<Development of maritime unmanned autonomous navigation system>

<Legacy 2014>

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Abstract

Researches on maritime unmanned autonomous navigation system have been performed actively with necessity in many situations such as sea rescue in severe weather, oceanographic investigation, ocean surveillance, etc. In naval architecture field, studies on integrating information and communication technology (ICT) into ships have been conducted but achievements from those studies are yet insignificant.

In this study, we developed independent maritime unmanned autonomous navigation system and adjusted it to a small ship. This system includes sensing (GPS, GYRO, Vision, LIDAR), propulsion and control programs.

1. Introduction

Our team name 'Legacy 2014' is intended to follow creative challenging spirit of Ju-yung Chung, the first chief director of the foundation of the University of Ulsan (UOU), and to raise the conscience solidarity among the youth and to share innovative ideas with them. This challenge seems to be a very good opportunity to learn about maritime autonomous robotic systems and develop them consistently with superb universities and institutions.

We used LabVIEW from National Instruments Corporation for the system coding and developed coding for each task and combined them afterward.

2. Technical Approach

2.1 Composition of maritime unmanned autonomous navigation system

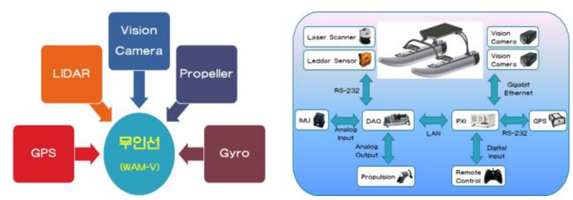


Figure 1 Composition of maritime unmanned autonomous navigation system

Figure 1 shows the composition of the unmanned autonomous system. Real-time embedded distributed control, PXI System and Compact RIO, from National Instruments, Inc. is used. Sensors for recognizing obstacles and cameras for recognizing shapes and color patterns are installed. GPS for securing current position is composed by using serial communication. GYRO which IMU(Inertial Measurement Unit) is built in is installed using analog signal to get the heading value of the ship.

Also propellers equipping motor driver autonomously are used as a propulsion system.

Figure 2 WAM-V

Figure 2 shows the arrangement of WAM-V and Table 1 shows the principal dimensions of WAM-V.

Table 1 Principal dimensions of WAM-V

Beam	2.43m (96”) [outside to outside]
Overall Hull Length	3.94m (154”)
Ski Length	2.84m (112”)
Hull Diameter	0.42m (16.75”)
Payload	136kgf (300 lbs) max.
Full Load Displacement	248kgf (547 lbs)
Draft	0.16m (6.5”, estimated)

Figure 3 shows the simplified control algorithm for the maritime unmanned autonomous navigation system. A sensor sends data to DAQ and then DAQ gives feedback on the coding like path planning and avoiding obstacles and output data is gained and give it to the DC servo.

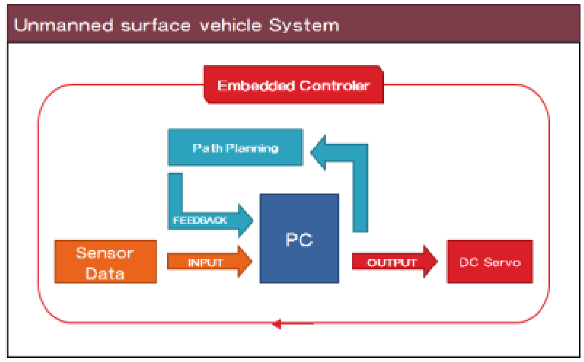


Figure 3 Simplified control algorithm of maritime unmanned autonomous system

2.2 Equipment of maritime unmanned autonomous system.

Product	cRIO-9022 Real-Time PowerPC Embedded Controller
Form factor	CompactRIO
Processor	533 MHz PowerPC
Memory	256 MB
Product	NI 9205
Type	Analogue Input(±10)
Isolation	Channel – ground Isolation
Channel	16, 32 channel
Resolution	16 bit
Sampling rate	250 kS/s
Product	NI 9263
Type	Analogue ouput(±10)
Isolation	Channel – ground Isolation
Channel	4
Resolution	16 bit

Figure 4 Embedded controller

Figure 4 shows the embedded controller of National Instruments Corporation. We use cRIO-9022 Real-Time PowerPC Embedded Controller and NI 9205 for input and NI 9263 for output.

Model	Minnkota, RT80/EM
Thrust	36.3kgf(80 lbs)
Input V	25V(DC)
Current	60A

Figure 5 Propeller

Figure 5 shows the propeller RT80/EM from Minn kota with 0.5 horse power as the propulsion system

Model	Hemisphere VS330
Channel	L1 GPS
Features	Fast acquisition times
	5 cm rms enabled heave accuracy

Figure 6 GPS

Figure 6 shows GPS VS330 from Hemisphere. This receives the signals through the two antennas. An error range of this is 0.7 meters but we found it is around 2 meters from the test.

Leddartech IS16
16 independent segments with simultaneous acquisition capabilities
45-degree beam, for optimized field of view
0 to 50 meter detection
Rapid data acquisition rate — 50 Hz
IP67 weather-resistant enclosure
Best cost/performance ratio

Figure 7 LIDAR

Figure 7 shows LIDAR IS16 from LeddarTech. This device is used for the obstacle detection. It divides 45 degrees into 16 segments. The detection range of this is 50 meters maximum and this is water-proof.

Model	Basler Ace GigE Vision
FPS	50 fps
Resolution	2048 x 1088
Input	Gigabit cable

Figure 8 Vision camera

Figure 8 shows Basler Ace GigE Vision camera from Basler. This device is used for the color and pattern recognition. It has 50 fps, 2 million pixels and uses Gigabit interface.

Model	Xbox 360
Input type	Digital Input
Signal Range	10m

Figure 9 Controller

Figure 9 shows the controller from Xbox. This device is used for manual control of USV and is of wireless type. We changed the wireless type into the USB type because the receiver of the wireless type couldn't get the signal from the controller at far distance.

2.3 Development of maritime unmanned autonomous navigation system

We have developed a maritime autonomous navigation system with Graphic User Interface using LabVIEW for our USV. This system is divided into three step, recognition, calculation, order. In the recognition step, the system recognizes the current position and the target position using GPS, obstacles through the path using

LIDAR, colors and patterns using vision camera. In the calculation step, the path is calculated using data from the recognition step. In the order step, orders are given to the propulsion system to move through the calculated path.

In the recognition step, the latitude and the longitude of the current position are gained from GPS. Obstacles are recognized using LIDAR and the azimuth of the vessel is detected using GYRO. In the calculation step, grids which both latitude and longitude as units from the current position are made and the obstacles recognized by LIDAR are mapped on the grids and all paths are calculated from the current position to the goal position and then the optimized path is selected.

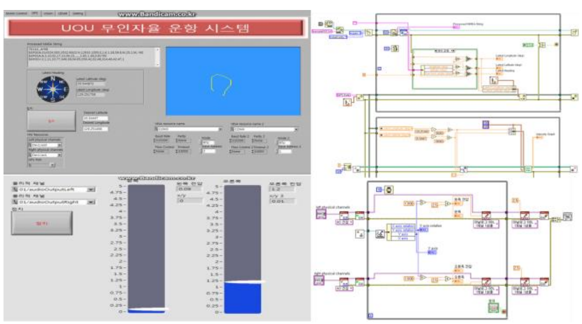


Figure 10 Navigation and control

Figure 10 shows our code for navigation and control. The left shows the front panel and the right shows the block diagram. The yellow line in a blue box shows the trajectory of our vessel and the red point represents the vessel. The blue bars of the control panel indicate propeller controller voltages under remote control.

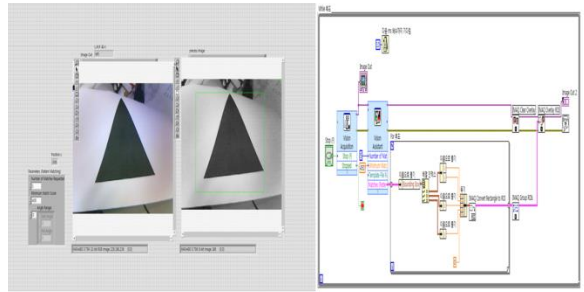


Figure 11 Shape identification

Figure 11 shows the block diagram and the front panel for shape identification. Two windows of the front panel are the original camera vision and the processed picture, respectively.

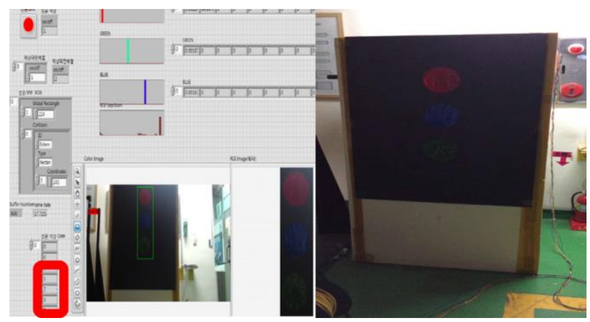


Figure 12 Color identification

The graph in Figure 12 indicates a color spectrum of the region of interest and the red box indicates the processed vision data.

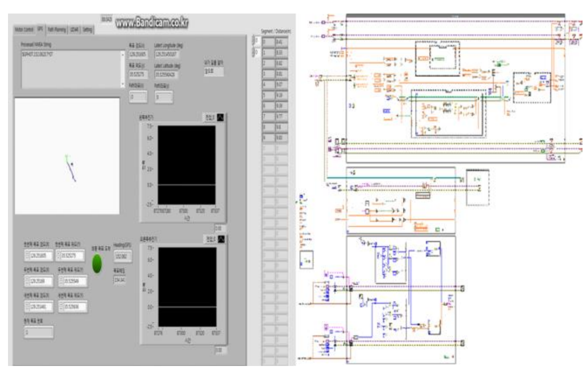


Figure 13 Detecting and avoiding obstacles

Figure 13 shows the block diagram and the front panel for detection and avoidance of obstacles.

3. Test

This test is performed to develop the maritime unmanned autonomous navigation system. The main purpose of the test is to make the vessel avoid the obstacle and arrive to the target position accurately. The tests were carried out both in the Ocean Engineering Wide Tank, UOU in Figure 14 and in the Doohyun Water Reservoir near university.

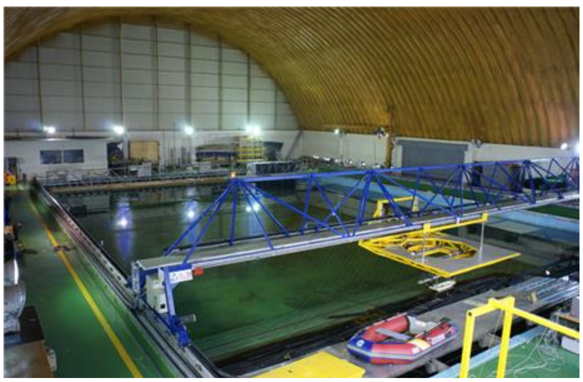


Figure 14 Ocean engineering Wide Tank, University of Ulsan (UOU)

Figures 14 and 15 show the picture of the Wide Tank where most tests are performed and the Doohyun Water Reservoir near UOU.

Figure 15 Doohyun Water Reservoir near UOU

Before carrying out the on-site tests with WAM-V, we installed the equipment on a small rubber boat in Figures 14 and 17 and performed the test with this boat in the Wide Tank. We set up a path of which shape is like U and located the vessel at the four angular points using the remote control system and saved the GPS coordinate values and then inserted them into the navigation system and checked whether the unmanned navigation was successful or not.

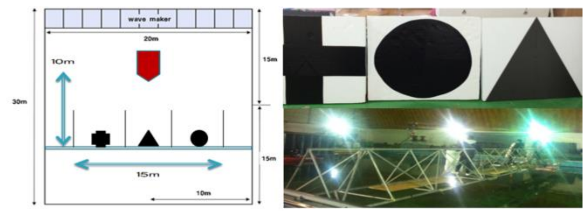


Figure 16 Shape identification test

At the shape recognition test, we prepared triangle, cross and circle shape and installed them at intervals of 5m on the sub carriage of the Wide Tank and performed the test 10 m away from the center of sub carriage using the boat with a camera as in Figure 16. At the color recognition test, we made a light tower taking turns in showing red, blue, and green colors at intervals of 0.5 seconds.

Figure 17 On-site test in Doohyun Reservoir using a rubber boat

After tests at the Wide Tank, we performed on-site tests in Doohyun Water Reservoir under similar test conditions and received GPS data and applied it to the system. We installed the devices on the rubber boat in Figure 17 instead of WAM-V and carried out the obstacle avoidance test with both manual control and autonomous control.

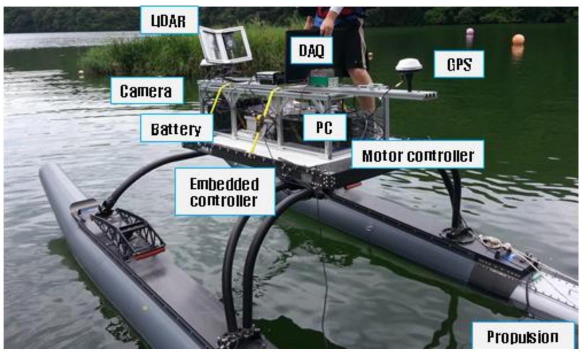


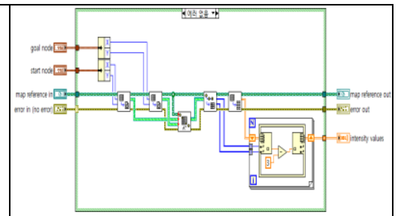
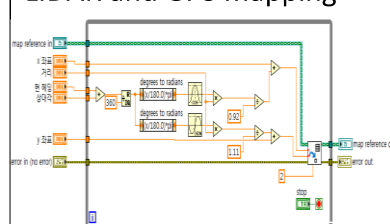
Figure 18 On-site test in Doohyun Reservoir using WAM-V

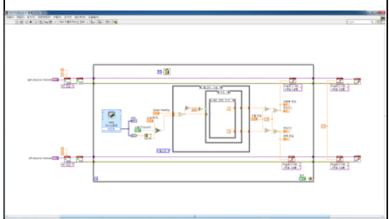
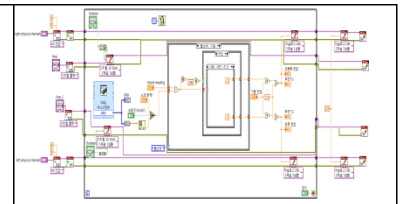
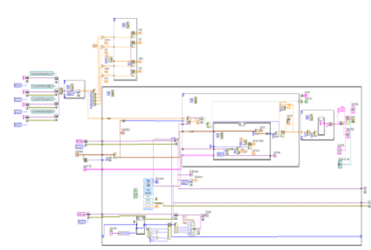
After tests with the rubber boat, we installed the devices on WAM-V. First, we checked if WAM-V moved forward in a straight path autonomously when GPS data was input. Also we put several buoys on the path and checked if WAM-V could avoid obstacles. And then we confirmed that WAM-V was autonomously operated well in each task.

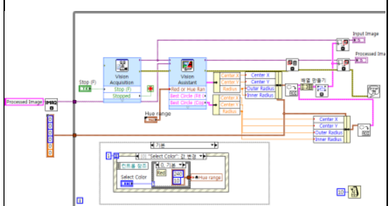
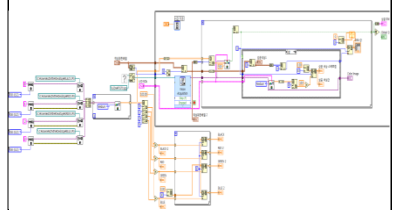
Development History

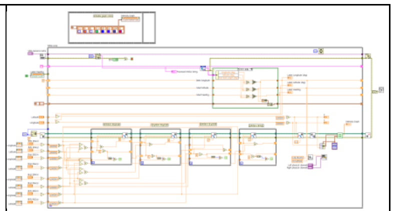
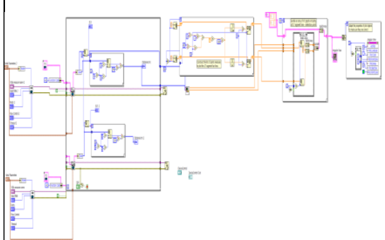
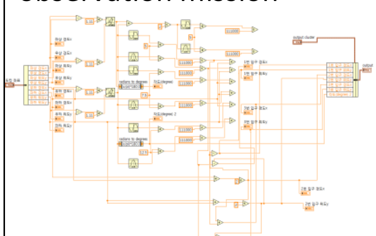
01/NOV/13	Meeting with professor
04/NOV/13	Understanding of competition rules
05/NOV/13	Meeting with NI (Check equipment specification)
11/NOV/13	Check camera specification
12/NOV/13	Search for references about obstacle avoidance
14/NOV/13	Study LabVIEW (Avoidance Algorithm)
15/NOV/13	Meeting with NI (GARMIN GPS Interface possible with LabVIEW)
18/NOV/13	Equipment investigation (LIDAR)
19/NOV/13	Equipment investigation (GPS)
26/NOV/13	Study (Dead bond, DAQ, laser sensor)
02/DEC/13	Study about unmanned car system
23/DEC/13	Experiment idea with a small boat
24/DEC/13	Meeting (Determination of equipment)
03/JAN/14	Meeting with GPS sales company
07/JAN/14	Take a lecture about SPSS
08/JAN/14	Take a lecture about GPS
09/JAN/14	Purchase camera for test and test camera
10/JAN/14	Vision shape recognition test

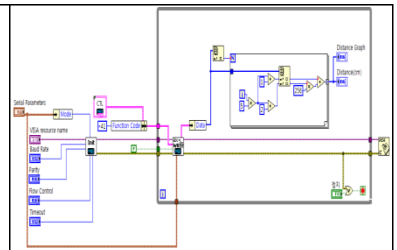
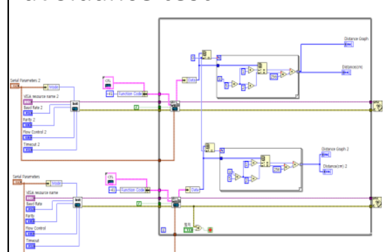
11/JAN/14	Shape and color identification (Think how to express each color)
13/JAN/14	Shape identification (No identification from a distance), Order LIDAR and propeller
14/JAN/14	Check the possible distance for shape identification, Make light bar
15/JAN/14	Check angle of view and motion identification of camera
16/JAN/14	Meeting with NI (PWM control, no GYRO heading value, LIDAR test)
20/JAN/14	Study AD star basic
20/JAN/14	Purchase of propeller 
22/JAN/14	Meeting with competition participants
23/JAN/14	Modelling propeller bracket using CATIA
24/JAN/14	Coordinate set up for region of interest
25/JAN/14	Color matching test from real time image information
27/JAN/14	Obstacle recognition coding using ASTAR code

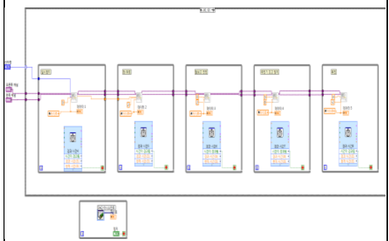
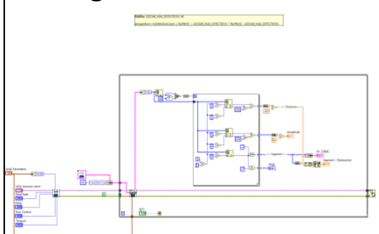
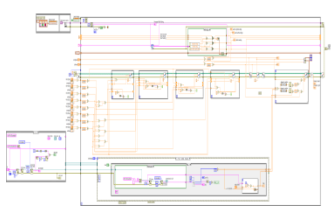
	
04/FEB/14	Product WAM-V prop, PID control, propeller control test with joystick
05/FEB/14	propeller control test with joystick
06/FEB/14	PID control test
07/FEB/14	Modify PID control, navigation test in wide tank
08/FEB/14	PID control test, boat water-proof treatment
12/FEB/14	Receive LIDAR cable and check operation
14/FEB/14	Receive data with LIDAR
17/FEB/14	PID control test,
18/FEB/14	LIDAR and GPS mapping 
19/FEB/14	Meeting with NI, PID control test
24/FEB/14	GPS real-time data test

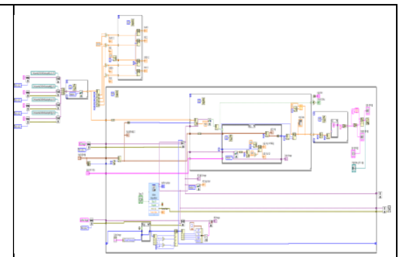
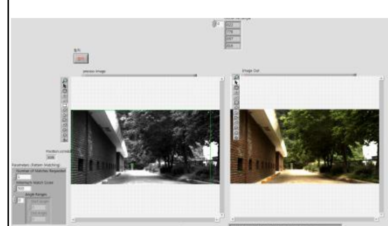
25/FEB/14	Organization functions for each mission, simplify front panel
01/MAR/14	Propulsion coding (straight), camera coding(shape identification) 
03/MAR/14	Propulsion coding (straight) and test
04/MAR/14	Propulsion coding (straight) and test
05/MAR/14	Propulsion coding (left and right), camera coding(shape identification)
08/MAR/14	Propulsion coding (left and right) and test
10/MAR/14	Propulsion coding (left and right), camera coding(shape identification)
11/MAR/14	Propulsion test (left and right)
13/MAR/14	Meeting
14/MAR/14	Propulsion coding (left and right) and test and Propulsion coding (turning)
15/MAR/14	Propulsion coding (left and right) and test Propulsion coding (turning)
	
18/MAR/14	Propulsion test (left and right and turning)
19/MAR/14	Propulsion coding (left and right and turning), obstacle avoidance coding
20/MAR/14	Propulsion test (left and right and turning), obstacle avoidance coding
21/MAR/14	Purchase of pontoons
24/MAR/14	Obstacle avoidance coding, camera coding(color identification)
25/MAR/14	Obstacle avoidance coding and test
26/MAR/14	Meeting
28/MAR/14	Obstacle avoidance coding and test, camera coding(shape identification)
29/MAR/14	Obstacle avoidance coding and test
31/MAR/14	camera coding(color and shape identification)
02/APR/14	camera coding(color and  shape identification)

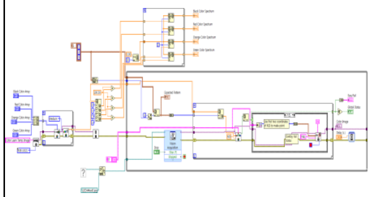
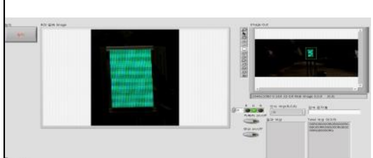
03/APR/14	camera coding(color and shape identification) and test
04/APR/14	Net meeting
05/APR/14	Shape identification test
07/APR/14	Shape identification test
08/APR/14	Color identification test
09/APR/14	 Color identification test
10/APR/14	Color coding using Arduino
11/APR/14	Color coding using Arduino
12/APR/14	Purchase kill switch
17/APR/14	Presentation at KTTC
28/APR/14	Production of propeller bracket
29/APR/14	Purchase of GPS 
30/APR/14	Production of aluminum profile (WAM-V, light bar, LIDAR, GPS)
01/MAY/14	Purchase items for on-site test (hat, tent, table, etc.)
02/MAY/14	On-site test with boat (GPS, shape and color identification) 
03/MAY/14	Coding for docking and observation
05/MAY/14	Coding for docking and observation
06/MAY/14	Purchase of camera 
07/MAY/14	Coding for docking and observation
08/MAY/14	Interim report
09/MAY/14	On-site test : Gain GPS value, path following, Velocity test for mission 1
10/MAY/14	On-site test : Gain GPS value, path following

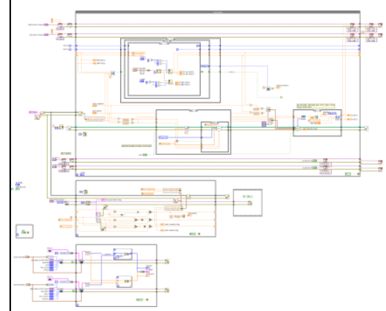
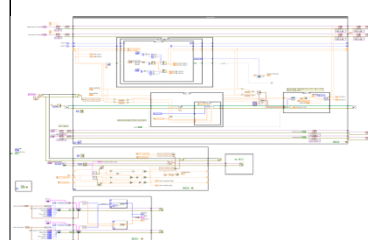
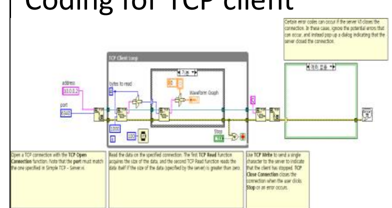
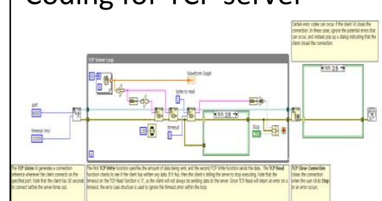
	
11/MAY/14	Obstacle avoidance test, Velocity test to determine the velocity for mission 1
12/MAY/14	Coding for docking, Coding for target buoy detection 
13/MAY/14	Coding for docking and observation mission 
14/MAY/14	Coding for docking and observation mission
15/MAY/14	Equipment preparation for On-site test
16/MAY/14	On-site test : Obstacle avoidance test
17/MAY/14	On-site test : Obstacle avoidance and velocity test with WAM-V
18/MAY/14	Docking and obstacle avoidance and observation test

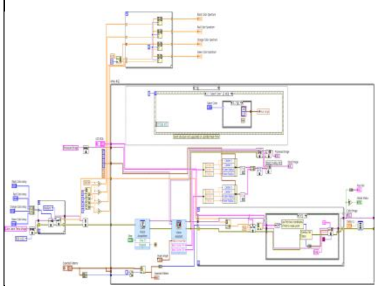
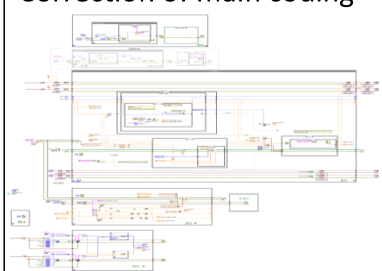
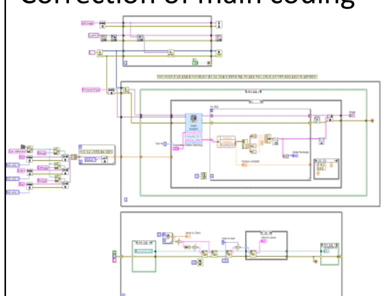
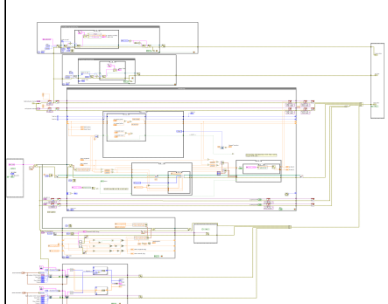
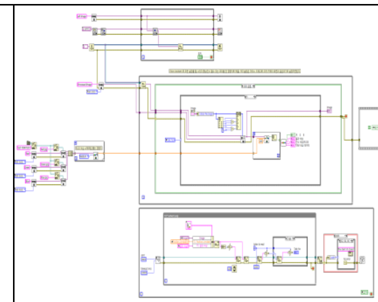
	
19/MAY/14	Connection of coding of each mission
20/MAY/14	Connection of coding of each mission and meeting about underwater searching 
21/MAY/14	Purchase of LIDAR 
23/MAY/14	On-site test : obstacle avoidance test
24/MAY/14	On-site test : obstacle avoidance test 
30/MAY/14	Meeting

31/MAY/14	Docking and observation coding 
01/JUN/14	Docking and observation coding 
05/JUN/14	Equipment preparation for on-site test
06/JUN/14	Test of each mission excluding underwater searching
07/JUN/14	Test of each mission  excluding underwater searching
08/JUN/14	Presentation at Korea Wind Energy Association
15/JUN/14	Coding for color recognition

	
23/JUN/14	Experiment equipment maintenance
24/JUN/14	On-site test : obstacle avoidance test
25/JUN/14	Connection of coding of  each mission
26/JUN/14	Docking and observation coding
27/JUN/14	Shape identification test 
28/JUN/14	Connection of coding of each mission
29/JUN/14	Shape identification test
30/JUN/14	On-site test : obstacle avoidance test

01/JUL/14	Shape identification test
02/JUL/14	Color identification test 
03/JUL/14	Docking and observation coding
04/JUL/14	Docking and observation coding
07/JUL/14	On-site test : Docking and observation
08/JUL/14	Equipment maintenance
11/JUL/14	Connection of each coding
15/JUL/14	On-site test : Docking and observation
17/JUL/14	On-site test : Obstacle avoidance and Docking and observation
21/JUL/14	On-site test : Docking and observation and shape and color identification 
22/JUL/14	Equipment maintenance
24/JUL/14	Connection of each coding
27/JUL/14	Meeting
28/JUL/14	On-site test : Docking and observation and shape and color identification
03/AUG/14	On-site test : Obstacle avoidance and Docking and observation

04/AUG/14	Connection of each coding 
07/AUG/14	 Connection of each coding
08/AUG/14	Meeting
18/AUG/14	On-site test : Obstacle avoidance and Docking and observation
19/AUG/14	Coding for TCP client 
22/AUG/14	Coding for TCP server 
23/AUG/14	TCP test
26/AUG/14	Correction of color

	identification code 
29/AUG/14	Correction of main coding 
04/SEP/14	Correction of main coding 
09/SEP/14	 Correction of main coding
13/SEP/14	Correction of main coding
	
29/SEP/14	On-site final test

Collaboration

When we programmed the system coding, application engineers of National Instruments Corporation supported us. Also we didn't have our specific roles in coding and studied together while developing the system.

Conclusions

From test results we had made a good success in Tasks 1~5 except for Task 2 because we received the underwater detection sensors, only a week before packing all equipment and WAM-V for air transportation to Singapore. However, we will do our best even in Task 2. Also we expect some technical troubles due to wind or waves, especially in the Color and Pattern Recognition Test and the Capturing Shape Test.

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