An Intelligent Robotic Platform for Conducting Geodetic and Ecological Surveys of Water Bodies

Andrii Tkachuk[1][a], Mariia Hrynevych[1][b], Tetiana A. Vakaliuk[1,2,3][c], Oksana A. Chernysh[1][d] and Mykhailo G. Medvediev[4][e]

[1]*Zhytomyr Polytechnic State University, 103 Chudnivsyka Str., Zhytomyr, 10005, Ukraine*

[2]*Institute for Digitalisation of Education of the NAES of Ukraine, 9 M. Berlynskoho Str., Kyiv, 04060, Ukraine*

[3]*Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine*

[4]*ADA University, School of Information Technologies and Engineering, Baku, AZ1008, Azerbaijan*

Keywords: Robotics, Geodesy, Measurement, Acidity, Temperature.

Abstract: The article considers the relevance of using a new intelligent robotic platform to quickly conduct basic research on water quality assessment in reservoirs and analyze the relief of the reservoir bottom, preserving all the data. The paper proves that using an intelligent platform for water analysis significantly facilitates the research. Moreover, it increases the studied area of the reservoir. It simplifies the process of establishing the correspondence of data to a particular place on the reservoir compared to classical methods of water quality analysis in the reservoir. It describes the platform's advanced design, which consists of a housing, a control board, sensors, actuators such as servo motors and a brushless motor, a radio module, a GPS module, and a motor speed controller. In addition, it illustrates the cutting-edge platform control panel. The article analyzes a functional diagram of an intelligent robotic platform for water quality assessment and bottom topography. It presents the study of the developed system carried out on the reservoir, the main idea of which was to study the correctness of the system's operation, evaluate the effectiveness of the conducted studies, and display water quality sensors. The paper studies an ultrasonic sensor for measuring depth and sensors for water acidity and temperature. It presents the outcomes of the developed monitoring system experiments that resulted in a map of the reservoir's bottom area and certain conclusions on water quality.

1 INTRODUCTION

Modern realities signify a rapid increase in consumption and the amount of waste. Therefore the question arises whether new digital technologies can compensate for these changes. The answer is obvious: it is necessary to look for new solutions that will help solve the problem of climate change and contribute to preserving the well-being of the entire planet.

Water pollution is the negative change in the physical, chemical, and bacteriological water properties caused by an excess of inorganic substances (solid, liquid, gaseous), organic, radioactive, or heat, which limit or prevent the use of water resources for drinking and economic purposes.

Natural reservoirs, such as oceans, rivers, and lakes, can self-purify. However, getting too many pollutants into their system can cause irreversible damage. Therefore, it all depends on the number of pollutants.

Too many chemicals, bacteria, and other microorganisms cause severe water pollution. Chemical, organic, and mineral substances form colloidal solutions and suspensions. Natural factors determine the chemical composition of pollutants, for example, the decomposition of substances in soil and rocks, the development and death of aquatic organisms, and anthropogenic factors.

Consequently, a robotic platform enables remote analysis of water in the reservoir to measure the acidity of water, its temperature, and the depth of the reservoir. In case of acidity increase and water pollution detection, it will be possible to take a water sample from a particular reservoir area and carry out a de-

[a] https://orcid.org/0000-0003-2466-6299
[b] https://orcid.org/0000-0001-9183-5211
[c] https://orcid.org/0000-0001-6825-4697
[d] https://orcid.org/0000-0002-2010-200X
[e] https://orcid.org/0000-0002-3884-1118

Tkachuk, A., Hrynevych, M., Vakaliuk, T., Chernysh, O. and Medvediev, M.
An Intelligent Robotic Platform for Conducting Geodetic and Ecological Surveys of Water Bodies.
DOI: 10.5220/0012009600003561
In *Proceedings of the 5th Workshop for Young Scientists in Computer Science and Software Engineering (CSSE@SW 2022)*, pages 50-56
ISBN: 978-989-758-653-8; ISSN: 2975-9471

tailed water analysis in the ground laboratory. Moreover, the floating platform takes real-time readings from sensors and follows the executive mechanisms. Thus, it detects the source of pollution and marks the exact location by dropping a beacon in the highest pollution concentration for further investigation of the nature and pollution level.

Furthermore, the platform is a helpful tool for training qualified economists and promoting the development of environmental consciousness and motivation for transforming knowledge in behavioral models.

2 THEORETICAL BACKGROUND

The problem of water pollution is becoming more significant. Some "mobile" laboratories allow conducting research in field conditions. However, it is a long-term process that requires detailed preparation and preliminary water sampling.

There are no absolute analogs of the system presented.

The automated surface platforms that are fully autonomous or controlled are reviewed in (Dimitropoulos, 2019; Brans, 2021; Rivero, 2022; Niiler, 2020; Drăgan, 2021). Therefore, they are suitable for extreme conditions to research in the ocean or transport cargo along a specific, established route.

Sea Machines (Sea Machines, 2023) highlight an autonomous self-piloting system, which allows remote control of the vessel, receives information from sensors on the user interface, and has a complete picture of the vessel's state.

Li et al. (Li et al., 2020) suggested a spectral processing method for analyzing the reflectivity of water samples and applied machine learning methods to estimate water quality parameters.

Therefore, the investigation aims to develop an intelligent robotic platform for conducting geodetic and environmental research, which will be easy to manage, "mobile", and fast compared to similar systems. Moreover, it will also allow us to quickly make sets of water samples for more accurate and detailed analysis in the laboratory. In addition, it contributes to an actual experiment to assess the robotic platform's effectiveness and the system's correctness.

Koval' (Koval', 2015), Bezvesilna et al. (Bezvesilna et al., 2017) describe modern sensors for measuring acceleration and gravity anomalies. However, they do not indicate the feasibility of using them in the design of intelligent robotic platforms.

Various ways to control intelligent robotic platforms are suggested in (Chung et al., 2018; Tedeschi and Carbone, 2014). An example of a fuzzy neural network and a Kalman filter to control a mobile robot is provided. A stabilization algorithm with the applied close-loop control system, including an inertial measuring unit as a feedback sensor, is delivered. A Control system is applied to calculate the engine angles to achieve stability on the inclined surface.

3 RESULTS

3.1 The Structure of the Intelligent Robotic Platform

Zhytomyr Polytechnic State University scholars have developed an intelligent robotic platform for geodetic and environmental research. According to the criteria of "cost-effectiveness" and mobility, the new system will be the best among its known analogs. The design of the robotic platform (figure 1) consists of the following main elements: body; control unit (1), which includes a microcontroller based on an Arduino Nano board (2), a radio module (3), a JSN-SR04T-2.0 sensor control board (4), a PH-4502C module to which a water acidity sensor is connected (5); collectorless engine (6), its cooling jacket (7), engine regulator (9) connecting clutch (24) for transferring rotation from the engine shaft to the deadwood shaft (23), which in turn is connected to the propeller (22)); the system is powered by a battery (8); servomotors (10), (11), (12) and (13) are used as cargo compartment drives (25) and (26), steering wheel drive (21) and water intake mechanism drive; sensors for temperature (14), acidity level (15), ultrasonic for measuring the distance from the bottom of the platform to the bottom of the reservoir (16), distance sensor (27); navigation of the platform is provided by the GPS module (28) and the antenna (29); overall emitters (17) – (20) help in driving in the dark.

The platform equipment is powered by a Turnigy Li-Po 7.4V 5300mAh 2S2P 25C battery, which allows you to use the robotic intelligent platform for a long time and provides the necessary power supply voltage for the correct operation of the system. An Arduino Nano board built on an ATmega328 microcontroller was chosen as the control device. It is compact and enables all the tasks set in this project. For remote data transmission and platform control, the NRF 24L01P+ radio module is used, ensuring good signal reception and transmission quality at a distance of up to 1 kilometer. Furthermore, the following sensors receive data about the environment: ultrasonic distance sensor JSN-SR04T-2.0, which provides mea-

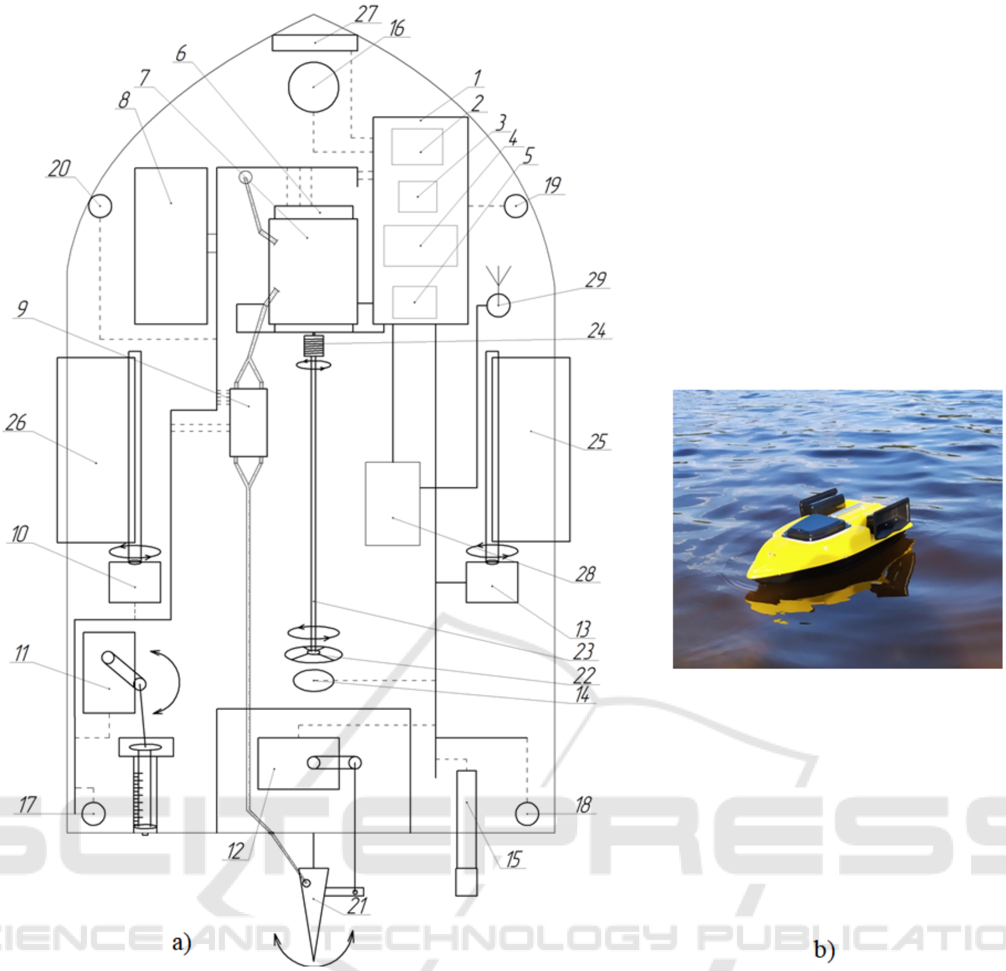

Figure 1: Structural elements of the robotic intelligent platform (a) the robotic platform (b).

surement of the distance from the swimming platform to the bottom of the reservoir and thereby allows displaying a map of the topography of the bottom by constructing a graph based on the data received from the sensor, as well as measuring depth in a specific place of the reservoir and make a preliminary calculation of the water volume of the reservoir; the DFRobot ADC151 water acidity sensor is used to analyse water quality, which helps to explore and determine the acidity of water almost instantly; to measure the water temperature, a DS18B20 digital sensor is used with the function of an alarm signal for monitoring the temperature and the range of the measured temperature from 55 to +125 °C; the Sharp GP2Y0A21YK0F infrared distance sensor was used to determine floating obstacles that may appear in the path of the platform; to determine the exact location of this system and further build a map of the bottom and link the received data to exact coordinates, the GPS module GPS NEO-6M SMA + IPEX and the active antenna ANT GPS BY-GPS-07 SMA-M were used to increase sensitivity and increase the ratio “signal-to-noise” and reducing the impact of interference. The executive mechanisms are in the form of MG995 Tower Pro and MG996R-180 servomotors, which are necessary to implement the water collection mechanism for its further in-depth analysis, as well as to ensure the movement of the swimming platform in the required direction and to unload the cargo placed in two cargo compartments on top of the platform.

3.2 Control Panel

We developed the control panel for the platform by modernizing the existing panel, the structural diagram of which you can see below.

Control is carried out by the Arduino Nano board, which provides data processing. Moreover, it performs the control device function and ensures data processing from the GPS module and their recording

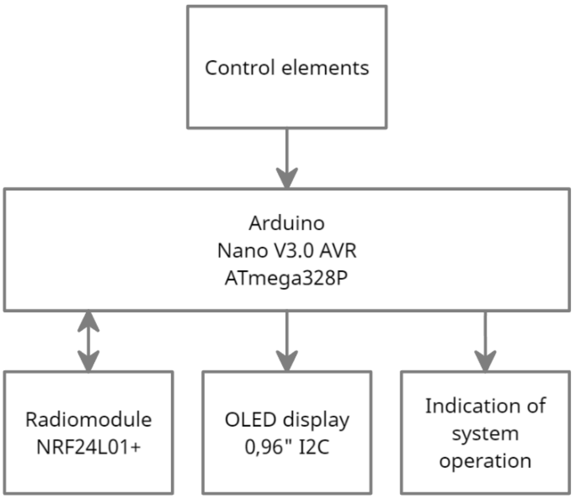

Figure 2: Structural diagram of the remote control panel.

on a flash drive.

Sticks are employed to control the platform remotely; buttons are used to drive the cargo compartments and activate the water sampling system. LEDs are used to display the status of the system.

The control panel receives and transmits data via the NRF 24L01+ radio module. The received sensor data from the radio module are processed by the control board and displayed on the OLED display of the control panel.

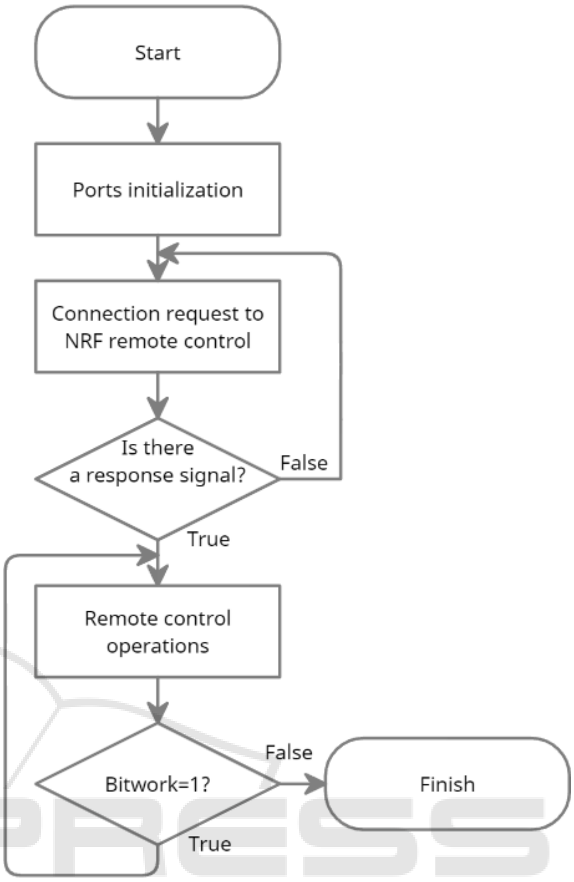

Figure 3: The basic algorithm of the robotic intelligent platform.

3.3 Algorithms of System Operation

For the operation of the robotic intelligent platform, it is necessary to organize the synchronous operation of the swimming platform and the remote control (data reception and transmission). First, according to the system's algorithm (figure 3), the controller ports are configured, and the input data is zeroed. In this case, the transmitter considers the robotic intelligent platform, i.e., the initiator of the data exchange. Then a request is sent to the air to connect to the control panel. If there is no response, a cyclical request to connect to the control panel is sent again. If there is a connection and a signal is received, a response occurs to work on exchanging data with the remote control and checking the necessity of continuing work. If the work is finished, the cycle ends. If the system continues, cyclical work with the remote control takes place until the work with the remote control is finished.

The control panel operations algorithm (figure 4) begins with initialization. Then, the remote control acts as a receiver. Therefore, there is a wait for a free request on the air to connect to the robotic intelligent platform. In the absence of active requests, there is a cyclic wait for a connection request. In the case of a connection and receiving a signal, it is essential to exchange data with the platform and check the need to continue work. If the work is finished, the cycle ends.

3.4 Features of the System

When activating the data recording system for building a three-dimensional model of the reservoir bottom, the system activation is checked, the GPS module and the SD module are launched, and their settings for operation are performed. The GPS module needs time to connect to satellites and determine its coordinates. Therefore, determining the coordinates of the robotic platform location takes time. Then a file is created to make further recordings of the depth sensor data and the corresponding coordinates. In addition, a timer is started, which is set to 10 minutes by default. During this time, the data will be recorded in the created file. Next, the coordinates and depth are cyclically read. Finally, this data is written to a file with an interval of 30 seconds during the time set by the timer. This data file is the basis for construct-

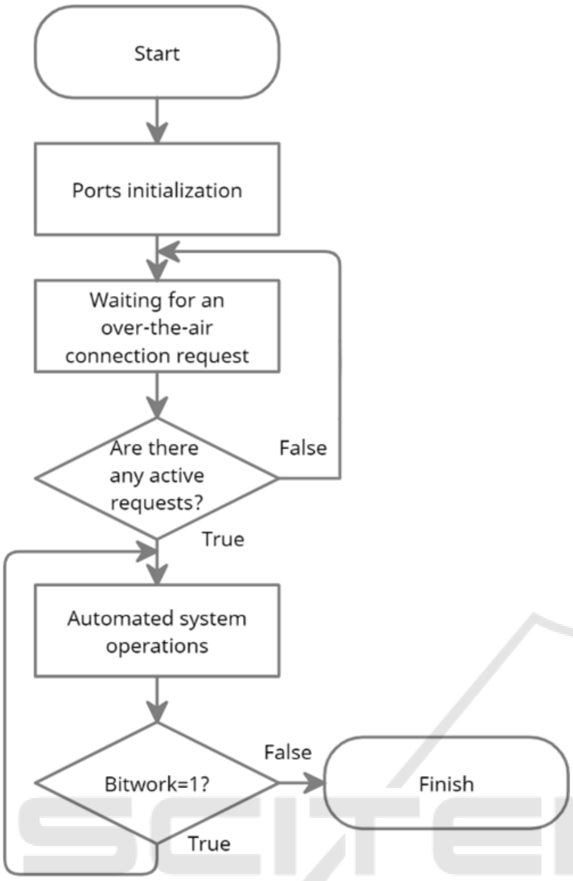

Figure 4: The basic algorithms of the control panel.

ing a wavelet diagram of the reservoir bottom section. If the data recording system is activated again, it is checked whether the coordinates of the module are determined, and the work continues in the cycle. Otherwise, the reactivation of the system is expected.

With the help of radio modules, such data as control signals from the remote control are transmitted. They are responsible for the movement of the platform, turning on/off the dimensions, and collecting a water sample for deeper analysis. In addition, there is a data transfer received from sensors, namely water acidity level, temperature, depth, coordinates of the platform location, and battery charge level.

To create a map of the bottom relief, first of all, it is necessary to collect data on the depth of the reservoir using an ultrasonic distance sensor JSN-SR04T-2.0. Then, two more parameters are needed to build a three-dimensional model. One of them is time, and the other is coordinates, the determination of which is performed using GPS data of the mobile platform location on the reservoir. Finally, when conducting research, it is necessary to choose a site on the reservoir and, moving through the reservoir step by step, receive data from the depth sensor and coordinates at these points, respectively, and write this data to a file on the platform of the RPi 3B+ mini computer installed on the mobile platform.

3.5 Data Processing

The MATLAB system was used to process the data and build a three-dimensional relief model of the bottom of the reservoir, namely the Wavelet Toolbox, which provides functions and applications for analyzing and synthesizing signals and images. The toolbox includes algorithms for continuous wavelet analysis, wavelet coherence, synchrosqueezing, and data-adaptive time-frequency analysis. Using continuous wavelet analysis, it is possible to study how spectral functions evolve with time, identify common time-varying patterns in two signals, and perform time-localized filtering. Discrete wavelet analysis helps to analyze signals and images in different extensions to detect discontinuities and other defects that are not easily visible in the raw data. In addition, it is possible to compare signal statistics on multiple scales and perform a fractal analysis of the data to reveal hidden patterns. Finally, with the Wavelet Toolbox, you can obtain a sparse representation of data valid for denoising or compressing data while preserving important features. Many toolbox functions support C/C++ code generation.

A1 | fx | 9:42:34

	A	B	C	D	E	F	G
1	9:42:34	50.236396	28.611356	155	24	6	5
2	9:42:37	50.236400	28.611360	146	24	6	5
3	9:42:40	50.236412	28.611358	140	30	6	4
4	9:42:43	50.236412	28.611354	134	29	6	4
5	9:42:46	50.236415	28.611351	145	29	6	4
6	9:42:49	50.236412	28.611351	132	30	6	4
7	9:42:52	50.236396	28.611356	144	30	6	4
8	9:42:55	50.236385	28.611362	144	30	6	4
9	9:42:58	50.236381	28.611370	135	30	6	4
10	9:43:01	50.236377	28.611373	151	30	6	4
11	9:43:04	50.236373	28.611377	136	30	6	4
12	9:43:07	50.236370	28.611379	147	30	6	4
13	9:43:10	50.236362	28.611383	156	29	6	4
14	9:43:13	50.236358	28.611383	131	29	6	4
15	9:43:16	50.236354	28.611383	138	29	6	4
16	9:43:19	50.236354	28.611381	147	29	6	4
17	9:43:22	50.236354	28.611377	149	29	6	4
18	9:43:25	50.236354	28.611375	99	29	6	4
19	9:43:28	50.236354	28.611371	89	29	6	4
20	9:43:31	50.236354	28.611370	96	29	7	4
21	9:43:34	50.236358	28.611366	105	30	6	4

Figure 5: Recorded data from a flash drive.

The investigation results prove that using wavelet transformations at the given stage of work is not entirely appropriate. Undoubtedly, it is necessary to follow a clear route to use wavelet transformations. For instance, it is crucial to select the coordinates of

Figure 6: Intelligent robotic platform movement route and two-dimensional depth plot.

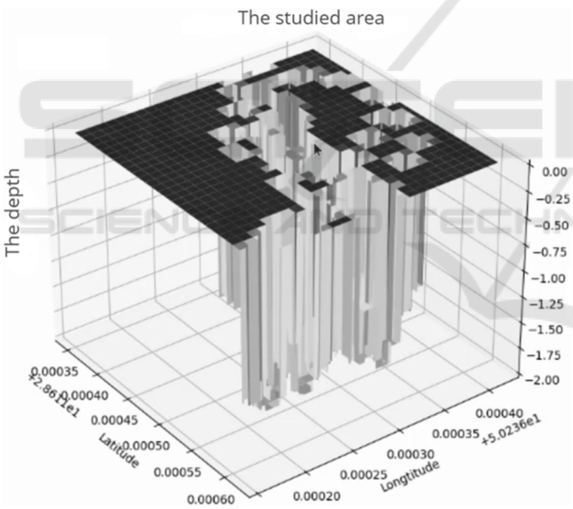

Figure 7: Three-dimensional model of the bottom of the reservoir.

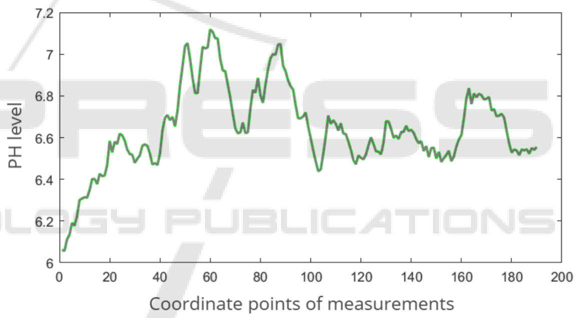

Figure 8: Changes in water acidity in the reservoir.

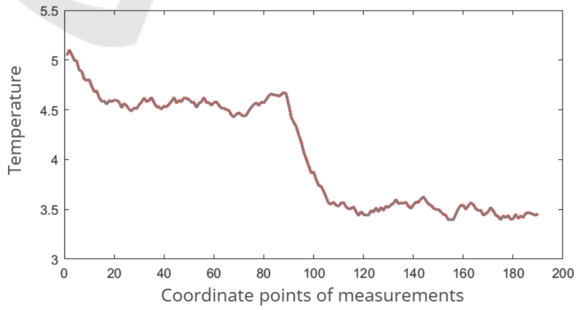

Figure 9: Water temperature changes in the reservoir.

a specific section, which are autonomously traversed robotically by the platform at the same speed, the same passes, and exclude measurement errors due to the influence of external factors.

4 CONDUCTING AN EXPERIMENT

Before the experiment, the platform and all elements' efficiency were thoroughly checked. Then, a shallow water body was chosen for the test launch of the intelligent robotic platform and the necessary data collection. Finally, a route with different trajectories was traversed, and sensor data were recorded, which was the primary aim of the research.

All the research data is recorded in a file stored on a flash drive. It is convenient for further processing and analysis. Some recorded data is shown in figure 5.

The GPS module determines the current location and indicates the exact time regarding the location in specific coordinates. The data analysis makes it possible to build a map of the intelligent robotic platform's route and a two-dimensional depth graph (figure 6).

Furthermore, a three-dimensional model of the reservoir bottom was built based on the platform's route data and measured data at specific points along the route. However, it is not highly detailed, as it considers only the specified points of the route. Thus, to increase its informativity, all intermediate points must be filled with relevant data (figure 7).

According to the readings of the temperature and acidity sensor at each determined point of the robotic platform route, graphs of changes in these values were built (figure 8, 9).

5 CONCLUSIONS

The research introduces a new intelligent robotic platform for geodetic and ecological studies of water bodies. It helps assess water quality and measure a water body's depth. It provides a detailed layout of all structural elements, describes the methodology, and clarifies further data processing. Sensitive system elements such as temperature, water acidity, and distance sensor were chosen, which meet all platform installation requirements. Finally, it investigates the effectiveness and correctness of the system performance on a natural reservoir (a river and a lake). Furthermore, all necessary measurements were taken, including a water sample. Based on the results, conclusions were made about the water quality in the reservoir. Moreover, three-dimensional models of the studied bottom area and graphs of changes in the values (temperature and acidity) were constructed. In addition, the research highlights the problem of using a wavelet diagram to describe the area of the reservoir bottom.

The installation has a set of functions, which can be increased in the future, for example, adding the function of work autonomy at specified points, which contributes to building a full-fledged detailed map of the reservoir bottom. In addition, the article considers the possibility of a more detailed analysis of water locally.

REFERENCES

Bezvesilna, O., Tkachuk, A., Chepyuk, L., Nechai, S., and Khylchenko, T. (2017). Introducing the principle of constructing an aviation gravimetric system with any type of gravimeter. *Eastern-European Journal of Enterprise Technologies*, 1(7(85)):45–56. https://doi.org/10.15587/1729-4061.2017.92941.

Brans, P. (2021). What Norwegians are learning as they pioneer autonomous ships. https://tinyurl.com/4pcatcdt.

Chung, H.-Y., Chung, Y.-L., and Hung, Y.-J. (2018). An Effective Hexapod Robot Control Design Based on a Fuzzy Neural Network and a Kalman Filter. In *2018 IEEE Region Ten Symposium (Tensymp)*, pages 248–253. https://doi.org/10.1109/TENCONSpring.2018.8691947.

Dimitropoulos, S. (2019). The New Ocean Explorers. https://www.popularmechanics.com/technology/infrastructure/a29849406/unmanned-ocean-drones-antarctic-voyage/.

Drăgan, O. (2021). This Solar-Powered Electric Ferry Is the First Maritime Robotaxi in Europe. https://tinyurl.com/4bf65wut.

Koval', A. V. (2015). Simulation of gravimetric measurements by gyroscopic integrator of linear accelerations. *Gyroscopy and Navigation*, 6:344–347. https://doi.org/10.1134/S2075108715040070.

Li, Y., Wang, X., Zhao, Z., Han, S., and Liu, Z. (2020). Lagoon water quality monitoring based on digital image analysis and machine learning estimators. *Water Research*, 172:115471. https://doi.org/10.1016/j.watres.2020.115471.

Niiler, E. (2020). The Robot Ships Are Coming ... Eventually. https://www.wired.com/story/mayflower-autonomous-ships.

Rivero, N. (2022). Japan is home to the world's first autonomous container ships. https://tinyurl.com/bdfpdf7e.

Sea Machines (2023). SM300 Autonomous Command & Control.

Tedeschi, F. and Carbone, G. (2014). Design Issues for Hexapod Walking Robots. *Robotics*, 3:181–206. https://doi.org/10.3390/robotics3020181.