

DIRECT INVENTORY TAKING OF UNDERWATER OBJECTS USING A HANDHELD GPS RECEIVER

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ABSTRACT

The paper presents application of the GPS - Thales Mobile Mapper satellite navigation receiver for conducting the direct underwater inventory and location of objects on the bottom of inland water reservoirs.

The design description of the measurement set consisting of the manual GPS/GIS receiver, specialist watertight casing with function keys and floating GPS antenna is presented. The possibilities of using the set directly in underwater navigation conducted by a scuba diver on shallow depth were investigated. The results of search for obstacles located earlier using the hydroacoustic methods: the single beam echo sounder (SBES) and side scan sonar (SSS) were described. The analysis of accuracy of the underwater GPS navigation was also conducted.

INTRODUCTION

During inland bathymetric measurements various objects on the bottom, wrecks, obstacles, large boulders, etc. are found frequently. Usually those discoveries are made using the single beam echo sounder (SBES), the hydrographical system most frequently applied in shallow inland waters and using the side scan sonar (SSS) (Popielarczyk, 2002).

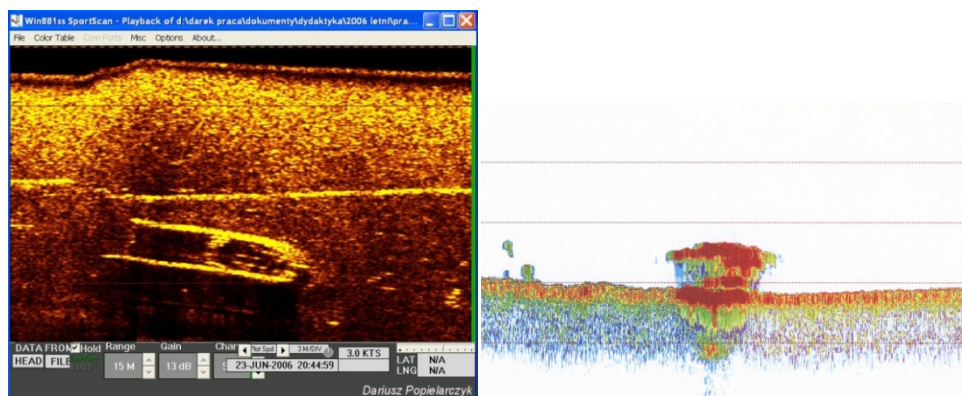


Fig. 1. Wreck of a motor boat in Lake Krzywe. Sonogram and echogram.

Analysing the echogram image in most cases it is difficult to identify the object presented. It is definitely easier to interpret the object using the complementary sonar images. The direct underwater inventory taking, however, is the best way to achieve unquestioned identification of the object found on the bottom.

In this article the application of the GPS/GIS - Thales Mobile Mapper satellite navigation receiver for location of objects situated on the bottom of inland water reservoirs is presented. The application of that method as support for bathymetric measurements for unquestioned identification of objects visible in the echograms is described. That method can also be applied for underwater navigation towards the earlier set points or along the set path. The underwater experiments were conducted on lakes Narty and Łęsk in Warmińsko-Mazurskie voivodship, county of Szczytno and Krzywe within the area of the City of Olsztyn. During the tests measurements of the diving trajectories and measurements of characteristic underwater objects were conducted. Photographic documentation has also been prepared. After processing the results of satellite observation in the DGPS post processing mode using the data from the ASG-EUPOS net the results were compared with those obtained from the direct measurement applying the automatic method.

OBJECTS FOR EXPERIMENTAL TESTS

A fragment of Lake Świętajno (commonly called Narty), situated in Warmińsko-Mazurskie voivodship, county of Szczytno, municipality of Jedwabno was selected as the basic experimental area. That lake has the surface area of ca. 175 ha, maximum depth of 30.5 m, average depth of 11 m, length of 2.2 km, width of 1.2 km and the water level surface positioned 138.8 m above the sea level. That reservoir was chosen for the test field for two basic reasons. First, in the vicinity of the Narty village a scuba diving base is situated in the area of which many objects of diversified size such as trees, diving platforms, cars, boats, etc. have been sunk. As a consequence conducting measurements of numerous interesting objects within a relatively small area was possible. Second, that lake is quite a good place for underwater inventory taking because of good visibility that reaches 4-6 metres. This is of key importance in conducting underwater works, in particular in case of underwater navigation and taking photographs. The lake bottom is sandy, sloping slowly and the vegetation is not excessively developed, which also facilitates conducting the experimental works.

Additionally, the experiments were conducted on Lake Krzywe in Olsztyn (close to the base of the research team) and on Lake Łęsk near Szczytno (very good water transparency).

BATHYMETRIC MEASUREMENTS

Conducting hydroacoustic sounding on the basic experimental area was the first stage of the work. The single beam echo sounder Simrad EA501P and the set of geodesic satellite receivers Topcon Hiper Pro were used. On the base of the bathymetric data gathered during the hydroacoustic sweeping the spatial bottom model and the digital map of depths were made.

On the base of the developed spatial bottom area model and the individual echograms the places where search for objects should be conducted using the Side Scan Sonar. The measurement was conducted using the Imagenex SportsScan 881 sonar (Dobrowolska, 2009). As a result of the conducted survey several objects were identified for further detailed underwater inventory taking.

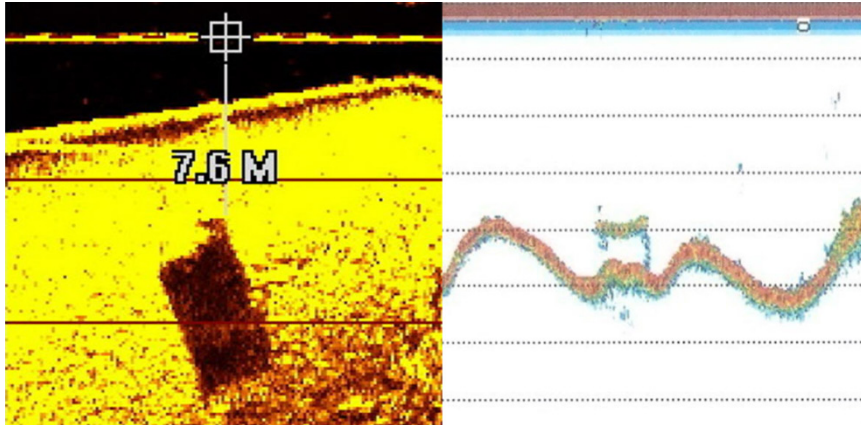


Fig. 2. Object on the bottom positioned in the sonogram and echogram.

The coordinates of the individual objects were computed on the base of the readings from the sonograms. The following data was also used: slant distances to the first echo of the bottom and object echo, coordinates from the beginning and end of the sonogram at the time when the object was situated in the image centre, layback (distance of the sonar processor to the GPS antenna). The coordinates from the sonograms were compared to the coordinates from the echograms. Next the characteristic objects situated on the bottom of the area surveyed that required direct inventory taking for the purpose of identification were defined clearly. The determined coordinates of the objects were manually input to the Mobile Mapper Office software, which allowed importing them to the GPS receiver used for underwater works.

PREPARATION OF THE MEASUREMENT UNIT

Prior to conducting the surveys on the selected test areas in the form of direct underwater navigation, the measurement equipment was prepared. The GPS receiver, specialist watertight housing and floating GPS antenna were used.

The housing was designed especially for the Thales Mobile Mapper receiver with the post-processing function. That receiver allows gathering information on land as well as raw data recording. This allows increasing the accuracy of the results obtained by adding raw satellite observations from the reference station in the Mobile Mapper Office software. The housing is constructed of duralumin with the front panel with keys made of plastic. The housing has the watertight connection for the external floating antenna.



Fig. 3. GPS set: Thales Mobile Mapper in the housing for underwater works. GPS antenna.

The GPS antenna is integrated with the cable line that serves receiving satellite signals by the receiver and hauling the floating platform supporting the GPS antenna on water surface. The cable line is ended with the watertight connection.

UNDERWATER GIS

The author's designed method of conducting the underwater GIS was used for conducting the direct underwater navigation. The Thales Mobile Mapper receiver with the post processing option and the watertight housing designed and made especially for that receiver was used. The satellite signals were fed to the receiver using the floating antenna and 10 metres long cable line. The coordinates of the objects were input into the receiver as the subject layer, which allowed underwater navigation and reaching the obstacles on the bottom without problems.

Experiment: Lake Krzywe

The planned experiment aimed at finding the object in the form of the wreck found on the bottom of Lake Krzywe in the vicinity of Olsztyn (the wreck is presented in Fig. 1). The object is found at the depth of 8.2m. The bottom at that location is characterised by a slight slope westwards. The measurement using the SSS was planned in the area of the expected location of drowning and covered the area of ca. 26 800 m².

The sonograms obtained from the initial sounding allowed clear definition of the wreck positioned at the depth of 8.2 m, measuring ca. 9 m by 3 m. The sonar worked with the GPS receiver assuring determination of the position in the global system of coordinates for each pixel in the sonogram (Popielarczyk et al., 2008).

Using the rough coordinates and the method of underwater navigation proposed by the author, the direct inventory of the wreck by divers was conducted. The wreck was marked with a buoy and next the exact object coordinates were determined in post-processing mode by OTF method.

Precision analysis for determination of the object location registered in the sonogram using the autonomous GPS position was also conducted. The accuracy of the wreck position determined on the base of the sonogram was around 7 m. This allows precise enough positioning of the object situated under water during hydroacoustic sounding considering the shift of the side scan sonar in relation to the receiver antenna positioned on the vessel. The differences between the position of the object determined on the base of sonograms and the actual position did not exceed 9.02 m, which represents satisfactory precision. Considering the precision of the measured values necessary to compute the adjusted positions such as cable line length, immersion of the side sonar, slope distance between the object and the sonar or the position measurement itself the result can be considered very good. During the direct inventory taking, using the rough coordinates, the diver did not have significant problems with finding the wreck despite poor water transparency.

Experiment: Lake Świątajno

The direct location of objects on the lake bottom defined earlier on the base of hydroacoustic sounding using the single beam echo sounder and the side scan sonar was the aim of the experimental works in Lake Świątajno (otherwise called Narty). After preparation of the equipment the divers conducted underwater tests. The works were done by two persons. One diver operated the satellite receiver under the water while the

other secured the safety of the experiment conducted and prepared the photographic documentation. After immersion of the divers the GPS antenna moved following the divers retained on water surface. During the experiment the Thales Mobile Mapper satellite receiver recorded the trajectory of the diver's path. The coordinates of objects found under water were also recorded.

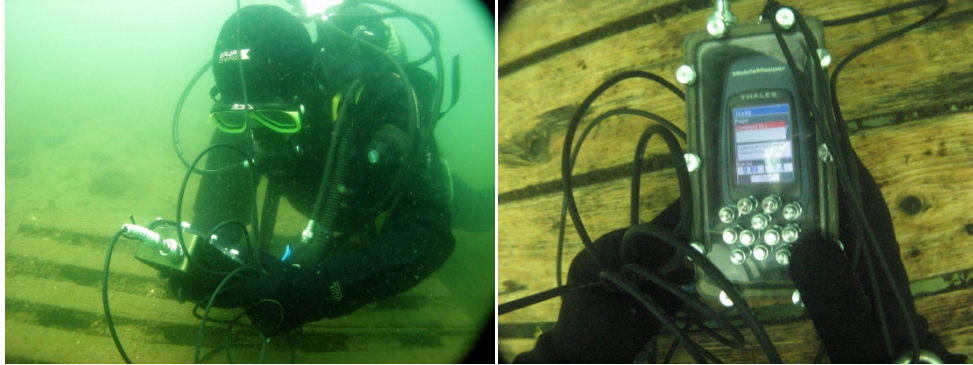


Fig. 4. Operation of the receiver under water.

Photo: Dariusz Popielarczyk. Photo: Michał Bancewicz (Sokolowski, 2009).

During the dive the operator recorded the path covered under water in the GPS receiver and conducted measurements of the earlier found and input points. The following figure presents the route recorded by the receiver together with the characteristic objects: wooden training platforms 1 m above the bottom (identified as PL1 and PL2), rowboat (LODKA) and sank Trabant car (TR). The trajectory was presented in the Mobile Mapper Office v. 3.20 software.

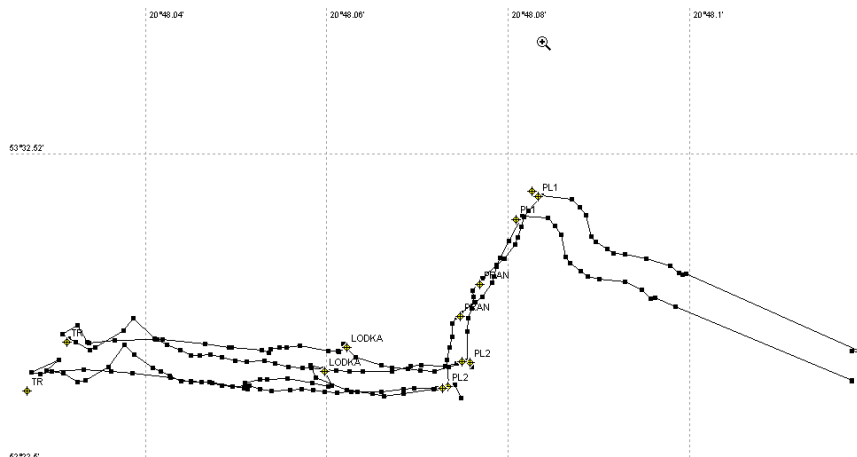


Fig. 5. Paths of the dives and measurements before and after postprocessing.

During the measurement the raw satellite observations were also recorded for later processing in the Mobile Mapper Office v. 3.20 software. The data from the OLST (Olsztyn) reference station obtained through the ASG-EUPOSystem was used. On the base of the autonomous coordinates of diver travel trajectory and DGPS post processing coordinates the difference in geographic latitude and longitude was computed. He differences of horizontal coordinates (Latitude and Longitude) were characterised by high variability – from 0 to almost 10 metres. The average geographic latitude difference was almost 3.5 m while that of geographic longitude slightly over 4 m. The route line after computations in the DGPS post processing mode was shifted in the southern and western direction. The above results show that in case of conducting

underwater inventory taking of obstacles and various objects situated on the bottom or in case of measurement of surface objects (surveys of stone reefs, vegetation, etc.) the possibility of computing the satellite observations recorded in the DGPS post processing mode has a significant influence on increasing the precision of the location determined. This is particularly important in case of the necessity for conducting another inspection of the earlier found object.

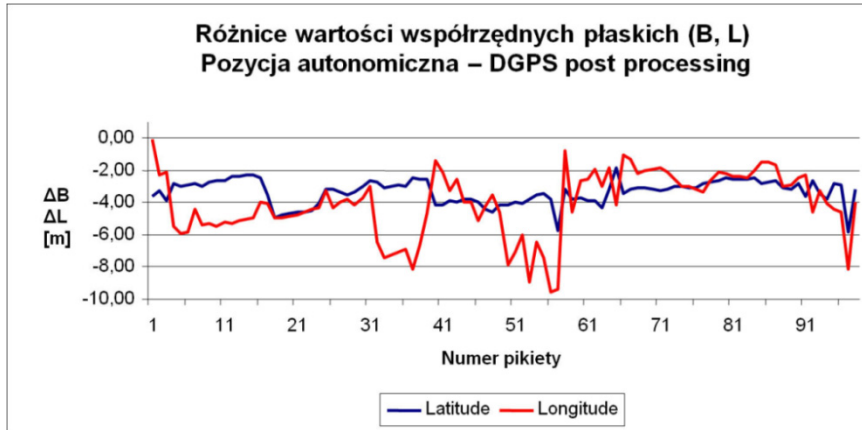


Fig. 6. Differences in the coordinates: autonomous position – DGPS post processing.

Table 1. Differences in B, L coordinates

	Latitude (m)	Longitude (m)	Altitude (m)
Max	5,83	9,60	23,15
Min	1,85	0,05	18,74
Average	3,34	4,09	20,29

Table no. 1 presents the minimum, maximum and average values of the differences between the autonomous positions (Thales Mobile Mapper) and the coordinates obtained as a result of DGPS post processing computation in the Mobile Mapper Office software.

The proposed technique for measurement of the objects on the bottom using the satellite GPS receiver Thales Mobile Mapper with the post processing option provides the possibility of direct and clear inventory taking of objects earlier located in an echogram or sonogram. Underwater navigation also allows conducting direct measurement and creating a map in real time directly during the dive (underwater GIS). The functions of the satellite receiver used allow earlier establishment of the library of objects, inputting it into the receiver and using it directly during performance of measurement on the bottom.

Thanks to that the operator is creating the map directly at site. During location of underwater objects and obstacles the photographic documentation is gathered using the digital camera placed in a special housing.

Experiment: Lake Łęsk

Another experiment of underwater GPS navigation was conducted on Lake Łęsk near Szczytno. The earlier described measurement set: the GPS/GIS Thales Mobile Mapper receiver with watertight housing and the GPS antenna placed on the float connected with the receiver using a 1 metres long cable line and watertight connection. The measurement aimed at conducting conscious navigation by two divers along the steep

slope of the lake bottom at the constant depth of 5-6 m. At the same time the coordinates of characteristic objects encountered on the bottom had to be recorded. The photographic documentation was also made. During the experiment the dive trajectory was recorded in the receiver memory. The route path was monitored continuously on the receiver screen, which allowed the team returning to the measurement starting point.

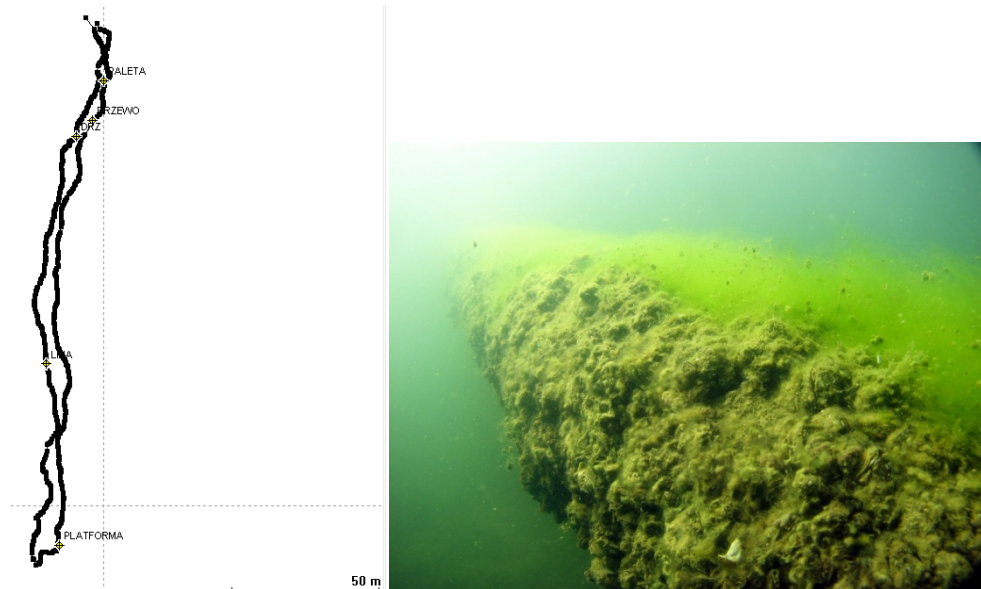


Fig. 7. Dive path and characteristic objects on the bottom of Lake Łęsk. Sunk tree. Photo: Dariusz Popielarczyk.

During the experiment 982 route points and 6 characteristic objects: a wooden pallet ca. 1.2 x 0.8 m (marked as PALETA in the figure), sunk tree trunk with the diameter of ca. 0.6 m and length of ca. 10 m (marked as DRZEWO and DRZ for measurement of the same object from different sides), the holding rope leading vertically from the lakeshore towards the lake (measured in only one point and marked as LINA) and the wooden platform for divers' exercises measuring ca. 2 x 2 m (PLATFORMA) were recorded. The last of the objects represented at the same time the half-point of the dive route. After measuring it and taking photographs return towards the starting point was undertaken.

CONCLUSIONS

In this paper the author proposes using modern GNSS satellite positioning techniques for direct survey of the bottom, location of objects and taking the inventory of shallow inland water reservoirs. The measurement set based on the GPS/GIS receiver Thales Mobile Mapper with post processing option was developed. Special watertight housing for the receiver was designed and commissioned for making. The housing was made of duralumin and plastic. Special watertight keys allowing control of the receiver operation under water were installed. The satellite signal is fed to the device from the floating GPS antenna and cable line (10 m in length) with watertight connection. The set allows direct underwater navigation, recording the divers' trajectories and recording the coordinates of objects found on the bottom.

The results of the conducted tests confirm high usability of the technology proposed for gathering spatial geodata on the bottom of inland water reservoirs. Using the rough

coordinates of objects read from sonograms and echograms the underwater inventory taking route can be planned and next completed precisely navigating under the water using the GPS receiver. That technology can also be used for surveying the presence of surface objects under water such as stone reefs, areas covered with vegetation, etc.

Certain inconveniences of the measurement technology developed were also noticed. In case of, low visibility during the dive (under 1 m), clear identification of individual objects is difficult because despite reaching the rough position of the given object it cannot be found and appropriate photographic documentation cannot be made. The precision in determining the position of up to a few metres has a definitely negative effect in this case. The length of the cable line that allows conducting measurements to the depth of 10 metres only is another limitation, although that problem could be solved by applying a longer cable line. The extended length, however, would hinder manoeuvring under water by the diver who is already equipped with a lot of equipment. After acquiring certain skill in using the device the measurements would not pose a serious problem even with the cable line twice longer. The extended length of the cable line would not be, however, without influence on the precision of measurement as a consequence of the cable line twisting and imprecise positioning of the float vertically above the observed point.

Still, the “underwater GIS” can be used successfully for performance of underwater works using the manual GPS receiver. The presented technology offers the possibility of navigating along the set route or to the set point under water, performance of the direct measurement of the objects found and taking the inventory of obstacles with rough coordinates. The applications of the method seem very wide starting from supporting bathymetric measurements through location and identification of underwater obstacles, boulders and wrecks as well as making photographic documentation of interesting objects. Conscious taking of the inventory of all the targets on the bottom and hydrotechnical structures is possible. The set also allows surveying the extent of underwater vegetation and organisms, direct creation of the database of objects on the bottom, supporting exploration and archaeological works. It can support underwater tourism and makes diving bases more attractive.

In the author’s opinion, the above-described measurement technology, the “underwater GIS”, may find wide applications in many fields of contemporary science and life.

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