Multibeam Echosounder and LiDAR in Process of 360-Degree Numerical Map Production for Restricted Waters with HydroDron

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***Abstract*—In order to increase the safety of inland navigation and facilitate the monitoring of the coastal zone of restricted waters, a model of multisensory fusion of data from four hydroacoustic and optoelectronic systems mounted on the autonomous survey vessel HydroDron will be developed. In the research will be used modern data acquisition technologies such as the LiDAR laser scanner, multibeam echosounder, side sonar and rotary camera. Data from sensors available on the platform can be obtained from two separate dedicated software. They can be simultaneously visualized and edited in one Hypack software, which enables effective integration of sensors.**

On the HydroDron platform are mounted LiDAR VLP-16 sensors from Velodyne and compact dual transducer 3D sidescan 3DSS-DX450 Ping DSP company. LiDAR enables to scan the area around HydroDron and creating a point cloud. The 3DSS-DX450 system simultaneously collects 3D side-scan data, 2D side-scan, and bathymetry data from the sea-bed surface. The HydroDron is multi-variant, which allows the configuration of the survey system for the user's needs. It also means that the user can add another sensor e.g. from a rotating camera to increase the visualization.

The main purpose of the research is to develop new models of data processing from sensors, their comprehensive fusion and consistent visualization. This will allow to present data in the form of 360 degrees spatial maps for restricted areas. Such a spatial 360 degree map is a future-proofed map of the new generation. It enables the visualization of spatial data both horizontally and vertically, creating one spherical image of the terrain surface. This multi-sensory fusion of data obtained from four sensors will develop hydrographic researches [1].

The high level of product innovation determines its potential for commercialization. The benefits of the implementation of work effect may include the provision of services, such as the development of the West Pomeranian Water Atlas, which is directly related to the development of tourism in the region or inventory and monitoring of the coastal zone of restricted areas.

Keywords—high-resolution imaging, terrain mapping, unmanned autonomous vehicles.

I. INTRODUCTION

Nowadays, there is a turbulent development of modern technologies that enable the collection of a huge amount of spatial information in a relatively short time. The research questions revolve around the issue how to visualize spatial data with different characteristics, obtained from various sensors so that they are coherent and accurate. Due to the different specifics of individual sensors, there is no possibility of their direct adaptation. New methods dedicated to vessels equipped with a number of modern devices that collect underwater and surface information should be developed. Undertaking this task is associated with solving a number of problems in various fields of geoinformation, hydrography, navigation, data processing, mathematical modeling and cartography.

The main purpose of the research presented in a given article is to develop a data fusion model obtained from four hydroacoustic and optoelectronic sensors. Geodata used during the research will be acquired using the HydroDron floating platform, i.e. a mobile laser scanner, a rotary camera, multibeam echosounder, 3D side scan sonar and other necessary devices for data recording process.

The HydroDron floating platform can operate on shallow areas due to its mobility and dimensions. This type of vehicles have become more and more popular. It is related to the possibility of installing more sensors [2] and doing surveys without an operator on board. This opportunity reduces the weight of the vehicle and its manoeuvrability. Unmanned vehicles automatically perform their mission in restricted areas [3].The concept of a restricted area should be understood as each water area, which will be considered as a difficult due to its proximity of the land [4].

II. EXISTING SOLUTIONS

Some undertaken issues of the problem have already appeared in existing studies presenting a used in practice combination of geodata from several sensors.

One of the existing solutions is the data integration of the laser scanner LiDAR (Light Detection and Ranging) along with the multibeam echosounder MBES (Multi Beam Echo Sounder). The solved problem was to investigate the flood embankment in California above and below the waterline. For measurements due to shallow depths and limited access to the study area, an unmanned, remotely controlled surface vehicle was selected - Seafloor EchoBoat USV (Unmanned Surface Vehicle). The bathymetric data was obtained from the Norbit multibeam echo sounder iWBMSc. A cloud of points around the vehicle was acquired using VLP-16 LiDAR. Collected data from all sensors was integrated in the Hypack software. During the measurements, almost 6 million points were obtained. Data was being collected simultaneously through the software and processed into the X, Y, Z cloud file. Data sets from both sensors have been edited and processed independently. The result of the work which can be seen in Fig. 1 was the data from two selected sensors fusion model,. The waterline border with the data on the flood embankment and the bottom surface has been clearly defined [5].

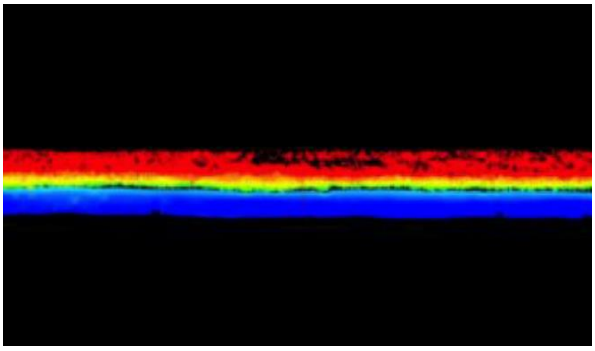

Figure 1. Data fusion from two sensors [5]

Another example are the company Fugro Pelagos Inc. researches which undertook the simultaneous collection of ALB (Airborne LiDAR Bathymetry) data and bathymetric data from a multibeam echosounder on the ship. The scope of research included the city of Sitka, Alaska. The purpose of the task was to provide data for the production of nautical charts for enhanced navigation safety. The project used the SHOALS-1000T ALB system and multibeam systems Reson 8101 and Reson 8111. LiDAR supplied both the bathymetry and the topography of the area. The raid was carried out from a height of 400 m. Flight planning, data processing, quality control and data export were carried out in the SHOALS Ground Control System. LiDAR data was combined with bathymetric data from a multibeam echo sounder in the CARIS software. According to Fugro, integration of data from the LiDAR system and multibeam echo sounder is a breakthrough in the creation of navigational charts. Such use of systems reduces the time needed to create and update maps [1].

Another example of multi-sensory fusion was the measurement of Olimpic Coast Wahkiakum County and Mouth of the Columbia River as part of The Washington State Department of Ecology Coastal Monitoring & Analysis Program, with the help of the George Davidson R / V unit equipped with the R2Sonic 2022 multibeam system, LiDAR Optech ILRIS-ER with compensation of movements and Position and Orientation System for Marine Vessels by Applanix (POS MV 320 V5 RTK) consisting of an inertial navigation system (IMU), two GNS antennas and a computer with real-time LiDAR data synchronization along with ship position and orientation [6].

Acquisition and control of data was performed in the Qinsy program using measurement lines generated using POSPac MMS (Applanix, Ontario, Canada), which uses ephemeris data from the satellite to determine the exact position of the ship. The initial result of the measurements was the point cloud acquired using LiDAR and the depth points acquired using MBES.

Another example of a commercial solution is the Orbit software that integrates large-scale data from laser scanning. However, there is no possibility to load data from modern hydrographic systems that present information about the underwater situation.

There are also scientific publications related to the spatial data fusion. Kulawiak and Lubniewski present the processing of data obtained from LiDAR and multibeam echosounder in the publication [7]. The authors focus on describing the methods of data reduction from these two sensors and present differences between them.

A very interesting approach is presented in the journal Sensors titled „Adjustments of Sonar and Laser Acquisition Data for Building the 3D Reference Model of Canal Tunnel" [8]. The authors showed the results of 3D visualization for the selected channel. During the integration of data from multibeam echo sounder and laser scanning, they focused on the problems related to the overlapping of geodata and their orientation.

III. CHARACTERISTICS OF THE PROBLEM

All existing solutions do not take into account as many as four different sensors mounted simultaneously on the vessel. The integration of these data is a scientific and technological challenge. In addition, the planned visualization model will allow for a comprehensive analysis of the underwater and surface situation. Spherical visualization of data will bring incomparably better perception of the system user than in the case of existing solutions. The sensors planned for use during the tests and the data obtained with their help are shown schematically in Fig. 2.

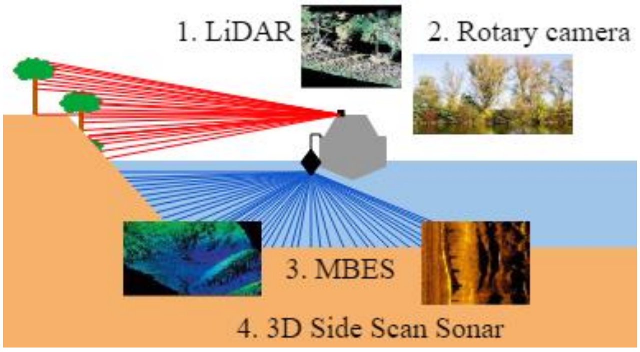

Figure 2. Sensors planned for use in research (own study)

At the initial stage of research, the requirements of end users should be specified in detail and a general sensory fusion project developed. The necessary spatial data should be obtained and properly developed. To this end, clear guidelines will be created on these stages. In the next step, a model of multi-sensory fusion will be developed, which involves several problems in the field of geoinformatics. First of all, the integration of geodata from various sources, in different formats or coordinate systems should be indicated here. An additional problem is that the data from modern sensors belong to the group called Big Data or large data sets. It will be necessary to verify and optimize such as reduction, generalization, correction of orientation, vertical transposition, horizontal transposition, segmentation, merging and others. A detailed model of data integration will be include in the developed method. At the next stage, a database will be create that can be included in any system. In addition, for verification purposes, a 360 degree visualization model will be developed. This model will have the form of a multimodal numerical spherical map. The concept of collecting and processing geodata is presented in the Fig. 3.

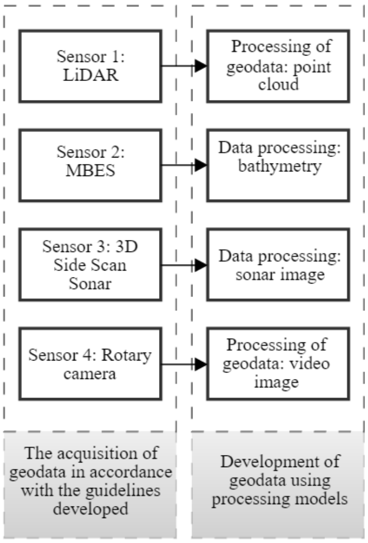

Figure 3. Data acquisition from four sensors (own study)

As indicated above, there is a need to develop a multi-sensory fusion model of data obtained from four sensors, which will allow visualization of the spatial map of the water areas along with the adjacent land part. For a multimodal spherical map a dedicated visualization model will be developed. The concept is shown in Fig. 4. The visualization model will be perceived by the end user in an intuitive way.

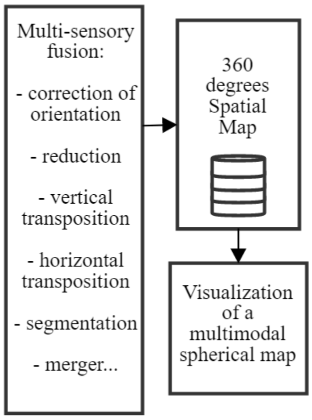

Figure 4. The concept of multisensory fusion (own study)

Both schemes together create a concept of multi-sensory fusion of data from hydroacoustic and optoelectronic systems in the process of 360 degrees multimodal spatial maps creation for restricted areas. In relation to study issue there is the need to develop comprehensive guidelines for the acquisition and collection of data from individual sensors. Partial purpose of the task is also to develop models of preliminary processing of data from sensors, including their generalization and georeferencing, and multi-sensory fusion of geodata. In light of these problems, the study appears as the challenge of combining interdisciplinary areas of research in various fields. The finale of the research will be developed methods of verification tests to be carried out under laboratory and true conditions - using modern vessel HydroDron and installed on board research equipment. On the HydroDron platform are mounted LiDAR VLP-16 sensors from Velodyne and compact dual transducer 3D Side Scan 3DSS-DX450 Ping DSP company. LiDAR enables scanning the area around HydroDron and creating a point cloud. The 3DSS-DX450 system simultaneously collecting 3D side-scan data, 2D side-scan data, and bathymetry data from the sea-bed surface. Rotating camera on the HydroDron platform affects better visualization.

IV. EQUIPMENT

The HydroDron floating platform requires small, durable devices to acquire data. The project will examine the acquisition of data from four sensors mounted on the unmanned vehicle. Ping DSP proposes a solution for integrate two sensors into one 3DSS-DX-450 compact sonar device. At the same time, it obtains very good quality bathymetric data of the studied area and 3D image. The system uses the latest technologies of acoustic transducers. One of the most important technologies used by the bathymetric system is Softsonar™ [9].

It allows to separate the backscatter from the bottom, the sea-surface and the target. It means that the target in the water column does not blend into the seabed. Sonar uses dedicated software that allows the user to acquire a 3D point cloud in real time. At the same time, the 3DSS-DX-450 device is compatible with Hypack software, available on HydroDron, which enables integration of sonar with other sensors. Fig. 5 shows the 3D image acquired with the 3D Side Scan Sonar [9].

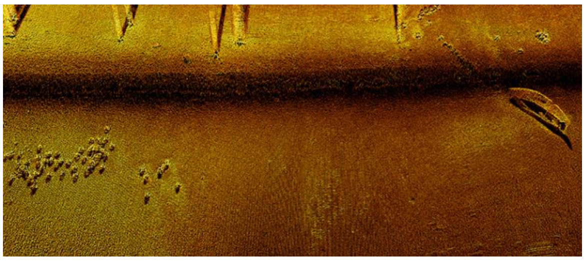

Figure 5. 3D image acquired with 3DSS-DX- 450 [9]

Fig. 6 shows the bathymetry of the same area made with the same measuring equipment.

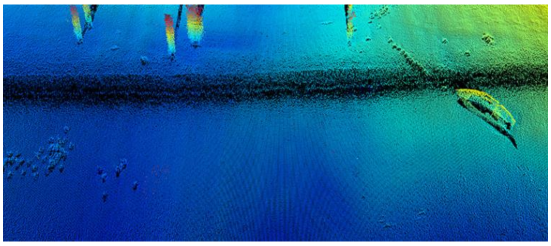

Figure 6. Bathymetric data acquired with 3DSS-DX-450 [9]

The result is a 3D image with side scan covering the entire water column and a perfect swath sensor from one devices [9].

The third main sensor is a laser scanner LiDAR. The potential of light laser scanners is mentioned in [10]. LiDAR Puck V-16 from Velodyne company is mounted on HydroDron and will be used during research. The device creates 3D images in 360 degrees horizontal field of view. It uses 16 laser beams mounted in a compact housing. The device performs from 5 to 20 rotations per second, releasing the beam thousands of times. It provides a varied point cloud in real time. Velodyne provides its own dedicated software and VeloView software for data visualization, shown in the Fig. 7. At the same time LiDAR is compatible with Hypack software, where real-time visualization is ensured [11].

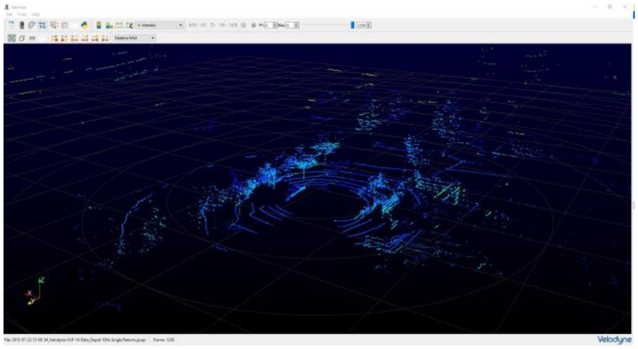

Figure 7. Visualization of sample data in VeloView software (own study)

The fourth sensor used in the research is the rotary camera. It provides information about the environment in real time. In the case of the described research, it will definitely improve the visualization. It is imperative that the camera is resistant to bad weather conditions, temperature variability and high humidity. The video image from the camera will be superimposed on the points cloud obtained from LiDAR.

V. CONCLUSION

The methods developed as products of individual research tasks will be the final result of the research. A measurable effect will be a multimodal numeric map for spherical visualization, which will be an innovative solution without direct counterparts in the market. The high level of product innovation determines its potential for commercialization. There is no known method in the world that combines data from four different hydroacoustic and optoelectronic sensors.

The developed visualization model will allow to present the geodata of the restricted area, in a more intuitive way for the end user of the product than previous solutions. The received multimodal numerical maps can be used in the development of water tourism, including the development of Water Atlas of voivodships under the Regional Infrastructures of Spatial Information. Additionally, they may be used during inventory and monitoring of limited water areas, such as water dams, wharfs, bridges, breakwaters, piers, locks, weirs, marinas, coastal fortifications, flood embankment, water courses, movement and deposition of bottom sediment. The multimodal numeric map can be also used during the inspection of the state of the navigational marking, e.g. navigational buoys. End users will gain complete and multidimensional data on restricted areas. The implementation of the product may facilitate the updating of flood risk maps from the sea, including marine internal waters.

The main innovation of the researches will be possibility of simultaneous analysing and multimodal processing spatial data in order to build a digital map to spherical visualization dedicated to restricted areas. Multimodal data from multibeam echosounder, 3D side scan sonar, laser scanner - supported by mobile video image and processed multi-sensory fusion will form the content of digital numerical maps. Underwater scanning technology with multi-beam echosounder, unique 3D side scan sonar or terrain scanning LiDAR is an innovative technology that is rapidly developing in the world. Addition of 3D data from the 3D sonar and video camera to the vector data from the multi-beam echosounder and LiDAR is a completely new approach on a global scale.

Acknowledgment

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