion along Z and Y direction also appears.

From the experiment results, it is difficult to estimate the position or the motion of the UOS when the IMS is only employed. Therefore, the complemental data or sensor of IMS is required.

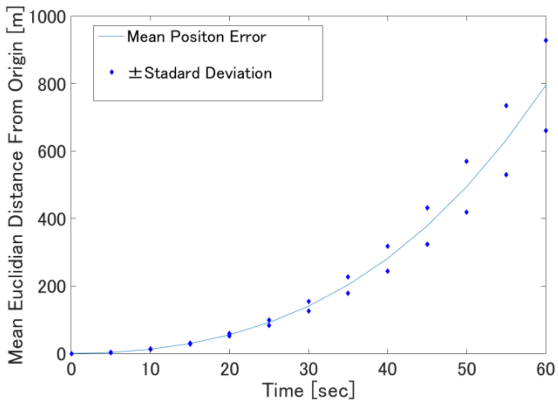


Fig.5 The UOS's stationary position error.

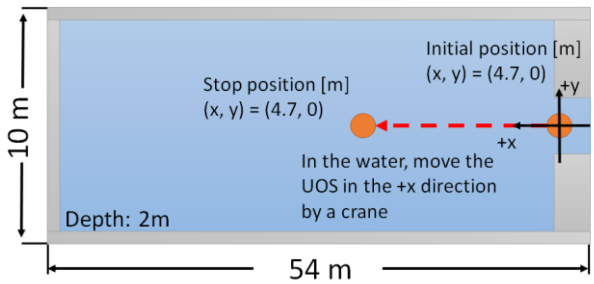


Fig.6 The setup for the position estimation experiment.

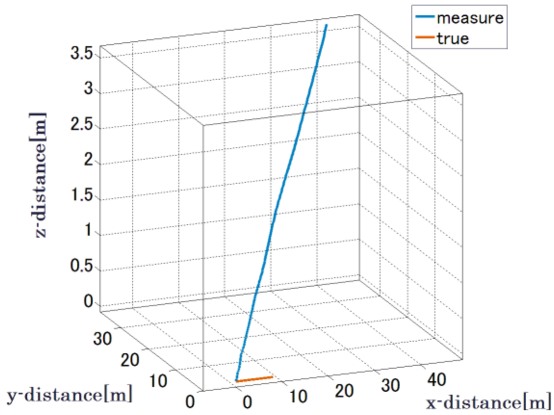


Fig.7 The UOS's trajectory under the water.

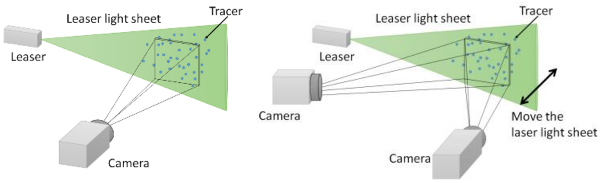
4. APPLICATION OF DYNAMIC IMAGE ANALYSIS

We consider that the PIV is suitable as the complementary system of IMS because the installation cost is low and the four cameras built-in the UOS can be applied to measurement of the complement data as recording the underwater movie.

PIV is a measurement method to observe velocity distribution of fluid. Generally, PIV requires particle as a tracer and sheet laser as a light. The image in a certain frame are compared in a next frame at each pixel. According to the comparison result, direction and distance of the fluid stream is obtained by computing the tracer. In PIV method, high-power laser is used as a light source and the fluid is irradiated with the sheet laser light [6]. Bright monochromatic and high-speed flush is employed since the exposure time becomes shorter than using normal light. Figure8 shows two typical PIV installation. One is 2D PIV and the other is 3C2D PIV. 2D PIV is basic PIV. One camera records tracer on one 2D surface irradiated by light sheet. 3C2D PIV is the method for measuring three direction components of velocity in plane irradiated by light sheet. To observe velocity distribution in 3D space, the area irradiated by light sheet is moved perpendicular to the sheet plane. And the final 3D velocity map is obtained by the superimposed image [6]. Usually, two or more cameras are used for 3C2D. In typical PIV, tiny particles are used as tracer in order not to disturb the flow of fluid. It is sometimes used ink or liquid instead of particle. For the Gyogyotto camera, dynamic image analysis based on 3C2D is applied because several cameras are able to be installed inside the glass sphere. Figure9 shows the installation of the apparatus for PIV. For typical setup of 3C2D, the cameras are placed at certain angle as shown in Figure8 (b). However, the space inside the glass sphere is limited. Then, two cameras are placed in side by side as shown in Figure9 (a) for the experiment. For such an installation, the image recorded by one camera is different from the image recorded by the other camera owing to 6.3cm interval of two cameras if both cameras are recorded the same objects. Hence, we considered that it is possible to do 3C2D PIV in the set up as shown in Figure9. At this point, the recorded image is distorted due to the employment of wide-angle lens. Then, it is needed to correct the trajectories of the tracer.

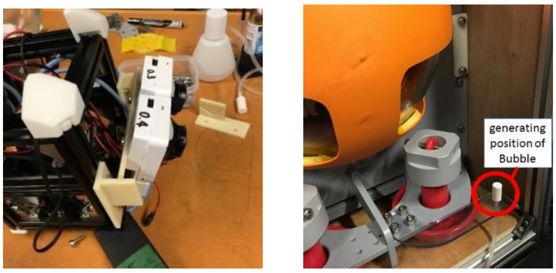
As shown in Figure9 (b), the bubble regulator is also installed for providing the tracers. Figure10 shows the recorded images in the experiment. Figures10 (a) and (b) are recorded color images while the bubble regulator is opened. In Figures10 (a) and (b), the UOS is stationary. Figures10 (c) and (d) are binary images in the conversion of Figures10 (a) and (b). The recording rate of the cameras are 30fps and H.264 compression mode. In the stationary state, the generating bubble can be recorded by each camera. The bubble images can be distinguished as shown in Figures10 (c) and (d). According to the images, it is considered that the bubble can be employed as a tracer.

On the contrary, the UOS is progressed by the crane at 0.35m/s of velocity as mentioned in section 3. When the UOS progresses, the bubbles move outside the recordable area of camera.



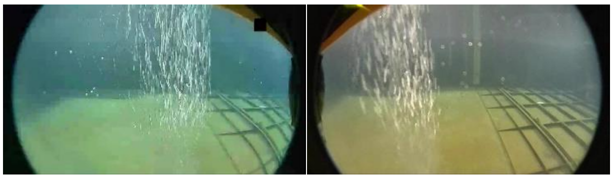
(a) 2D PIV (b) 3C2D PIV

Fig.8 The typical installation of PIV.

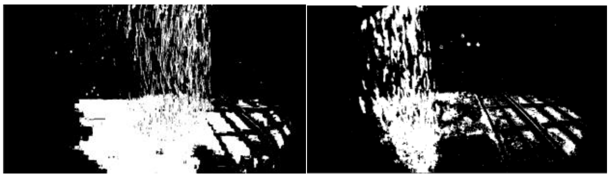


(a) Setup for cameras (b) Setup of bubble regulator

Fig.9 Setup of cameras and of bubble regulator.



(a) Left camera (b) Right camera



(c) Left camera (binarized) (d) Right camera (binarized)

Fig.10 Images of generated bubble when the UOS is static.

CONCLUSIONS

In this paper, we describe the development of new free-fall type UOS that is able to monitor and record entire circumferential underwater image in real time. The position estimation under the sea is also tried. The correct motion of the UOS cannot be obtained by only IMS. Then, application of PIV to Gyogyotto Camera is proposed using the combination of the camera and the bubble regulator. Our future plan is to realize the position estimation of UOS using the proposed method.

ACKNOWLEDGEMENT

We all appreciate for technical officer Miyagawa. Our experiment has not been completed without his help. He spent time for our experiment after office time. Thank you so much.

REFERENCES

[1]Y. Koike, Environmental measurement of Deep Sea using Internal Physical Data of a Glass Sphere for Free-Fall Exploration System (in Japanese), IEICE Technical Report. ASN, Ambient intelligence and Sensor Networks, 114(166), 195-200, 2014

[2]J.H.Li et al, Development of P-SURO 2 Hybrid AUV and its Experimental Study, Conference Publications: OCEANS-Bergen, MTS/IEEE, 2013

[3]M. Ozawa and E. Shimizu, Development of UHF Band Communication Method under the sea, Proc. Of 2012 International Offshore and Polar Engineering Conference, 472-478, 2012

[4] Home page of Shin-Enoshima aquarium: http://www.enosui.com/en/, accessed January. 2016

[5]Oliver J. Woodman, An introduction to inertial navigation, Technical Report, Number 696, University of Cambridge Computer Laboratory, 2007

[6] M. Raffel, C. E. Willert, J. Kompenhans, Particle Image Velocimetry, Springer, 1998