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NEW PROPOSAL CONCERNED WITH DISPLAYING UNDERWATER VEHICLE PARAMETERS

ABSTRACT

The article presents a proposal, based on an analysis of the software used for displaying parameters of two underwater vehicles, for extending display applications by using the Lab View environment. The purpose of the solution presented is to uniform data displays transmitted from underwater vehicles, used by operators to operate these vehicles as well as consider the possibility for extending the software offered by producers of vehicles by new elements facilitating evaluation of the vehicle's condition and the effect of the environment on this condition when the vehicle is being operated.

Key words:
Remotely Operated Vehicles (ROV), display of underwater vehicle parameters.

INTRODUCTION

Unmanned underwater vehicles are one of the fastest developing areas of robotics. The dynamics of progress in this area, to a large extent, depends on technological progress. Progress in underwater robotics is associated with extending the areas of use of ROVs, based on adaptive intelligent computer systems, development of new algorithms and principles of intelligent control of vehicles in water, as well as appearance and implementation of innovative materials and technologies. At present these vehicles are, among others, widely used to [7]:

- develop maps of sea bottom shape;
- study sea bottom shape in order to plan pipeline and cable routes (e.g. fiber optic);

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- check technical condition of pipelines or cables;
- study ecology issues;
- conduct exploration work or support divers carrying out such work;
- detect mines in shallow water;
- carry out observation and inspection in water environment;
- transmit, in real time data, on underwater situation;
- support rescue operations, etc.

A multitude of concepts and implementations of underwater vehicles is a cause of the absence of uniformity. These vehicles are most often classified with reference to their autonomy, which is defined by power independence and the method of communication with the operator [7]. Using these two factors they are defined as non-autonomous remotely operated vehicles, not having a propulsion system no matter what method for communication with the ROV operator is used, and Autonomous Underwater Vehicles (AUVs), vehicles power independent, capable of transmitting data wirelessly, they are often capable of carrying tasks set to them without participation of the operator. The considerations presented in the article relate mostly to the first group of vehicles, i.e. ROVs. The other type of classification takes into account the method of navigation employed and it is analogous to manned underwater vehicles [5]. The first group comprises vehicles employing dead reckoning navigation, based on readings from on-board measuring instruments, e.g. inertial ones. Differences that occur in this group of Unmanned Underwater Vehicles (UUV) are: configuration of measuring sensors and filtration form of the readings obtained. The second group includes objects with bathymetry based navigation. Their position is fixed using a sea-floor chart developed earlier or using some features of the water region, e.g. the specific coastline. The last class includes vehicles which employ hydro-acoustic navigation systems. Their navigation is based on measuring ranges from the so called baseline [7]. The scope of data collected by a vehicle is limited only by its parameters and the type of on-board equipment installed in it. The equipment may include, among others, a TV camera, sonar, instruments for measuring water hydrological parameters and other. A big advantage of an ROV is its relatively high mobility and capability to operate for a long time at great depths, sometimes in extremely difficult conditions. The personnel who operate these vehicles have to be trained in how to operate and maintain the vehicles and technical appliances directly cooperating with them. The objectives of such training include, among others, knowledge of construction and principles of operation of an ROV, developing practical skills concerned with the current operation, prophylactic maintenance of an ROV and operation of an ROV in a water column.

This article comprises elements of the BSc thesis *A Proposal for Displaying Measurement Data from an ROV based on the Labview environment*. The aim of the thesis was to extend the capabilities to display measurement data offered by ROV producers by elements tailored to individual physical, mental and intellectual abilities of an operator.

REMOTELY OPERATED UNDERWATER VEHICLES

Remotely Operated Vehicles (ROV) gain higher and higher popularity in the marine environment. They are extensively used in maritime industries, in defense applications, as well as research and development activities. They are mainly used to inspect underwater technical infrastructure, carry out construction or repair work [1, 2, 4]. In military applications an ROV can be used for Mine Warfare, recovery of sunken objects of military significance, rescue of submarine crews, carrying out reconnaissance missions, as well as obtaining intelligence data, etc. Moreover, these vessels increase safety and effectiveness of search and rescue operations. They substitute, to a large extent, work by rescue-diver, especially in dangerous or arduous conditions [1, 11]. The basic advantage of an ROV is that, unlike a diver, the vehicle can operate under water for long hours. An additional advantage is the possibility to automatically set the course or position to unmanned vehicles, an option used in some models which greatly facilitates control of ROV executed by an operator as he/she does not have to monitor and observe all parameters [1].

The possibility to install additional sensors of various types or appliances (cameras, sonar, probes, manipulators, etc.) increases its functionality. Complicated vehicle stabilization systems allow the operator to operate in high comfort despite very difficult conditions. In these vehicles communication between the operator and the vehicle is secured by means of a tether. In this way orders from the operator are transmitted to the vehicle and all the return data from the vehicle to the operator, such as images from a camera or other data from on-board instruments. ROVs have complicated systems for spatial stabilization to maintain the depth, course and drift of the vehicle so that they can operate in difficult conditions. They counter external factors using thrusters to maintain the vessel in the fixed position [4].

An example of this kind of vehicle is VideoRay Pro 4 used in the Underwater Robotics Laboratory of the Institute of Electronics and Automation and LBV200-4 used by the Department Underwater Work Technologies of the Naval Academy. Both of these vehicles are used for similar operations. However, they differ in methods of data display and parameters they measure, as well as in the most significant factor which is control.

Fig. 1. VideoRay Pro 4 and LBV200-4 [9, 10]

VIDEORAY PRO4

VideoRay Pro 4 is a series of one of the most popular in the world small ROVs. VideoRay Pro 4 replacing the previous series of vehicles has been fitted with modern technological solutions which makes it the most advanced and versatile ROV on the market [2]. It contains entirely new electronics, including camera, LED lighting, processor, 3D compass and sensors (temperature sensor, accelerometer, voltmeter, leak alert, etc.) Computer-based controls together with new software VideoRay Cockpit make the Pro 4 more advanced and intuitive than any other vehicle in this class. Additional improvements include a more accurate depth indicator or optimized ballast adjustment. The set of the remotely operated vehicle VideoRay Pro 4 consists of such elements as: a vehicle, control panel, manual control console, tether connecting the ROV to the control panel, and accessories.

An ROV is designed to submerge to the depth of 300 meters (1000 feet) and it can reach the speed of up to 8 km per hour (4.2 knots). It weighs 6.1 kilograms. The ROV is fitted with two water thrusters which ensure its mobility. They are controlled manually from the surface by means of the console. It is also fitted with a camera, LED lighting and sensors so that it can reach places which are searched for, investigated or inspected [10].

The software of the VideoRay Pro 4, the so called VideoRay Cockpit provides communication connection with the ROV. That is why the operator can set control signals and receive return information from the camera and the set of sensors installed in the vehicle. The software platform consists of a few elements: a window displaying an image from the camera (Video Window), displays and controls of particular parameters (Control Instruments) and a Control Bar shown in the table 1 [10].

Fig. 2. VideoRay Pro 4 Video Widow [9]

Tab. 1. Display elements in the VideoRay Pro 4 Video Widow [10]

Element	Description
ROV condition	Offers access to information on condition of ROV key operating parameters, including the control system of energy, power, internal communication, humidity and internal temperature. The condition controls are green if the status is right and they change into red if a problem is detected.
Compass and artificial horizon	Displays information on ROV's course, indicates ship attitude by means of artificial horizon. Compass is also used to control the ROV and set the Auto Pilot.
Video Window	Displays images from the camera.
Video and lighting control	Displays information on camera and lights. It is used to control light flux and camera location angle.
Temperature control	The reading show external temperature. Temperature sensor works both in water and air and readings are displayed in Celsius or Fahrenheit.
Depth gauge	Displays ROV's depth status of Auto depth. Depth gauge is also used to operate ROV.
Sensitivity adjustment	Can be used to regulate response of ROV to control from console relating to submergence and vehicle movement.
MENU BAR	Used to control various settings, start integrated applications and provide access to VideoRay Pro 4 Operator Manual.

LBV200-4

LBV200-4 is a vehicle which has a quite efficient propulsion system and low hydrodynamic drag generated by the tether. An additional advantage is that a large number of optional pieces of equipment can be connected to the vehicle [3].

The construction of LBV200-4 allows it to operate at the depth of up to 200 meters. The vehicle is fitted with a system of 4 thrusters which are used to control its maneuvers in four degrees of freedom (linear motion in the direction of longitudinal, transverse and vertical axes and angle motion in relation to the vertical axis of symmetry). The system allows the vehicle to move on surface at the speed of 1.5 m/s and negotiate sea currents at the maximum speed of up to 1 m/s. Its standard equipment includes a color camera having resolution of 520 lines and sensitivity of 0.1 lux integrated with a 700 lumen LED matrix having the angle of sight 270 degrees. The vehicle considered in the article is also fitted with Blue View sonar, a probe for physico-chemical measurements of the marine environment, underwater navigation system USBL and a rear reflector [3].

A picture transmitted from the front camera is displayed on the screen, which is part of the set, (transfer to the image from the rear camera is also possible) together with the basic parameters.

Fig. 3. LBV 200-4 Video Window [9]

Below are presented explanations for the Video Window [9].

Tab. 2. Elements of LBV 200-4 Video Window display [9]

Element	Description
User information	Placed in the upper part of the screen above the image from the camera, displaying maximum 28 signs. Entered by the user.
Control of thrusters in vertical direction	Allows for regulating the ROV response to control from the console relating to submergence and vertical movement of the vehicle (1 = 10%, 2 = 20%, 3 = 30% ... 0 = 100%).

Element	Description
Trim and level of lighting control	If nothing is displayed on the screen, it means that both trim and lights are off. Switching the trim function on is indicated by information TRM. If the light is on and display is poorly visible, the light level control will display light intensity, which ranges from10% — L1 to 100% — L10.
Course control	Displays information on vehicle's course. It is used to control the ROV and set the Auto Pilot.
Vehicle revolutions control	The control displays the number of revolutions made by LBV in one direction 360º. Symbol '+' shows clockwise turns whereas symbol '–' anticlockwise turns. It is a valuable tool which allows the operator to follow the revolutions occurred on the tether. Before recovering the LBV the operator should withdraw these turns in order to facilitate coiling the tether, and this way avoid damage to the fiber optic cable.
Camera position angle control	Displays information on the angle of camera position. Digit 0 indicates that the camera is directed 0º in relation to the horizon. Reading +90 indicates that the camera is directed straightforward, and –90 indicate that the camera is directed downwards.
Date	Displays current date preset by the manufacturer. However, it can be easily changed into the time zone in which LBV is operating.
Control of thrusters in horizontal direction	Is used to regulate the ROV response to control from the console in relations to vehicle's submergence and horizontal movement (1 = 10%, 2 = 20%, 3 = 30% ... 0 = 100%).
Selection of accessories	Is used to control various settings, start integrated applications and accessories.
Depth control	Displays the ROV's depth and Auto status of depth. The depth gauge is also used to perform control of ROV. Depth can be displayed in meters of sea water (msw), meters of fresh water (mfw) or if feet of fresh water (ffw). Next to the depth control there appears the sign '*' if function Auto is off.
Temperature control	The reading displays external temperature. Temperature sensor works both in water an in air, and the value may be displayed in Celsius or Fahrenheit.
Time control	Displays information on current time (hour), preset by the manufacturer, but can be easily changed into the time zone in which the LBV is operating.

COMPARISON OF THE PRESENTED UNDERWATER VEHICLES

The vehicles presented have similar use and construction. However, apart from the basic difference in their construction and parameters, they differ mainly in software which displays the collected data in different manners, and in the method used to control the vehicles.

The difference between the graphical software for these two vehicles is presented and briefly described above. Yet, the most significant difference is the method for executing control of the vehicles. They are fitted with manipulators having different functions, which require the operator to have skills necessary to operate both of them. An important fact is that in the case of the VideoRay Pro 4 the software used do display data is more helpful as the manufacturer used such tools as a compass or an artificial horizon which allow for more intuitive fixing vehicle's course than in the case of the LBV200-4, where these parameters are displayed only in the form of symbols and digits, in fact in not a very clear way. On the other hand the LBV200-4 can obtain significantly higher number of parameters thanks to additional equipment, such as sonar or a sounder.

In both vehicles the software does not have an important function such as a capability of obtaining and recording the measured parameters. Both producers offer only the function of data display. If data was recorded, it could be later displayed and analyzed. This function could prove helpful especially in research investigations where the obtained data could be processed or used for calculations. Therefore in the LabView environment an application was developed to display, download and record data as well as to control underwater vehicles. This is a universal solution for various vehicle types which can be used by an operator to operate several vehicles in the same manner.

LABVIEW ENVIRONMENT AS UNIVERSAL TOOL FOR DATA DISPLAY

LabView (**Lab**oratory **V**irtual **I**nstrument **E**ngineering **W**orkbench) is a modern tool that can be used in the software for measuring systems. The graphical programming language, called in short 'G' language, constitutes an integral part of this environment. This is a block presentation of operations which constitute the software and logical interconnections among them [2, 8]. In the 'G' graphical language the program code is presented in the form of diagram, procedures are represented by icons, and connections among them decide about the data flow. This way of programming does not require learning the syntax of the language or taking care about the correct use of symbols. Information on errors is clear and legible and shows the exact place of their occurrence [2, 6]. The LabView integrated programming environment is designed mainly to control control-measurement systems as well as to process and analyze data. It has libraries which allow for communication among devices and computers and realization of advanced mathematical, statistical, and many other calculations [2].

In the process of writing the BSc thesis *A Proposal for Displaying Measurement Data from an Underwater Vehicle based on the LabView environment*, among others, a stand was developed for carrying laboratory exercises aimed at providing students with skills necessary for using applications used to display parameters of underwater vehicle performance and programming in the LabView environment. Below presented is a block diagram of this stand (fig. 4) [2].

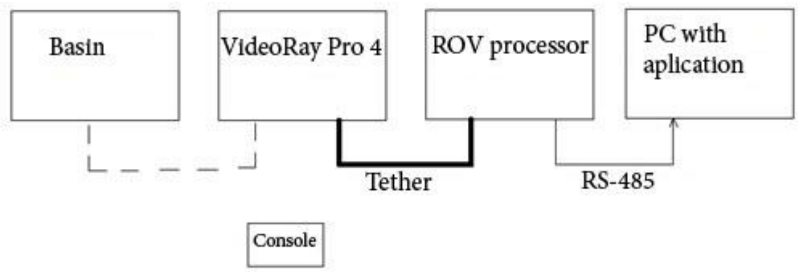

Fig. 4. Block diagram of laboratory stand [own work]

Fig. 5. Laboratory stand [own work]

Despite the fact that the application developed in the LabView was for a specific model of underwater vehicle (VideoRay Pro 4) it is a universal solution for a lot of underwater vehicles. The application consists of a few tabs separating particular parameters and of a side panel aimed at recording comments. In addition, the application allows for measuring and recording parameters to an external file in the Excel spreadsheet. This makes it possible for the user analyzes them later, e.g. transforming them to the form facilitating work for the vehicle operator [2].

A significant advantage of the application is that it is an open-ended solution, which in future will allow for its modernization by adding new functions or by modifying existing solutions. In addition the user can change the range of scale and color of displayed parameters according to their own preferences. At present the application can be used to display information on serial bit communication and display of parameters: depth and pressure, course, spatial heading, linear and angular acceleration along axes *X*, *Y*, *Z*, water temperature, and engine parameters. Below presented are examples of how to use the LabView environment to extend the producer programming offer employing the application mentioned.

A useful solution in using the vehicles for measurements would be a capability to set an alarm if the boarder range of a measured parameter was exceeded. The producer offers only diagnosing parameters influencing the vehicle condition, and as for the external parameters no settings (e.g. external water temperature) is offered. What is more, such alarms could be used for sensors which are not part of equipment but are connected do underwater vehicle instrumentation, e.g. probes testing salinity or a sensor measuring transparency of water.

For the operator the possibility to use the record of the route covered in the course of the task execution would be very helpful function of the LabView. Owing to this the operator could record the route covered and then implement it during another task so that the vehicle could follow the same route. This is useful especially during maintenance and repair work. The producer-made software allows for setting auto-depth or auto-course to the vessel, however, it does not have the capability of setting the same route. Such an application allows the operator to operate the vessel from the level of computer, and this way to avoid using the manipulator and to focus on monitoring and controlling the measured parameters, instead of focusing on the set magnitudes such as course or depth. What is more this is a universal solution for a lot of vehicles which allows the operator to save time for learning how to operate the new vehicle.

Using display of the vehicle position in 3D space (such display is not offered by the software delivered by the producers) would be an innovative tool. The operator could on the regular basis check the ROV moving in water and record it to the external file. Additionally by setting the trajectory they could determine the final point of the route and follow movement of the ROV in relation to it.

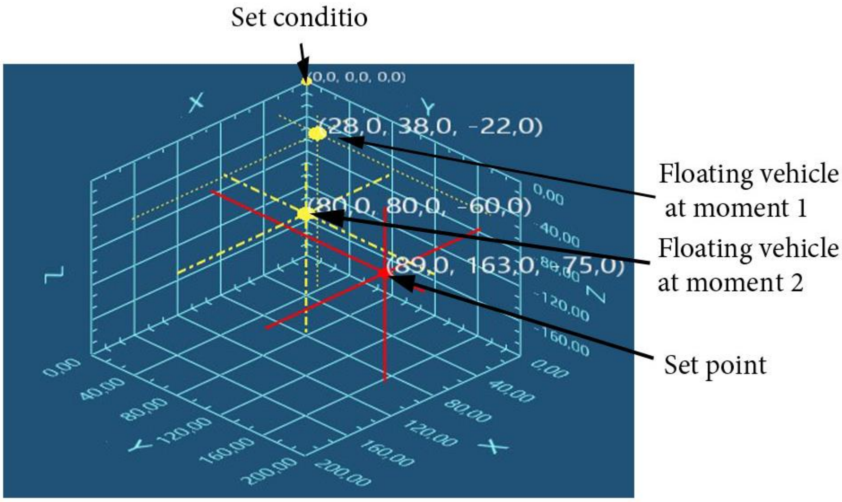

Fig. 6. Display of ROV in 3D space [own work]

Owing to the function of rotating the 3D set under any angle the user could set the projection on to the displayed space most convenient for him/her (fig. 7). At the set point and the point displaying the ROV coordinates which help the operator determine the distance remained to cover and deviations from the set course are displayed. The same functions are performed by the lines determining the coordinates. When they getting closer to each other, it indicates decrease in the distance between the objects, and when they overlap, it signals the arrival at the set point, which means reaching the objective.

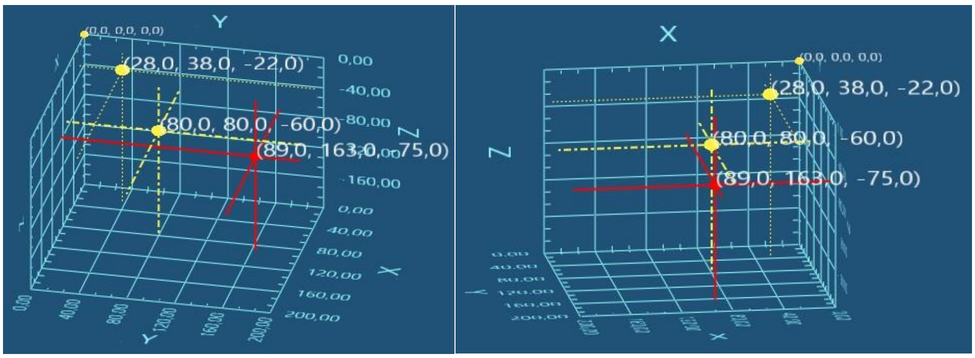

Fig. 7. Various projections on to 3D set, dependent on selected angle [own work]

Figures 8 and 9 show displays displayed by the VideoRay Cockpit software and vision of extension of the application in the LabView environment with the tab *display*.

Fig. 8. Display of data using VideoRay Pro 4 [VideoRay Cockpit]

Fig. 9. Display of data in the LabView environment [own work]

SUMMARY

The perspectives for developments in robotics are closely associated with extending the areas of ROV use. This way the vehicles can become more and more modern by being fitted with intelligent computer systems, development of new algorithms and principles of intelligent control of vehicle in water. The development and implementation of innovative materials and technologies will for sure influence the progress in this field [7].

The presented in this article application used to display parameters of an underwater vehicle is a tool which can be linked to various underwater vehicles so its universality is its advantage. A significant advantage of the application is also the possibility to extend by new functions. It can be used to display parameters required by a user (facilitating his/her work) which are not offered by the producer. Another unquestionable advantage of the application is the possibility to record measured parameters so that they later be analyzed or processed. Additionally the proposed solution of extending the application will to a large extent facilitate operating underwater vehicles.

REFERENCES

[1] Bessa W. M., Dutra M. S., Kreuzer E., *Depth control of remotely operated underwater vehicles using an adaptive fuzzy sliding mode controller*, 'Robotics and Autonomous Systems', 2008, Vol. 56, Issue 8, pp. 670–677.

[2] Jurczyk K., *Projekt wizualizacji danych pomiarowych z pojazdu podwodnego w oparciu o środowisko Labview*, Thesis the first degree-engineering, Gdynia 2015 [*A Proposal for Measurement Data from an Underwater Vehicle based on the LabView Environment* — available in Polish].

[3] Leszczyk D., *Projekt miniaturowego systemu sterowania kamerą*, Gdynia 2013 [*A design of a miniature system for camera control* — available in Polish].

[4] Sroka M., Ściegienka P., Babiarz A., Jaskot K., *Prototyp bezzałogowego pojazdu podwodnego — układ stabilizacji i utrzymania ruchu*, 'Przegląd Elektrotechniczny', 2013, No. 9 [*A Prototype of an unmanned underwater vehicle — stabilization and movement maintenance set* — available in Polish].

[5] Straszewski, P., *Żegluga podwodna i penetracja morskich głębin — historia, zastosowanie w gospodarce, przyszłość*, Thesis the first degree-engineering, Gdynia 2006 [*Underwater sailing and penetration of sea depths — history, use in economy, future* — available in Polish].

[6] Szaj W., *Podstawy programowania w LabView*, 'Elektronika Praktyczna', 2013, No. 4 [*Fundamentals of programming* — available in Polish].

[7] Tariov A., Kruszko S., *Bezzałogowe pojazdy stan obecny, potencjał biznesowy, perspektywy rozwoju*, 'Elektronika: konstrukcje, technologie, zastosowania', 2011, Vol. 52, No. 10, pp. 148–156, [*Unmanned vehicles — present state, business potential, development prospects* — available in Polish].

[8] Tłaczała W., *Środowisko LabView w eksperymencie wspomaganym komputerowo*, WNT, Warszawa 2002 [*LabView environment in a computer-supported experiment* — available in Polish].

[9] LBV200-4 Operator Manual, SeaBotix Inc. Users, 2009.

[10] VideoRay Pro4 Operator Manual, Videoray LLC, 2010.

[11] http://www.ppoz.pl/zajrzyj-do-srodka/technika/702-podwodne-roboty [access 24.05.2017].

NOWE SPOJRZENIE NA WIZUALIZACJĘ PARAMETRÓW POJAZDÓW PODWODNYCH

STRESZCZENIE

W artykule, w oparciu o analizę oprogramowania służącego do wizualizacji parametrów dwóch pojazdów podwodnych, omówiona została propozycja rozszerzenia aplikacji tych wizualizacji poprzez wykorzystanie środowiska LabView. Przedstawione rozwiązanie ma na celu ujednolicenie wyświetlania danych przekazywanych z pojazdów podwodnych wykorzystywanych przez operatorów do sterowania tymi pojazdami, jak również rozpatrzenie możliwości rozszerzenia oprogramowania proponowanego przez producentów pojazdów o nowe elementy, ułatwiające ocenę stanu pojazdu i wpływu środowiska na ten stan w procesie sterowania.

Słowa kluczowe:
pojazdy podwodne typu ROV, wizualizacja parametrów pojazdów podwodnych.