Testing and technical characteristics of a small overactuated marine platform

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Abstract - The construction of one-man-portable marine vessels presents a challenging task. One such vessel, the marine platform described in this paper, is actuated with four thrusters in an X-shaped configuration which enable motion in surge, sway and yaw degree of freedom. This configuration is highly convenient for dynamic positioning as well as path following. The platform is built in the Laboratory for Underwater Systems and Technologies and it comprises driver electronics for the thrusters, a GPS unit, a compass, batteries and a single board computer used for sensor integration and control. These components enable manual control from the ground station as well as autonomous operation mode. The communication with the ground station is accomplished using a two-way wireless link.

This paper focuses on the description of technical characteristics of the components as well as their integration. In addition to that, special attention is given to the control software developed in LabVIEW and its performances. Preliminary test results are given proving the functionality of the described technical system.

I. INTRODUCTION

Demand for small marine platform in marine robotics is very high, and its construction takes big part in whole project of creating an autonomous vessel. This one-man-portable platform is designed to be used on sea and lake for numerous applications, e.g. dynamic positioning, path following, virtual target algorithm, etc.

The platform is designed and developed at the Laboratory for Underwater Systems and Technologies (LABUST) by a group of students on master programme. It's made from polyester resin and some technical characteristics are shown in Table I. The platform is actuated by four SeaBotix® thrusters positioned in such a way that they form an x-shaped configuration as shown schematically in Fig. 1.b) what allows the design of complex guidance and control algorithms, especially dynamic positioning algorithm. The platform is equipped with two single board computers and with various positioning and communication devices which allow autonomous work with other vessels or divers and manual control by operator from the ground station.

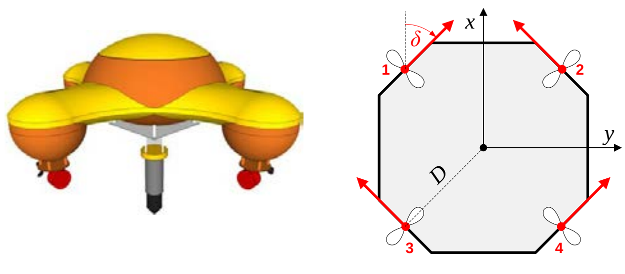
As LABUST already developed two platforms for testing in the pool in laboratory conditions [2], the main motivation for building this type of a platform was to construct the platform which could be tested in real and harsh environment in which marine vehicles operate, characterized with unpredictable disturbances (waves, winds and currents) and to assist divers in underwater navigation and communication with the ground station. Further on, the developed platform will be used in cooperative guidance of unmanned underwater or surface vehicles. This application would allow more precise underwater localization and online mission replanning. The relevance of the envisioned project is significant from the educational side, and the interdisciplinarity through marine robotics.

This research is divided into three steps:

- Step 1 includes the design of the small overactuated marine platform and acquisition of navigation devices;
- Step 2 includes integration of navigation devices, communication with ground station and software testing [1];
- Step 3 includes the design and implementation of algorithms for dynamic positioning, path following, virtual target, etc.

Step 1 was successfully ended in July 2011. and platform was ready for testing in pool conditions (Fig 2.).

This paper presents the next step in research activities regarding the implementation of navigation devices and testing them. It also presents how connection is established between platform, ground station and other vessels or divers. The results presented show that proposed navigation and communication devices can be used on a real system in real-time environment.



a) b)

Fig. 1. a) Virtual model of the platform for dynamic positioning and b) x-shape actuator configuration.

Step 3 is work currently in progress and the preliminary results are reported in [3] and laboratory tests can be seen in [7] and [8].

TABLE I. SOME CHARACTERISTICS OF THE PLATFORM

Height [m]	**0.35**
Width [m]	**0.707**
Length [m]	**0.707**
Weight [kg]	**≈ 25**

The paper is organized as follows. Section II describes general information about all devices used in platform. Section III presents testing of GPS module and gives experimental results in real environment. Section IV presents application interface in LabVIEW for control and communication. The paper is concluded with Section V.

Fig. 2. Platform for dynamic positioning constructed in LABUST

II. Devices Used in Platform

A. Advantech PCM-3362 single board computer

The single board computer used in platform is equipped with Intel® Atom processor with Microsoft® Windows operating system. This system is used for sensor integration because some navigation devices work only on Microsoft® Windows platform. Single board computer is used because of its reduced size and very low power consumption which is very important due to battery autonomy.

Fig. 3. Advantech single board computer

The computer is connected with wireless module and real-time single board computer via Ethernet, and its USB ports are used for connecting navigation devices to the system. LabVIEW application used in this system collects all data from sensors and sends it to real-time computer. Application communicates with other vessels or diver via USBL module and with ground station via wireless module.

B. National Instruments sbRIO-9642 real-time single board computer

The real-time computer from National Instruments with 400MHz real-time processor and 256MB of non-volatile memory is used for deterministic control of platform. Main LabVIEW application runs on this module and receives data from sensors or ground station to control the platform and other vessels autonomously or manually. sbRIO is connected via RS-232 port to driver electronics which drives the SeaBotix® thrusters. This module is used due to its high performance which could not be achieved with common single board computer.

C. USBL module

USBL (Ultra-short baseline) [4] is underwater acoustic localization method. It consists of transponder, transducer and control unit. Transponder is fitted on underwater vessel or diver which communicates with control unit via transducer and calculates position according to transducer position which is obtained from GPS module

Fig. 4. National Instruments sbRIO-9642 module

Data which control unit sends to single board computer is described in Table II. From this data the projected distance between platform and underwater vessel or diver must be calculated, as shown in Fig. 5. Projected distance can be easily obtained by simple equation

$$\begin{matrix} Projected \\ Distance \end{matrix} = \sqrt{(SlantRangeFromUSBL)^2 - (z)^2} \quad [1]$$

TABLE II. DATA RECEIVED FROM USBL MODULE

z [m]	**Transpoder depth**
SlantRangeFromUSBL [m]	**Distance between transponder and transducer**
BearingFromUSBL [rad]	**Transponder bearing**
USBL_z [m]	**Depth of transducer head**
USBL_yaw [rad]	**Transducer heading**

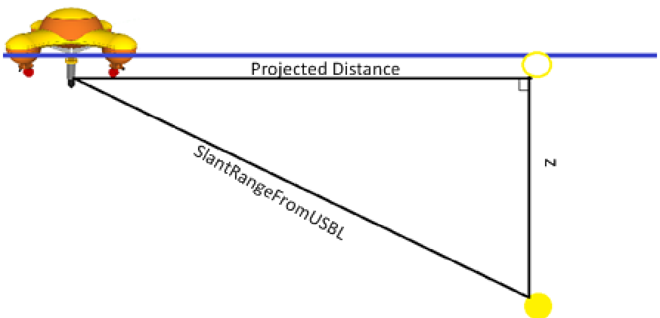


Fig. 5. Relevant measures obtained from the USBL sensor

D. GPS module

GPS module communicates with computer via USB port and sends NMEA sentences [6] with frequency of 10Hz. NMEA sentence which is used for acquiring GPS data is shown in Table III. Every GPS has horizontal and vertical variable error [5] in calculating the exact position which is big problem for dynamic positioning when platform moves with slow speed and has very little variation of position. GPS error can be calculated using S/N ratio obtained from each satellite to which it is connected. Error information which is important for platform positioning is called HDOP (Horizontal Dillution of Precision)

E. Compass module

Compass module works same as GPS module. It can be connected to computer via USB port or RS-232 port with output frequency of 40Hz. Module sends NMEA sentences which data is shown in Table IV. This module also has 3-axis accelerometer which can be used for speed and position measuring.

TABLE IV. EXAMPLE OF NMEA SENTENCE IN COMPASS

$C90.9P-0.6R-1.9T28.5D0.00*4E	
C90.9	**Yaw [deg]**
P-0.6	**Pitch [deg]**
R-1.9	**Roll [deg]**
T28.5	**Temperature [deg]**
D0.00	**Depth [ft]**
*4E	**Checksum**

F. AirLive AirMax2 wireless module

Platform computer is connected with this long range outdoor wireless module to the ground station providing clear signal over 10km distance using built-in antenna. With this module ground station can monitor and manually control the platform and other vessels [4].

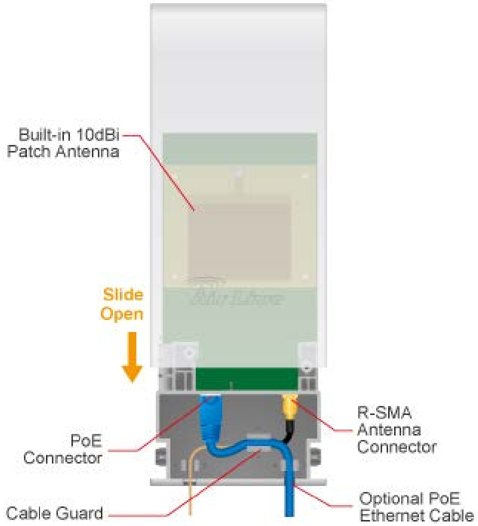


Fig. 6. AirLive AirMax2 wireless module

TABLE III. EXAMPLE OF NMEA SENTENCE IN GPS MODULE

$GPGGA,123519,4807.038,N,01131.000,E,1,08,1.3,545.4,M,46.9,M,,*47		
$GPGGA	**Sentence Identifier**	
123519	**Time**	
4807.038,N	**Latitude**	
01131.000,E	**Longitude**	
1	**Fix Quality:** **- 0 = Invalid** **- 1 = GPS fix** **- 2 = DGPS fix**	
08	**Number of Satellites**	
1.3	**Horizontal Dilution of Precision (HDOP)** **Rating**	**1 – Ideal** **>20 – Poor**
545.4,M	**Altitude**	
46.9,M	**Height of geoid above WGS84 ellipsoid**	
blank	**Time since last DGPS update**	
blank	**DGPS reference station id**	
*47	**Checksum**	

III. TESTING OF GPS MODULE

GPS module was tested prior to platform construction completion therefore it was done on ground. Couple of tests were done with two GPS devices; one is GPS module which is used in platform and the other is built-in GPS module in Getac B300 notebook which has output frequency 0.5 – 1Hz. One test was done in environment with many obstacles which interfered with visual connection of GPS module with satellites and the other test was conducted with clear view to the sky. Results show better reception with GPS module used in platform with higher output frequency than built-in GPS module which is visible in Fig. 7. and Fig 8.

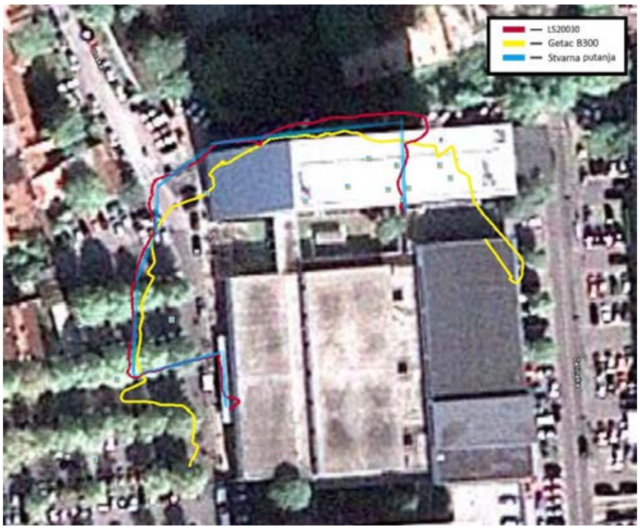


Fig. 7. GPS testing – different output frequency – noisy environment

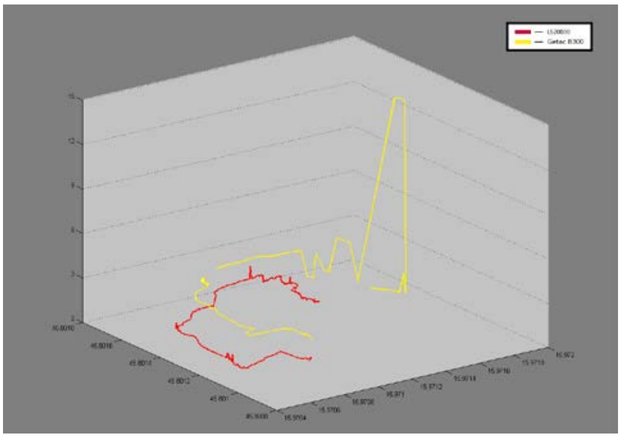


Fig. 8. Horizontal dilution of Precision – different output frequency – noisy environment

Results show that GPS module used in platform has better reception, always has more satellites connected and essentially smaller horizontal dilution of precision than the built-in GPS module. In second test HDOP is very low due to clear view to the sky and more satellites connected to GPS and that leads to very good tracking (Fig. 9 and Fig.10). It means that GPS module which is intended to be used in platform is well-chosen and with implementation of Extended Kalman Filter (EKF) will give good basis for dynamic positioning.

Fig. 9. GPS testing – output frequency 10Hz – clear view to the sky

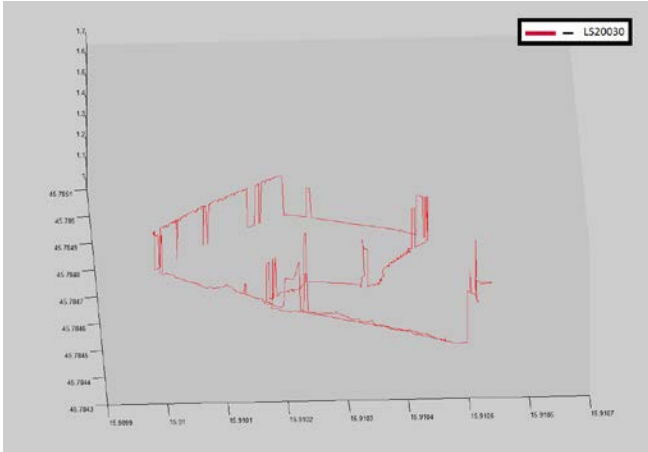


Fig. 10. Horizontal dilution of Precision – output frequency 10Hz – clear view to the sky

IV. LABVIEW APPLICATION

With real-time single board computer from National Instruments using LabVIEW environment imposes as the right choice. With LabVIEW, connecting the platform with ground station gives immediate access to platform control as well as monitoring of measurements on the platform. Real-time module gives numerous possibilities in design of controller and complexity which could never be performed on stock single board computer with desired efficiency. Single board computer also controls the other underwater and surface vessels via RF and USBL module. Whole concept of control is shown in Fig. 11.

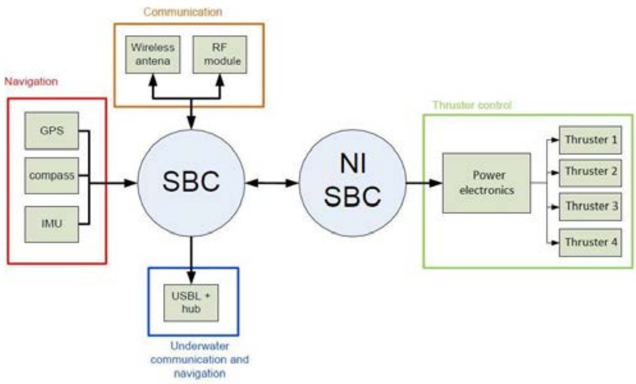


Fig. 11. Schematic representation of the hardware infrastructure

V. CONCLUSION AND FUTURE WORK

This paper describes the implementation of navigation and communication devices and testing of navigation devices. In addition to that, special attention is given to the control software developed in LabVIEW and its performances. Preliminary test results of GPS module are given proving the functionality of the described technical system.

The experiments were carried out in the Laboratory for Underwater Systems and Technologies (LABUST) at the University of Zagreb. The main task of the experiments was to verify the functionality and accuracy of GPS module.

The future work will include implementing complex controller for platform and other vessels. The final goal of this project is to achieve cooperation between marine robotics and human divers where the proposed platform will serve as an aiding system in diver navigation and communication with ground station will give more possibilities in research of underwater treasure.

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