Development and Control of Unmanned Floating Observer (UFO) for Inspection of Irrigation Tunnel and Canal

○ Taiga YOKOTA, Tokyo Metropolitan University
Yasunari FUJIMOTO, Tokyo Metropolitan University
Ryota INOUE, Tokyo Metropolitan University
Cheng TANG, Tokyo Metropolitan University
Weihong CHIN, Tokyo Metropolitan University
Naoyuki KUBOTA, Tokyo Metropolitan University
Naoyuki TAKESUE, Tokyo Metropolitan University
Shinichi TAKARABE, Walnut Ltd.
Koji SHIN, Walnut Ltd.
Yoshiyuki OKIYASU, Walnut Ltd.

***Key Words*:** Robot on water, Self-position, Inspection robot, Omnidirectional movement

1 Introduction

Many major irrigation tunnels and canals in Japan have been deteriorated for more than several decades after construction. In order to efficiently maintain and manage these waterways in the future, it is essential to periodically investigate the shape of the entire waterway by visual inspection survey, and to evaluate it based on the survey results[1].

However, there are facilities that are watered all year and cannot be easily cut off, and periodic inspections are difficult. Therefore, robots have been developed for inspection of waterway, which is difficult to cut off water. It is assumed that the investigation by the present robot is releasing the robot from the upstream entrance of the irrigation tunnel and collecting it at the downstream opening. In the conventional robot[1], the rotation of the hull is controlled so that the camera faces always directly against the side wall and the top wall surface, but it is not equipped with a thrust device, and the position in the waterway is not controlled. To improve the reliability of diagnostic data, an angle control for heading the flow direction of the waterway and a position control for positioning in the center of waterways are needed, as shown in the Fig. 1.

Therefore, we have developed a robot on water that can move in all directions for self-position control. Target waterways are closed facilities such as tunnels. So, it is difficult to obtain location information by GPS. Therefore, self-position control is performed based on the shape of the waterway. Since the shape of waterways may be complicated due to landslides and plants, a self-position estimation method that corresponds to curves and irregularities is required.

2 Developed Robot System

The developed robot "UFO" is shown in Fig. 2(a). The robot is equipped with LRF and PC for self-position estimation. In addition, the robot is controlled by four thrusters attached to the lower part of the robot based on the self-position estimation result. The arrangement of four thrusters is shown in Fig. 2(b). It is possible to move forward, back, left, and right, and rotate on the spot by combining the propulsion vectors.

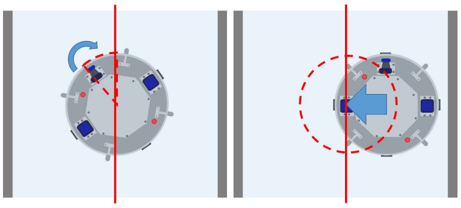
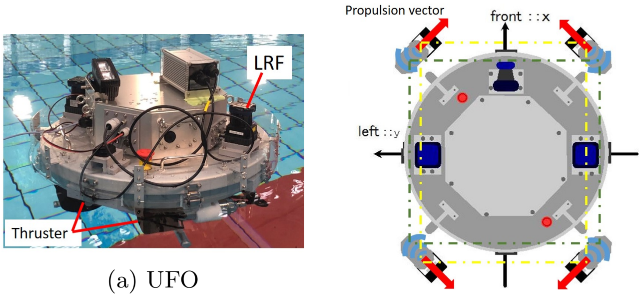


Fig.1: Control angle and position of the robot



(a) UFO

(b) Thruster arrangement

Fig.2: Developed robot

3 Self-position Estimation Method

3.1 Previous method

Fig. 3 shows the self-position estimation method in the previous study[2]. First, a linear approximation is performed for point cloud data on the left and right. The difference between the slope of the center axis of the robot and the slope of the obtained approximate straight lines is the relative angle between the robot and the wall surface. In other words, the robot should be controlled so that the approximate straight line is parallel to the center axis of the robot. Second, the distances from the center point of the robot to the approximate straight lines corresponding to the two walls (distances 1 and 2) are calculated. Then the difference between distances 1 and 2 means a deviation from the center. Therefore, the robot should be controlled so that distances 1 and 2 are equal. In this method, however, it is necessary to approximate the point cloud data in a straight line. If it is applied to the curved wall, an inadequate estimation would be obtained.

3.2 Proposed method

Fig. 4 shows a new self-position estimation method to accommodate curved walls. First, diagonal points between robots are connected as shown in Fig. 4(a). As a result, various diagonals can be obtained through the center of the robot, such as diagonal lines 1 to 3. Second, we focus on the shortest diagonal (diagonal 2) such as Fig. 4(b). This diagonal line is always perpendicular to the flow direction of the canal. Therefore, the angle between the diagonal 2 and the center line of the robot is the relative angle between the robot and the wall surface, and the robot can face the flow direction of the canal

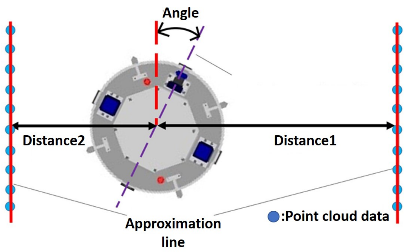
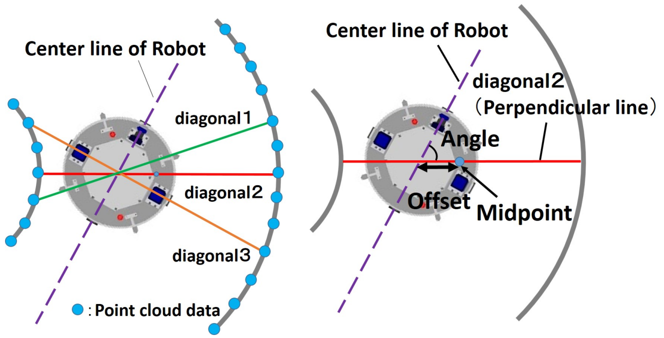


Fig.3: Self-position estimation of the previous study



(a) How to find the diagonal

(b) Perpendicular line and self-position

Fig.4: Self-position estimation of the proposed method

Fig.5: Plants in the waterways

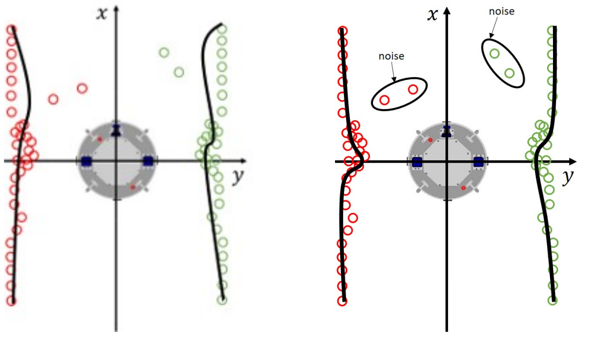
by controlling this angle to 90°. Furthermore, the distance between the center of the robot and the middle point of diagonal 2 is a deviation from the center because the middle point of diagonal 2 is the center of the canal. So the robot can be located in the center of the canal by controlling it to reduce misalignment. Thus, since the newly developed method does not require a linear approximation, it is possible to correspond not only to straight walls but also to curved walls.

4 Dealing with plants

In this section, we describe how to deal with the presence of plants on the wall surface. It was confirmed that the accuracy of the self-position estimation was deteriorated if there are plants on the wall as shown in Fig. 5. Therefore, a method for removing disturbances using approximate curve is developed. The specific steps are shown as below.

1. The point cloud data is roughly divided into two parts.
2. The approximate curve is calculated for each divided point cloud data(Fig. 6(a)).
3. After excluding the point cloud data distant more than a certain value from the approximated curve, the approximated curve is recalculated(Fig. 6(b)).
4. Self-position is estimated by considering the approximated curves calculated in the previous step (3) as walls.

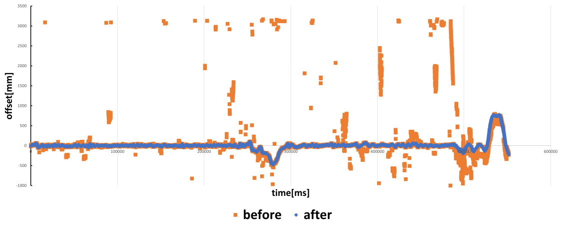
Fig. 7 shows the simulation results based on the new method using the log data of the waterway experiment conducted by the previous method (Fig. 5). As seen from Fig. 7, it was confirmed that the self-position can be estimated without skipping the values of both angle and offset. Therefore, it is considered that more accurate self-position control can be performed by using the new method.



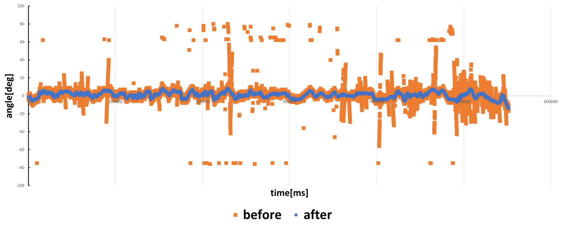
(a) Curve approximation

(b) Disturbance removal

Fig.6: Dealing with plants



(a) offset



(b) angle

Fig.7: Results of self-position estimation

5 Conclusion

We have developed a robot for unmanned inspection of canals and proposed the newly self-position estimation method. As a result of simulation, it could estimate the self-position even when there were curves and plants. It is expected that the control precision of the robot can be improved to about 100 mm. In the future, we extend the self-position estimation method so that it is applicable in case where only one wall is detected.

Acknowledgments

We would like to thank everyone involved in the Japan Water Agency for their cooperation.

References

[1] M. Mori, et al.: Evaluation of Applicability of the Continuous Scanning System for Irrigation Tunnel Lining, Technical Report of the National Institute for Rural Engineering, No.218, pp.51-63, 2016. (in Japanese)

[2] Y. Saito, et al.: Development of Robot System for Inspection of Tunnel Lining, Proc. SICE-SI2019, 3C5-07, 2019. (in Japanese)