Visual Servoing Experiments of Underwater Vehicle under Air Bubble Disturbances

Myo Myint, Mamoru MINAMI, Kenta YONEMORI, Yukihiro SAKA and Akira YANOU

1. Introduction

The role of decontamination work in radioactive contamination area has been highlighted in Fukushima prefecture which has been afflicted by disasters such as earthquake, tsunami and nuclear power accident. Ministry of Agriculture, Forestry and Fisheries researched concentration of radioactive substances in mud and soil deposited at the bottom of dam and reservoir in Fukushima [1]. Underwater vehicle has become essential for decontamination under water, seabed resource exploration and so on . Based on not only above motivations but also applications in countless domain in underwater tasks for society, the footprint of research on underwater vehicle in our laboratory, therefore, has been explored especially with the cooperation of KOWA Corporation.

A number of researches on underwater vehicle using visual servoing have being conducted in world wide[2]. Most of them using different image processing techniques[3][4], are very limited when environment under water poses difficulties against image recognition such as disturbances by marine snow to image. To overcome these issues, visual servoing system utilizing image recognition using Model-based Matching method and Genetic Algorithm (GA) has been proposed[7]. The proposed system (underwater vehicle) can be regulated at desired position and pose through visual servoing. In order to assess the effectiveness of the proposed system against noises in camera images, this report presents how the dual-eye reactive image recognition system be robust against air bubble disturbances and how the visual servoing system maintains the servoing performance even through the bubbles disturb the image feedback.

2. Visual Servoing System for ROV

The proposed system does not involve IMU (Inertial Measurement Unit) using certain sensors to estimate the position and orientation information. Instead, Based on known information about target(size,shape), the target's position and orientation information are calculated through recognizing process using model-based matching method and Genetic Algorithm (GA). Model-based recognition approach is applied because of its performance in terms of less sensitive on camera calibration, comparing to other methods like feature based recognition in which the pose of the target object should be determined by a set of image points, complex searching the corresponding points and time consuming[5].

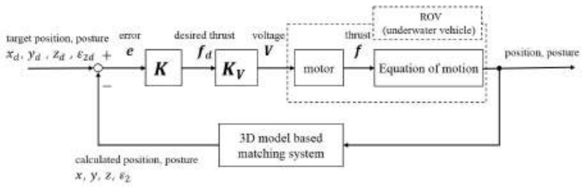

Fig.1 Block Diagram of Visual Servoing System

Fig. 1 shows the block diagram of the proposed control system. In this control system, the position and posture (x_d[mm], y_d[mm],z_d[mm], ϵ_{2d}[deg]) between the target and ROV are predefined so that the robot will regulate through visual servoing. Rotations around x and y-axes(ϵ_{1d}[deg], ϵ_{3d}[deg]) are neglected because of their less effectiveness to ROV's motion in this experiment. 3D position and posture of the target object are recognized by model-based matching method and GA. Finally based on the error between target value and recognized value, the control signal is generated using Proportional controller to keep the target position and posture. Overall processing is done in PC which is contacted to ROV by flexible cable. The underwater experiment is conducted in a pool filled with water.

2.1 Remotely Operated Vehicle (ROV)

Remotely Operated Vehicle (ROV) shown in Fig.2, manufactured by KOWA Corporation, is used for the proposed underwater experiment. Two fixed cameras (binocular camera) and four thrusters (traverse, horizontal and vertical direction) are installed in ROV. Maximum operating depth in water is 50[m].

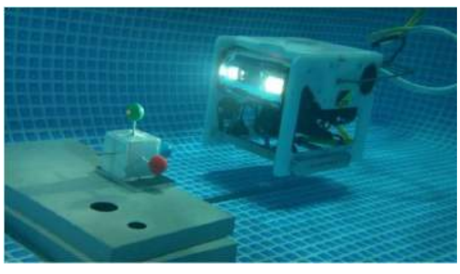

Fig.2 Underwater Vehicle

2.2 Feedback System using 3D Model-based Matching and Genetic Algorithm (GA)

Position and orientation of target object is estimated using model-based matching and GA based on known 6DoF (the position and orientation)of 3D model of the target projected to 2D image. Target object is consisted of three spheres (40[mm] in diameter) whose colors are red, green and blue. The target object is fixed to the constant position and posture during the experiment. It is assumed that the target object exists in the searching space.The recognition of vehicle ' s pose through three dimensional marker is executed by GA. GA provide faster recognition performance to the vision system to which every input image is evaluated by model-based fitness function, and the convergence of GA is realized in the sequences of dynamic images, which is named " 1- Step GA " . This method has been confirmed in our our previous researches[6][7][8]. The number of evolving generations in this experiment is 9 per 33 [ms] and the number of genes is 60.

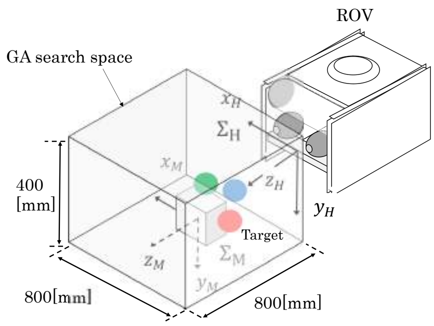

Fig.3 Searching Space in GA

2.3 Visual Servoing Controller

Proportional controller is considered as the main control to compensate the error between target value and recognized value. The control voltages of four thrusters are calculated by the following proportional control laws.

$$v_1 = k_{p1}(z_d - z) + 2.5 \quad (1)$$

$$v_2 = k_{p2}(\epsilon_{2d} - \epsilon_2) + 2.5 \quad (2)$$

$$v_3 = k_{p3}(y_d - y) + 2.5 \quad (3)$$

$$v_4 = \begin{cases} 5 & : x_d - x < -5 \\ 2.5 & : -5 < x_d - x < 5 \\ 0 & : 5 < x_d - x \end{cases} \quad (4)$$

where,v_1,v_3 and v_4 are the voltages for thrust of z-axis, yaxis and x-axis direction respectively. v_2 means the voltage for torque around y-axis. The control voltage(v_4) for x-axis direction is just on-off control. Based on not only motion equation and thrusters' characteristics but also experimental results, gain coefficients are tuned to have better performance in regulator process.

3. Experiments and Results

Even though the error from the relative target position and orientation appears constantly and the system operates the four thrusters simultaneously and constantly, recognition error changes with the water pressure due to reaction force during robot movement and reflected wave from the experimental pool sides. Besides, the appearance of bubbles in front of the three-dimensional marker is to perform as the main disturbance to recognition image as shown in Fig. 4.

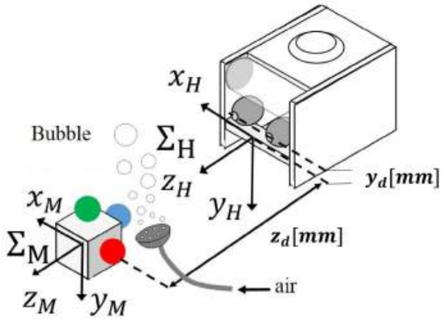

Fig.4 Experiment Layout with Coordinate Frames

According to the experimental result without disturbance as shown in Fig.6(left column),the fitness value rises up to more than 1 for the first few seconds of recognition process and maintains with the minimum value of 0.8. It is confirmed, therefore, that the recognition accuracy of GA is to be more than 0.5 of fitness value to perform visual servoing well.

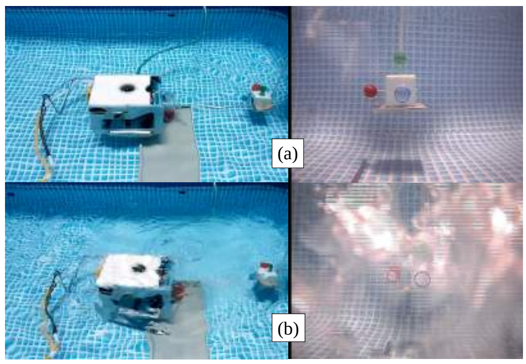

Fig.5 Experiment of visual servoing(a) without air bubble disturbance and (b) with air bubble disturbance

Fig.6(right column) shows the regulator performance with air bubble disturbance to image recognition. Variations in fitness value becomes larger comparing to the results without air bubble disturbance. Although the fitness value is reduced to about 0.4, it is confirmed that the underwater robot is regulated in relative target position and posture. Therefore, the proposed system has been verified to have the robust characteristics to return to the target position and posture.

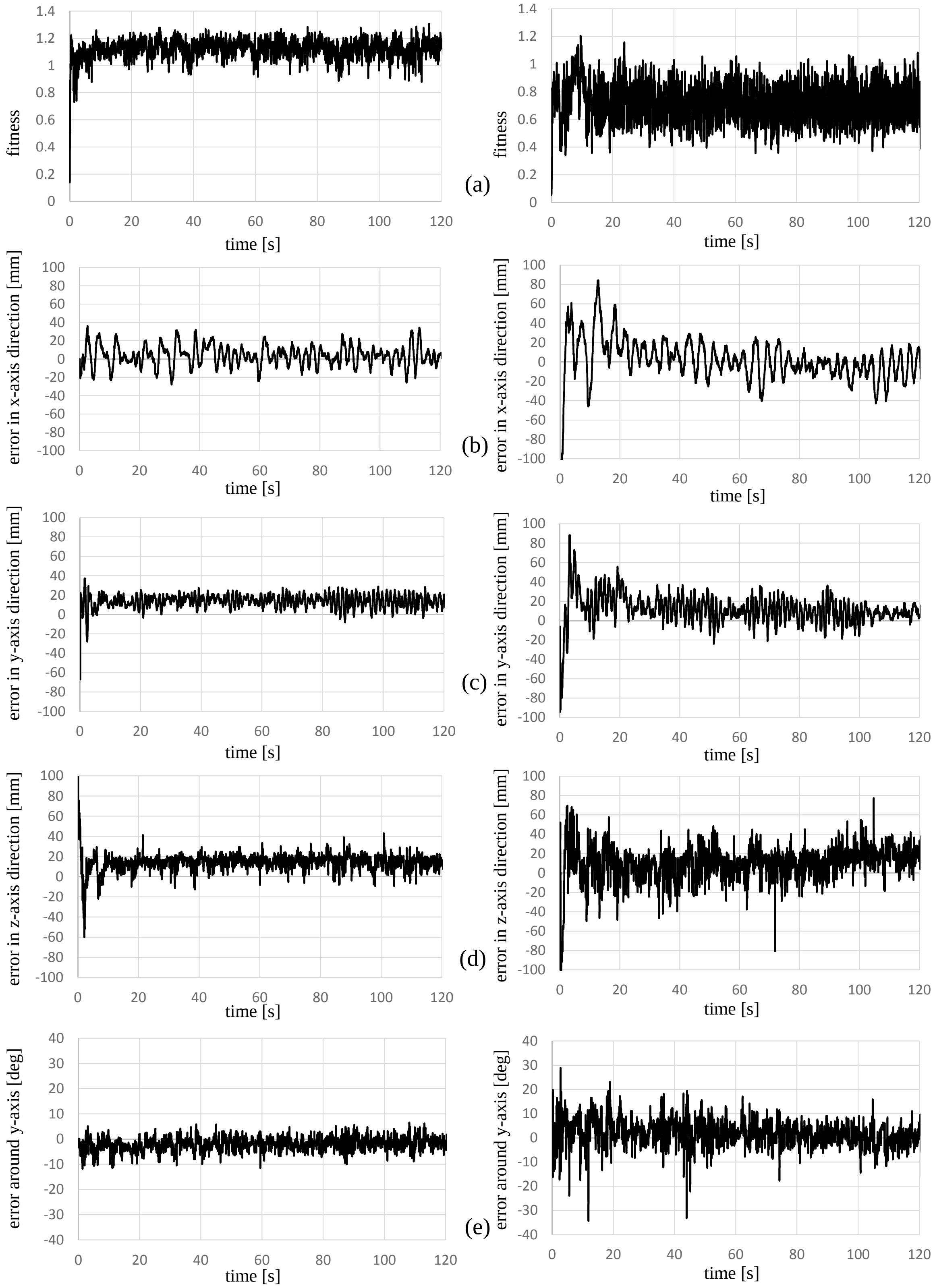

Fig.6 Regulator performance without additional disturbance(left column) and, with additional disturbance(right column) on image: (a)fitness value, (b)error in x-axis direction, (c)error in y-axis direction, (d)error in z-axis direction and (e)error around y-axis.

4. Conclusion

In this paper, visual sevoing system is proposed that focuses on the regulator performance with disturbance especially to recognized image. The system is evaluated for both with and without air bubbles disturbance. Results show that recognition process and regulator performance can be maintained using the proposed system even through there is air bubble disturbance to image. The system can control ROV for the proposed regulator function with good accuracy. It can therefore be said that the research equation related to the robustness of visual servoing against disturbance has been answered to some degree of solution with reasonable experimental results.

Reference

[1] Ministry of Agriculture, Forestry and Fisheries of Japan: "Recent status and provision of radiation contamination in FUKUSHIMA ponds", http://www.maff.go.jp/j/kanbo/jphp/saigai/pdf/tyukan.pdf(2013).

[2] Feihu Sun, Junzhi Yu and De Xu: "Visual measurement and control for underwater robots: A survey", Control and Decision Conference (CCDC), pp. 333 - 338, 2013.

[3] Foresti G.L., Gentili S. and Zampato M.: "A vision-based system for autonomous underwater vehicle navigation", OCEANS '98 Conference Proceedings, Vol.1, pp. 195 - 199, 1998.

[4] Balasuriya, B.A.A.P, Takai, M., Lam, W.C., Ura, T. and Kuroda, Y.,: "Vision based autonomous underwater vehicle navigation: underwater cable tracking", OCEANS '97. MTS/IEEE Conference Proceedings, Vol.2, pp. 1418 - 1424, 1997.

[5] Maeda. Y, Xu. G,: "Smooth Matching of Feature and Recovery of Epipolar Equation by Tabu Search", IEICE, Vol.J83- D-2, No.3, pp.440-448, 1999.

[6] Suzuki. H, Minami. M,: "Visual Servoing to Catch Fish Using Global/Local GA Search", IEEE/ASME Transactions on Mechatronics, Vol.10, Issue 3, pp 352-357, 2005.

[7] Yu F., Minami M., Song W., Zhu J. and Yanou A.: "On-line head pose estimation with binocular hand-eye robot based on evolutionary model-based matching", Journal of Computer and Information Technology, Vol.2, No.1, pp.43-54, 2012.

[8] Song W. and Minami M.: " 3-D Visual Servoing Using Feedforward Evolutionary Recognition", Journal of the Robot Society of Japan, Vol.28, No.5, pp.591-598 (in Japanese), 2010.