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A Fusion Positioning System of Long Baseline and Pressure Sensor for Ship and Harbor Inspection ROV

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Abstract

The maintenance of a ship is essential for safe navigation and hence regular surveys are prescribed according to the rule of classification societies. A hull inspection is generally performed by professional divers, but it takes a long time and the efficiency is low in terms of time and cost. In this research, a ROV(Remotely Operated Vehicle) named as SNU-ROV(Seoul National University-ROV) is developed to replace the conventional inspection method. In this system, the ROV is intended to be used for inspecting ship and harbor because harbor inspection is merging as a safety measure against any possible terror actions. In order to increase the efficiency of inspection, the ROV must be able to measure the exact position of damages. SNU-ROV has a positioning system based on LBL(Long Base Line). In shallow water such as harbor, however, LBL has bad DOP(Dilution of Precision) in the depth direction due to the limited depth. Thus LBL only can not locate the exact depth position. To solve the DOP problem, a pressure sensor is introduced to LBL and a complementary filter is attached by using indirect feedback Kalman filter. Thus developed positioning system is verified by simulation and experiment in towing tank.
Keywords: ROV(Remotely Operated Vehicle), LBL(Long Base Line), harbor inspection, kalman filter, positioning system

1 Introduction

The maintenance of a ship is essential for safe navigation and hence regular surveys are prescribed according to the rule of classification societies. The Inspection of ship hull is aimed to identify whether there are any damages and where they are, if any. Furthermore ship and harbor inspection is merging as a safety measure against any possible terror actions. As a result, ship and harbor inspection becomes more important work. However, currently professional divers inspect ship hulls, but it takes a long time and the efficiency is low in terms of time and cost. For example, it takes about a week to inspect a medium size cargo ship with 6 or 7 divers, because the diving time is restricted according to HSE

(Health and Safety Executive) regulations. In order to meet the inspection demand and the efficiency, a ROV with a camera can be applied to the inspection.

In this work, SNU-ROV is developed to replace the conventional inspection method. In order to apply to the inspection, the ROV must be able to measure the exact position of damages. LBL is a common method for underwater positioning. In shallow water such as harbor, however, LBL has bad DOP in the depth direction due to the limited depth. Thus LBL only can not locate the exact depth position. To solve the DOP problem, a pressure sensor is introduced to LBL and a complementary filter is attached by using indirect feedback Kalman filter.

2 SNU-ROV

Figure 1 shows the main body and Table 1 gives the specifications of SNU-ROV. The main frame of the ROV is made of stainless steel. The pressure can and the camera can are made of acryl. As shown in Figure 2, the ROV moves forward using 2 horizontal thrusters, vertically using the vertical thruster and it weaves using the lateral thruster.

The main power of 45V DC is supplied from outside and the ROV communicates with the host PC through RS-485, which is suitable for a long distance communication.

Table 1: Specification of SNU-ROV

Length (m)	0.65
Breadth (m)	0.44
Height (m)	0.62
Weight (Kg)	34(air), 0(water)
Propulsion	F: 150W DC motor ×2 V: 150W DC motor ×1 L: 150W DC motor ×1
Main POWER	1500 W
Can Material	Pressure: Acryl (t=25mm) Camera: Acryl (t=10mm)
Frame Material	Stainless Steel
Max. Depth(m)	50
Umbilical Cable(m)	200
Equipment	Camera ×2, Inclinometer ×2, Laser ×2, LED, Pressure sensor, Pinger

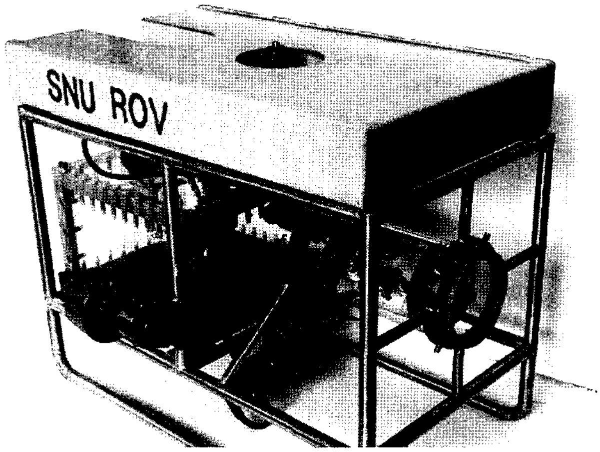

Figure 1: Main body of SNU-ROV

Forward and side cameras with LED lights in Figure 2 are installed in front of the ROV and give the image of ship and harbor. Two laser pointers of the side camera assist to measure the size of the damage and are used for calculating the relative position with ship and harbor.

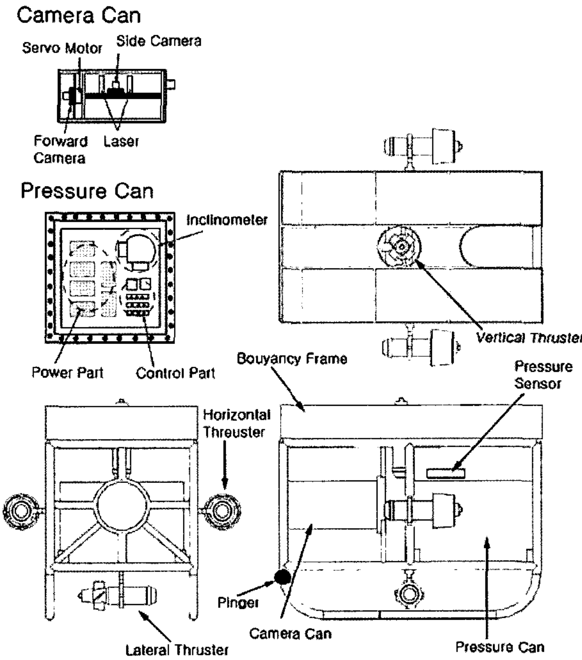

Figure 2: Detail draft of SNU-ROV

The main board shown in Figure 3 communicates with the host PC and controls the thrusters and sensors in response to the command from the host PC. 48V DC from outside is converted to 5V and 12 V for sensors, LED, cameras and other electrical system.

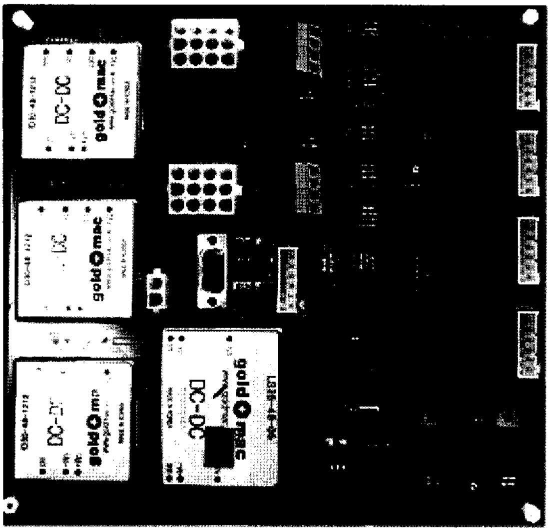

Figure 3: Main board of SNU-ROV

3 Positioning system of SNU-ROV

Possible damage and danger must be reported with the accurate position in order to manage the damage and danger. As a result, the positioning system of the ROV is the most important part for ship and harbor inspection.

The positioning system of SNU-ROV is based on LBL as shown in Figure 4. The pinger of the ROV sends signals and the receivers of PRUs (Position Reference Unit) measure the flight time of the signal, which can calculate the distance between the ROV and PRUs. The PRU consists of a buoy, a weight and an acoustic receiver and gives the position reference using GPS. As a result, the position of the ROV can be measured using triangular method as sketched in Figure 6.

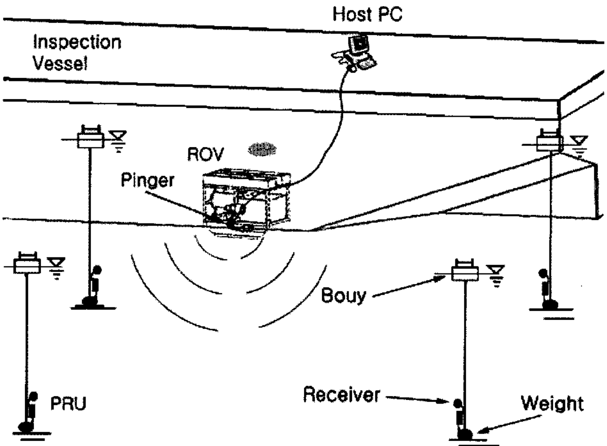

Figure 4: Positioning system of SNU-ROV

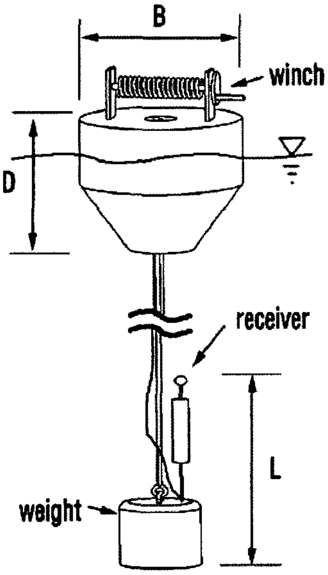

Figure 5: PRU

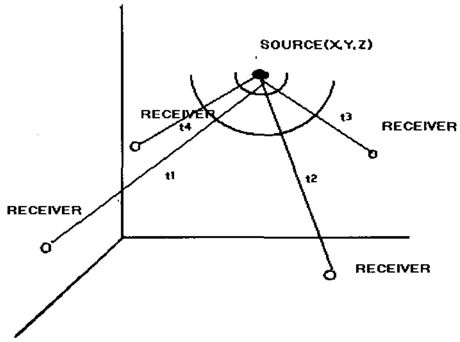

Figure 6: Triangular method

Table 2 shows the specification of the acoustic receiver. Considering the operation range and the arrangement convenience, the center frequency and directivity of the receiver is designed.

Table 2: Specification of acoustic receivers for SNU-ROV

Frequency	70 kHz
Source Level	148 dB re. 1uPa/V at 1m
Bandwidth	15 kHz
Receive sensitivity	-201 dB re.1V/uPa
Horizontal beamwidth	all hydrophones are omnidirectional +2dB
Vertical beamwidth	all hydrophones are omnidirectional +4dB
depth ration	1500 m
In water impedance	200 Ω
capacitance at 1kHz	8500 pF
dry weight(inc.cable)	0.18 kg

4 Fusion of LBL and pressure sensor

DOP is a GPS term used in geomatics engineering to describe the geometric strength of satellite configuration. As shown in Figure 7, DOP can be applied to LBL system because it is based on triangular method like GPS. In shallow water, where ship and harbor inspection is performed, the vertical DOP is poor compared with the horizontal DOP. As a result, depth information can be disturbed by noises of LBL system.

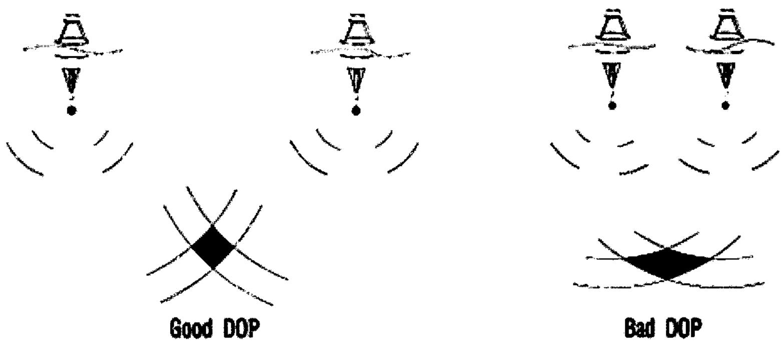

Figure 7: DOP comparison

In this paper, a complementary filter is designed in order to enhance the accuracy in shallow water. The complementary filter to combine depth sensor and LBL is designed using the indirect feedback Kalman filter as shown in Figure 8.

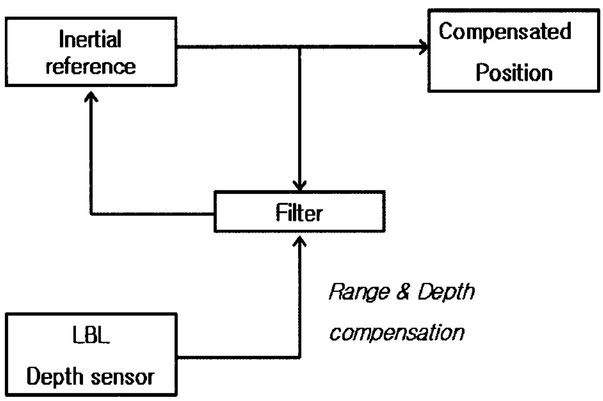

Figure 8: Complementary filter for positioning system

4.1 Stationary positioning experiment

In order to demonstrate the improvement using the positioning system of LBL and depth sensor, a stationary positioning experiment is carried out in towing tank.

Figure 9 and 10 show the experimental conditions and experimental results from standalone LBL system. Circles in Figure 9 and 10 show the positions of pingers and 1~4 shows the positions of receivers. In Figure 9 and 10, z-positions of pingers are different from the exact positions. Figure 11 shows measured data from depth sensor and z-positions compensated by the complementary filter. As shown in Figure 11, z-positions from the complementary filter are well coincided with the exact positions.

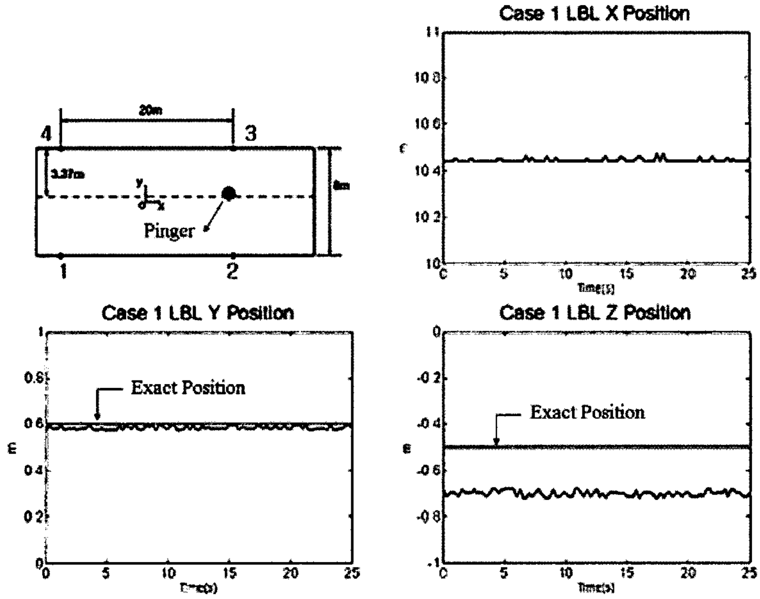

Figure 9: Result of stationary positioning experiment (LBL alone), case 1

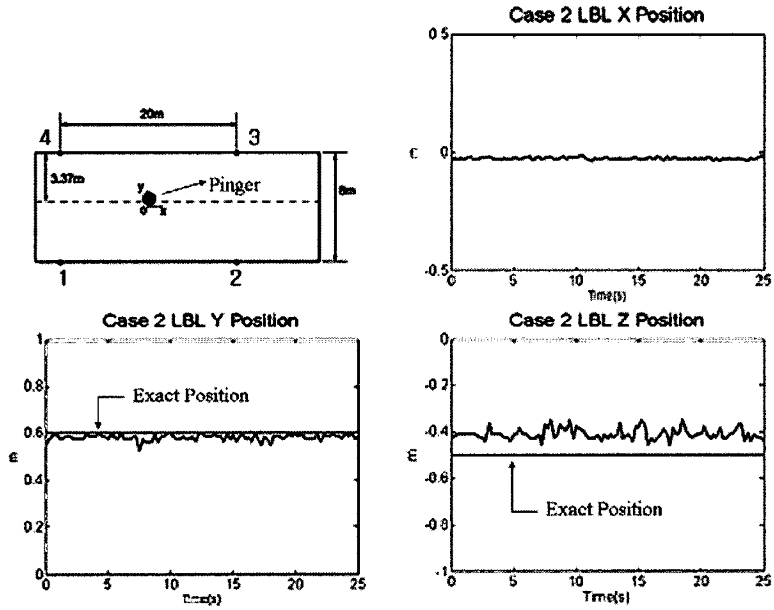

Figure 10: Result of stationary positioning experiment (LBL alone), case 2

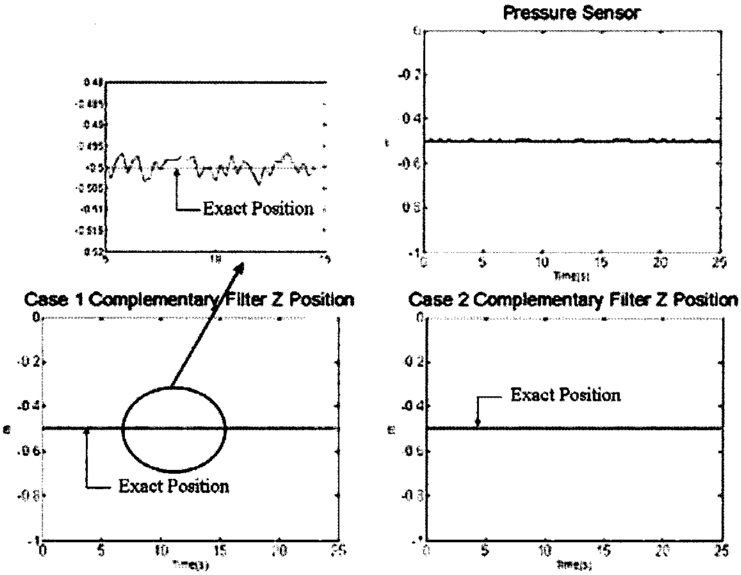

Figure 11: Result of stationary position experiment, with LBL Add pressure sensor

4.2 Tracking experiment

Figure 12 and 13 show the experimental condition for tracking experiment. The moving pinger is used for this experiment. The carriage is used for giving the exact course of the pinger, which is fixed to the carriage. The exact position of carriage is given from the mechanical sensors, such as an odometer.

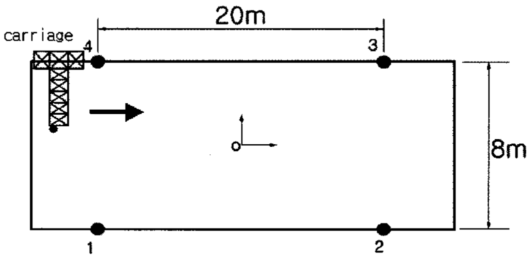

Figure 12: Receivers arrangement for tracking experiment

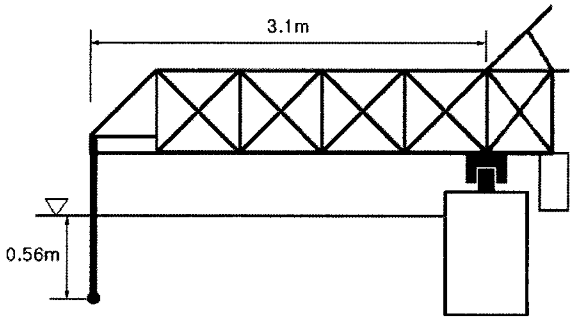

Figure 13: Installation of the pinger for tracking experiment

Figure 14 and 15 show the experimental result. Errors shown in the result are caused by the multi-path error, which comes from the reflection of the acoustic signal. Except the multi-path error, the position well agrees with the exact position which is marked as red line.

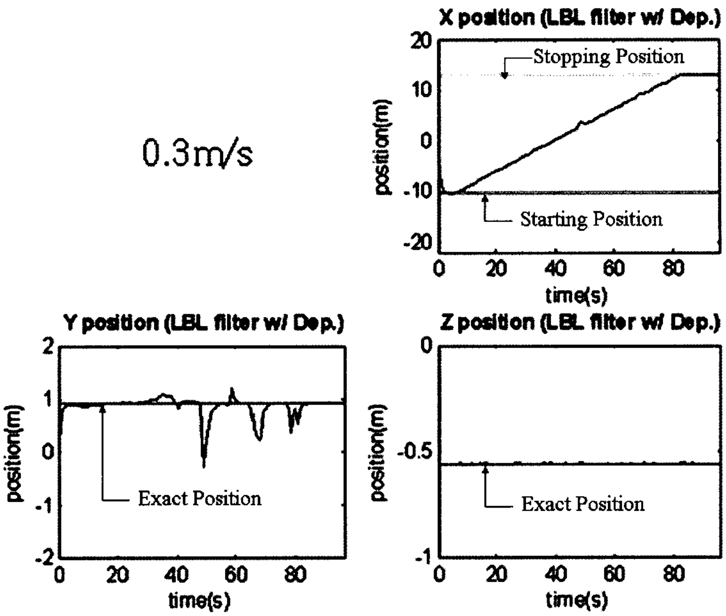

Figure 14: Result of tracking experiment, 0.3m/s

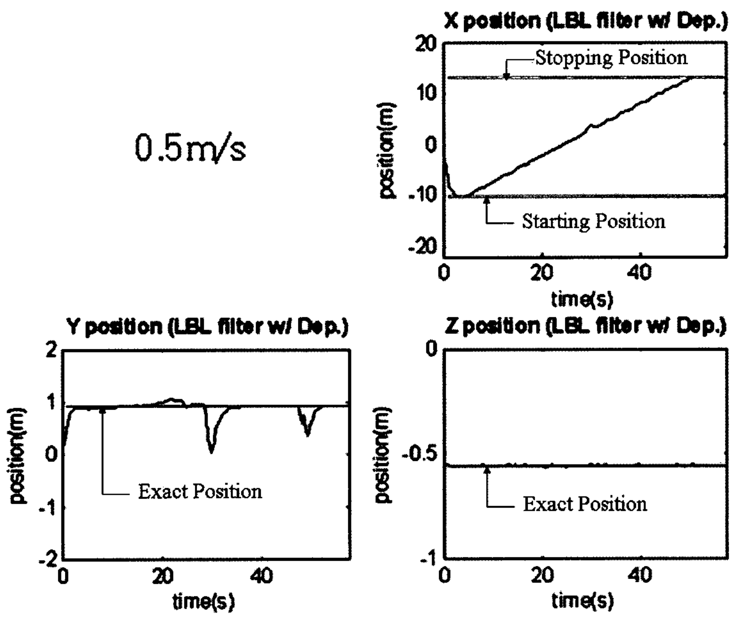

Figure 15: Result of tracking experiment, 0.5m/s

4.3 ROV positioning experiment

Positioning system installed to the ROV is examined in towing tank. As shown in Figure 16, the pinger fixed to SNU-ROV sends the signal and the positioning system estimate the position of SNU-ROV in real-time. The exact position of SNU-ROV was not measured.

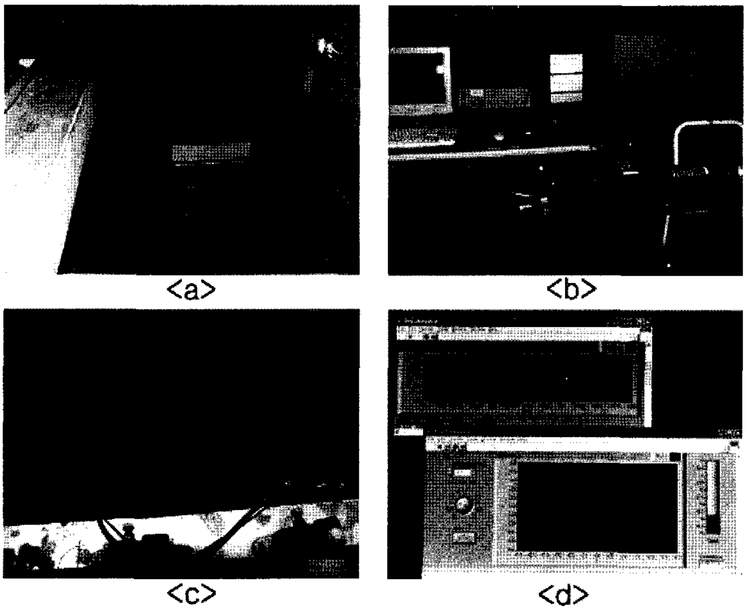

Figure 16: Positioning experiment in towing tank

Figure 17 shows the experimental result. The arrow shows the moving direction of the ROV. In Figure 17, two distinct points are shown. The position difference is due to the multi-path error. Some obstacles in tank such as pipes block the signals. Except those points, the position of the ROV is well measured. In order to increase the accuracy and applied to the practical use, multi-path error has to be removed.

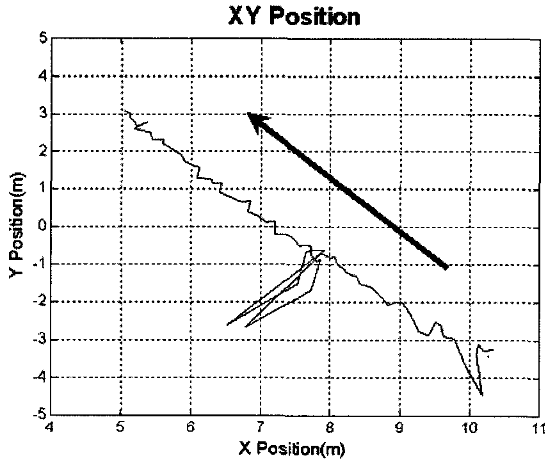

Figure 17: ROV trajectory result

5 Conclusion and future work

The positioning system for ship and harbor inspection ROV based on LBL system is developed. In order to increase the accuracy of the positioning system in shallow water, a complementary filter is designed using the indirect feedback Kalman filter. Various positioning experiments are performed in towing tank and show the improvement of accuracy. In order to reduce the error from multi-path problem, the elimination algorithm is now under development.

Acknowledgements

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