

Software for tracking aquatic environment geographic information systems for further integration with advanced search capabilities

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Abstract. A close inspection of existing software for relatively accessible underwater imaging and data-gathering systems reveals its inadequacy for conducting search operations and subsequent map making. In order to broaden the application of existing recreational and low-cost echo sounders and side scan sonar (SSS), the authors of this paper propose a program, which is part of a specialized software and hardware complex under implementation. Being the initial stage of the project, the proposed program is capable of visualizing routes on a graph and displaying the resulting trajectory using a GNSS receiver, further synchronizing it with hydrographic data from a sonar device.

1. Introduction

Current advances in various geosciences are unimaginable without the implementation of information technologies. This has resulted in the appearance of a wide assortment of software products with unique characteristics and tailored for solving a spectrum of specialized tasks. However, to our knowledge, there are very few complex systems allowing their implementation for solving interdisciplinary tasks. This highlights the importance of designing such tools, as integrated geographical information systems (GIS) with search capabilities.

An example of an area facing this problem is hydrography. Recent advances in sonar technology enabled the production of relatively low-cost side scan sonar (SSS) and other recreational-grade sonar systems that can be effectively used to study aquatic environments in the remotest locations. Unfortunately, many of these systems, despite their satisfactory imaging capabilities, have inadequate or complicated application software. While utility software is available for popular sonar manufacturers, it is often limited to data processing and recreational cartography. Accordingly, the development of a GIS with search capabilities for aforementioned sonar systems could greatly benefit aquatic research.

Furthermore, there are other tasks that need to be solved within the GIS, such as using a variety of maps, including those freely available online, recording tracks, gathering supplementary data with additionally installed equipment (e.g., conventional sonar for recording water depths thereby enabling the design of bathymetric maps), and supporting the thorough investigation of predetermined areas in order to detect objects of interest. The latter can be accomplished employing various remote sensing

and imaging equipment, including SSS. It is essential for the operator of such equipment to be able to construct the route that is intended to be followed within the study area prior to the actual investigation. This is especially important when a large area needs to be covered within a limited time period. Prior to the development of the proposed software, there were scenarios when it was necessary to operate two programs from different computers, the first running the SSS software, while the second was following a track in a GNSS program. This put additional stress on the operator, making it necessary to focus on two programs at once, thereby increasing the chances of missing an important object.

During the initial stage of developing the software complex, it was proposed to create a program that can, using available equipment, record the movement of objects along with any additional information, such as (in the case of the project), elevation above sea level and water depths.

Similar work has been carried out in many research facilities around the world. These include the development of GIS of separate geographic objects, entire regions, and more complex digital atlases. For example, in [1], the structure of a model GIS of Lake Baikal is discussed. In [2], there is a description of building a GIS for the rivers and lakes of the northern part of European Russia. In [3], the topic of developing thematic maps of the Ob River is considered, thereby proposing geographic information and cartographic support for the study of this river's basin. It should be noted however, that these projects are all independent. They propose novel software that can, however, be used only for a specific project. There are currently no shared software platforms that can be used interchangeably for accomplishing different tasks.

2. Description of the equipment

It is proposed that the computer appliance should include equipment capable of obtaining the current geographic coordinates of latitude and longitude, elevations, depth to the surface of a reservoir's bottom. Further, we shall discuss the necessary equipment, needed to solve this problem.

A GNSS receiver is a device designed to determine the current location at any point on the surface of the Earth based on geographic coordinates transmitted by satellites to the navigation system [4].

A SSS is a device that enables examining the structure and topography of the surface of the bottom of a reservoir, locating submerged objects and aquatic organisms. Towed by a watercraft or mounted on its hull, the SSS can continuously track changes made in the reservoir for the purpose of obtaining data on changes in underwater topography [5].

The coordinates x and y (latitude and longitude) can be obtained using a GNSS receiver, the z coordinate, i.e. the depth of the reservoir, by using a sonar device, or by using a GNSS receiver when considering elevation above sea level.

The majority of navigation devices use the NMEA 0183/2000 Protocol to send messages. This protocol includes a message system for exchanging information between the navigation devices and the consumers of this data. The messages are transmitted in an ASCII format and have the following structure:

$$\text{\$}<\text{ID navigation system}><\text{message ID}>,<\text{data fields}>*<\text{checksum}><\text{CR}><\text{LF}>.$$

The navigation system ID shows which satellite systems are currently operational, such as GP-GPS, GL-GLONASS, GN-GPS, and GLONASS. The message ID indicates the type of message being sent. For example, messages with the following types provide data: (1) GGA-time and location; (2) GSM-used satellites; (3) GSV-visible satellites; (4) RMC-recommended minimum navigation data. Data fields are separated using the "," symbol. GGA and RMC data types are used to determine the geographic coordinates transmitted by the GNSS receiver over the NMEA 0183/2000 Protocol, and only GGA is used to determine elevation above sea level. SDDPT and SDDBT packages are used to determine the depth transmitted by the sounder using the NMEA 0183/2000 Protocol [6].

GNSS hardware and the NMEA Protocol are frequently used in software products that are currently being developed and are presented in [7–9].

3. The development of the software

In order for the program to operate when recording and displaying tracks on the map and for the subsequent construction of a three-dimensional map of a site, a GNSS receiver and an echo sounder are used. Before proceeding to the development stage, the following minimum set of requirements for the software was determined: (1) receiving messages from navigation devices using the NMEA 0183/2000 Protocol; (2) recording the route based on the received data along with displaying it with markers; (3) loading a certain section of the map into the device's memory. The software is currently in the final stage of development and is available for use on the Microsoft Windows platform.

The software development uses the .NET Framework and the C# programming language.

For two-dimensional maps, the library GMap.NET is used. It allows embedding maps from various sources for the project in C# or VB.NET without using the program code [10]. It is possible to use maps of the following services: Google Maps, Yandex.Maps, OpenStreetMap, Yahoo! Maps, Bing Maps, ArcGIS, SigPac, Mapy.cz.

In addition, the library GMap.NET allows drawing geometric shapes that are superimposed on the map. Thereby it is possible to display routes in a graphical form, or select the area of the map that the user needs. Markers can be added to the map with the selected icons or by using custom images.

In the proposed application, data on the recorded routes, markers, and downloaded map sections is stored in each specific project with its designated name.

Figure 1 shows the main window of the application, which features a map from the Bing Maps service. The main part of the window is occupied by the library element GMap.NET, which displays the map. The main window contains a menu that enables creating or opening a project, importing a previously created route, saving a screenshot, customizing the appearance of the main window, opening the "Options", and asking for help.

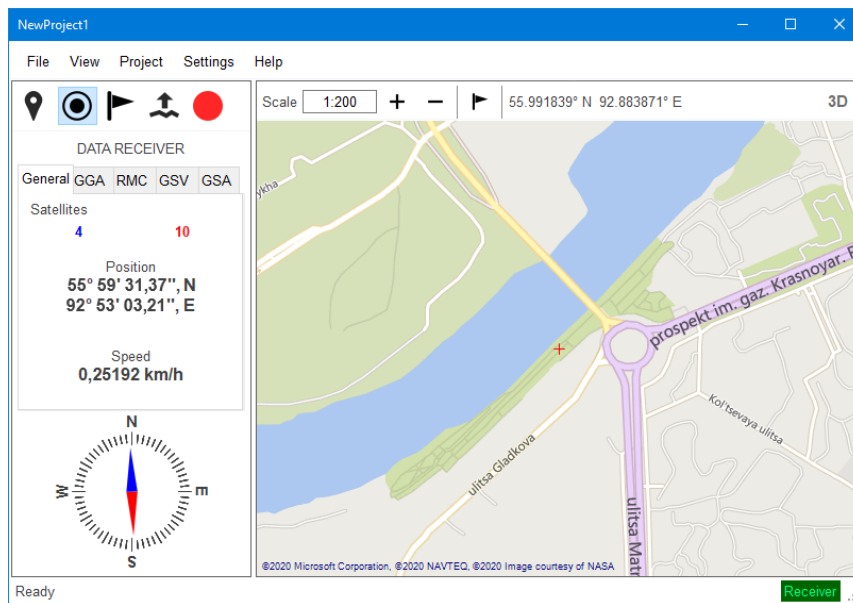


Figure 1. The main window of the developed application.

At the top of the map, there is a map control panel, which allows you to control the map scale, create new markers, manually specify the location, and switch the 2D/3D mode.

On the left side of the main window, there is a control panel that allows performing basic functions and receiving data from the receiver. At the top of the panel are the following buttons:

- Current location. When this button is clicked, the map moves to the current location of the user (if there is a connected GNSS receiver that receives the coordinates of the current location).
- Data from the receiver. Clicking this button opens a tab with data received by the GNSS receiver.

- Markers. Clicking this button opens a tab with markers saved for the current project.
- Importing a map. Clicking this button opens a tab with a selection of parameters for importing the map to the current project.
- To start/stop recording the route.

At the bottom of the main window, there is a status bar that shows the current state of the satellite receiver.

The parameters allow configuring the application's operation, such the settings of the satellite receiver, selecting a map provider, and specifying route display settings.

Information about markers is stored in an XML file, each element of which contains the following data: the date the marker was created, coordinates (latitude and longitude), name, description, images, and color.

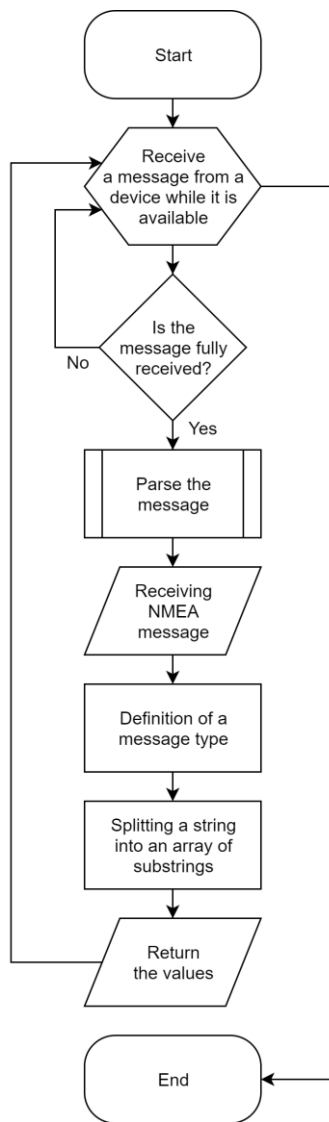


Figure 2. Flowchart showing the process of obtaining data from a navigation device.

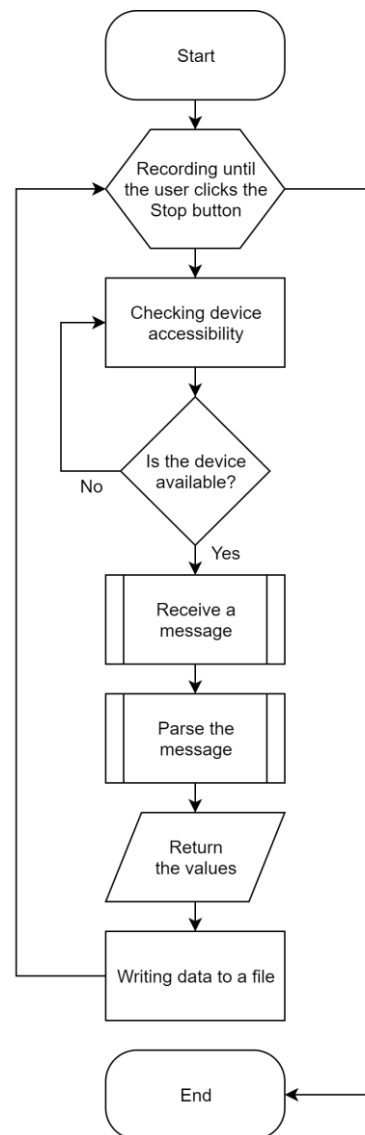


Figure 3. Flowchart showing the procedures for writing values to a file from a navigation device.

Currently, a parser of messages from the GNSS receiver and echo sounder is being developed. The parser class constructor argument is a string variable containing a message in the NMEA 0183/2000 format. Next, the parser determines the package of this message, and then splits the string object into an array of strings by separating the string with a comma. Each element of the array corresponds to the necessary data on the location. This can be latitude, longitude, depth, speed, number of satellites, etc. In figure 2, there is a flowchart showing how the program gets values from the navigation equipment.

The route is recorded in a specific project file containing each coordinate received at a certain time interval, as well as the date, time, and speed. In figure 3, there is a flowchart showing the procedures for writing values to a file using a navigation device.

4. Testing

A Beitian BN808 GPS receiver with the ability to transmit messages via the NMEA 0183 Protocol was used to test the software in urban environments. This device was connected to the computer through a USB port.

Figures 4 and 5 show the results of recording tracks in the city of Krasnoyarsk.



Figure 4. Track 1.

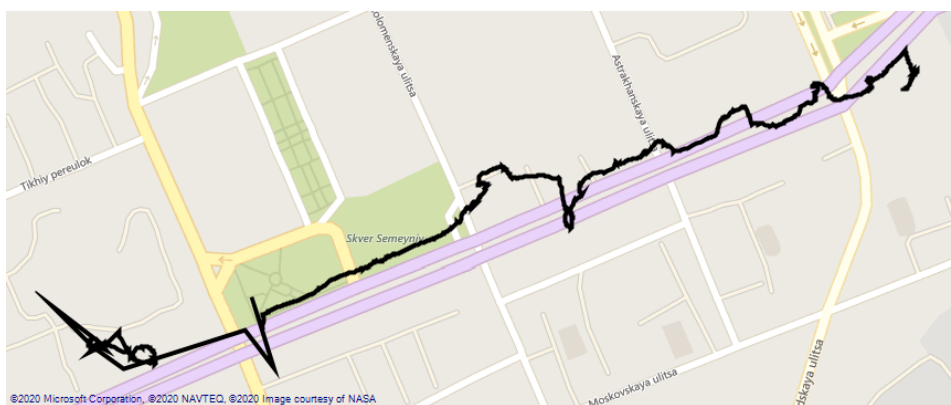


Figure 5. Track 2.

The analysis of the results shows that the GNSS receiver detects the location quite well; however, there is a small error associated with the quality of signal reception from satellites and the need to take into account various factors, such as signal reflection from buildings, water surfaces, and various interference.

5. Conclusion

The described program is the first stage of developing a complex software platform for designing geographic information systems with advanced search capabilities. Despite its simplicity, the program demonstrated satisfying results producing relatively accurate tracks. Their accuracy may be improved employing track optimizing algorithms with smoothing and filtering effects. The designed program was tested with identical results on land and water. In the second case, a multi-sonar complex, which included an echo sounder and a side scan sonar, was synchronized with the tracking program. Incorporating relevant hydrographic data into the system make it possible to convert two-dimensional aquatic maps into three-dimensional ones.

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