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UNMANNED FLOATING RESEARCH VEHICLE FOR BATHYMETRIC MEASUREMENTS

BEZZAŁOGOWA PLATFORMA POMIAROWA SŁUŻĄCA DO BADAŃ BATYMETRYCZNYCH

A b s t r a c t

Unmanned water vehicles have been routinely used for marine purposes. This technology has emerged only recently for inland waters. It is used for two main purposes: bottom area scanning, in order to create maps of bottoms of rivers and lakes, artificial or natural. This information is needed for water engineering development and rehabilitation projects, and for flood protection planning. The other use is for the determination of flow velocities in rivers and lakes, which is needed for the determination of hydraulic properties of rivers, also necessary for flood protection. For the first purpose, an original vehicle is shortly described (UPP-1E), for the other, a Commercial-Off-The-Shelf solution is presented (RiverSurveyor of SonTek).

Keywords: water reservoirs, sediment accumulation measurements, unmanned surface vehicles, echosounder

S t r e s z c z e n i e

Bezzałogowe platformy pomiarowe powszechnie stosowane są do badań na akwenach morskich. Na wodach śródlądowych technologia ta pojawiła się dopiero niedawno. Zastosowanie platform pomiarowych na akwenach śródlądowych służy do dwóch głównych celów, tj. pomiarów batymetrycznych jezior i rzek (pomiary te potrzebne są dla utrzymania obiektów w należytym stanie technicznym) oraz ustalenia prędkości przepływu wody w rzekach (pomiary te są niezbędne do określenia właściwości hydraulicznych oraz zwiększenia ochrony przeciwpowodziowej). Do tworzenia map batymetrycznych w artykule opisano platformę UPP-1E do wykonywania ustalania prędkości przepływu wody opisano urządzenie RiverSurveyor.

Słowa kluczowe: zbiorniki wodne, pomiary zalądowiania, bezzałogowe urządzenie pomiarowe, echosonda

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1. Introduction

Unmanned floating vehicles have been used for marine purposes for a long time. The first remotely controlled boat was a Nikola Tesla's invention from 1898 (end of XIX century!). The first one that was actually used was the British HMS Agamenmon of 1921 – an old warship, used for targeting practice, remotely controlled.

Since then, especially after the Second World War, unmanned floating vehicles are routinely used for marine practice. They were not used for inland waters, however. Until recently, there was not much a small craft could accomplish there, be it a drone or a manned boat. This has changed, however.

One of the main issues concerning flood protection is the information about the actual volume of water stored in large retention reservoirs. Those reservoirs offer the cheapest and the most effective tool against floods. The other tools – like dikes, small "dry" reservoirs and polders are important as well, but nothing can be compared to a vast water retention reservoir – concerning overall impact and the relative cost [1].

However, the overall volume of a reservoir can decrease with time. This happens mainly because of sediment accumulation, and that alluvia is "eating-up" a useful volume of stored water. That is a rather slow process, which may speed up considerably during flood events. Therefore, it is important to know the current volume of sediments accumulated in the reservoir, firstly, to be able to calculate useful volume of the reservoir storage capacity (which is needed for flood protection planning and other purposes), and secondly, for assessment of future reservoir operation.

Another related issue is the changing of river beds due to sediment accumulation and erosion. This can lead to dramatic changes in river cross-section geometry, thus alternating its hydraulics and making flood events much more likely and severe. Knowledge of the actual geometry of the river beds, especially for river segments inside towns and cities, is also very important for flood protection and planning.

For the above-mentioned issues, an unmanned floating vehicle can be a good research platform.

2. Measurements of the bed layout of large water retention reservoir

The first problem may be, sometimes, with not the best data concerning the reservoir volume gathered during its planning. For its initial volume assessment, classic geodesics methods were usually used. These methods give, because of their very nature, a comparatively small number of measured points (compared to a vast number which can possibly be obtained using an automated device floating on the flat surface of a future reservoir). This may lead to serious inaccuracies, as shown in the Fig. 1.

As it can be seen in the above picture, increasing the number of measured points directly leads to the increase of accuracy of valley shape determination, which in turn, almost always leads to an increase of the assessed volume of water stored in the reservoir. In other words – measurements using an automatic vehicle floating on the surface of water reservoirs almost always increase the recorded volume of water, which may be used for various reservoir

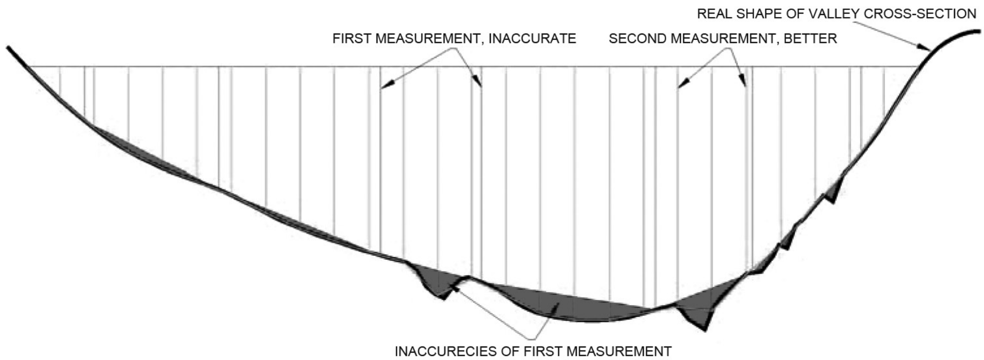

Fig. 1. Results of inaccurate measurements in valley layout and reservoir volume determination. Inaccurate initial measurements (red lines), better (denser) measurements (green lines). Errors in valley shape determination are shaded in red

purposes, including flood protection. This "extra" volume was there, of course, but it was usually not known to exist. In practice, this can be a quite meaningful number – given the fact, that the initial valley geometry has been measured with meagre (as for contemporary standards) resolution (see Fig. 1 above). It can be from a few, up to 20 percent of the overall, actual reservoir volume.

Usually, the measurements of the layout of the bed of a water reservoir are done using a device called "echosounder", mounted on a boat. The device emits sound into the water and measures time between emission and echo reception, thus allowing for distance calculation. It is attached to a boat and, together with a GPS receiver (this only for plane, or for XY, location), it is used to record actual water depth at a given position. To be able to do meaningful research, however, a lot of measurement points are required (hundreds of thousands or even more for medium-sized water reservoirs). The process is usually partially automated, but nevertheless, it is arduous, extremely time consuming and can be dangerous.

3. Our invention

To overcome the above-mentioned problems, we have developed an unmanned surface water vehicle (called UPP-1E), which is able to do that work much easier and faster. The vessel is a fully integrated device, consisting of the following subsystems (see schematics in Fig. 2):

- Measuring subsystem: high-class echosounder consisting of the central unit (signal reception and formatting) and dual frequency heads (transducers). This device is a NaviSound 215 of Teledyne-Reson.
- GPS receiver – Garmin 18x unit. Signal from that unit is directly fed into the central unit of the echosounder for combining with the depth data and then transmitted further – into central computer.

- Steering/propulsion and control system. Consisting of the central computer (with provisions for expanding into redundant double system in the future), and the switchboards (including associated firmware), electric motor and propeller. The power supply for all the systems is provided by a set of high energy density batteries (5 items, 12VDC) allowing for at least 6 hours of continuous work. Communication with the shore station is done using a GSM-based modem, allowing for almost blanket and stable signal coverage in almost all of Europe.
- Auxiliary systems. For now, it is a surveillance/hazard avoidance camera, mounted on a small mast on the fore part of the boat. Adding a forward looking, short distance hazard avoidance radar is planned in the near future (funds allowing).

The use of two measurements frequencies allows us to do two tasks at the same time: the first frequency (200 kHz) is used for first-contact measurement; this is what usually is understood as "real lake bed" depth. This sound frequency reflects off first obstacles near lake bed, be that sand, stones or vegetation. The other frequency (50 Hz) is a penetrating one, and can be used for direct deposit layer width determination. This must be carefully calibrated before any meaningful results can be presented.

A simple schematic of the system is presented on Fig 1, below:

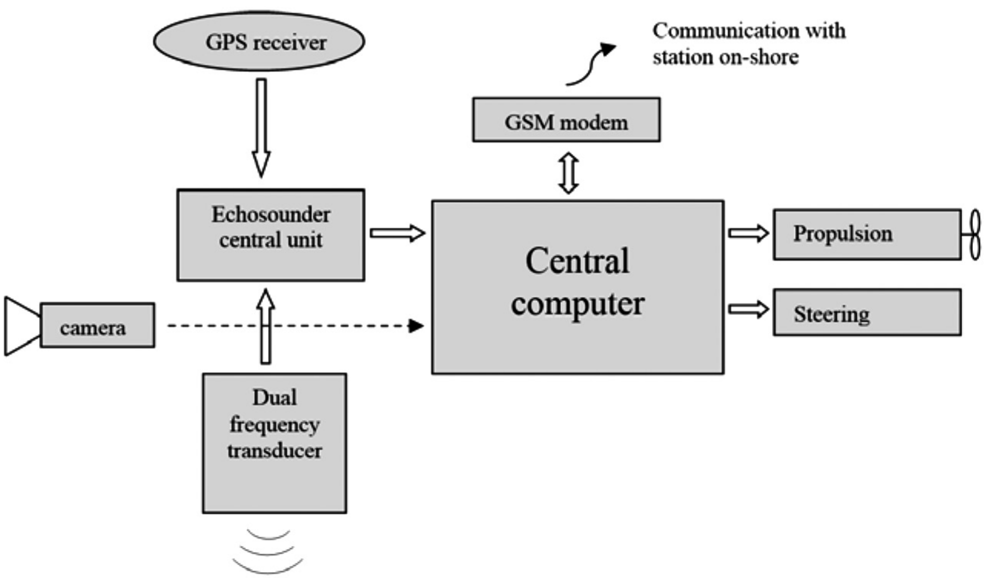

Fig. 2. Base schematics of the UPP-1E vehicle. The UPP-1E vehicle is pictured below

In the Fig. 3 the whole vessel can be seen. It is 200 cm long (not counting the rudder) and 80 cm wide (including impact dampeners – grey tube around the hull). Its projected draft shall be no more than 10 cm. The echosounder compartment is between the camera and the tall mast (first white cover). The other compartment is for batteries/propulsion (see Fig. 7).

Fig. 4 shows the details of the steering mechanism. A removable rudder will be utilized to allow for rapid replacement in case of expected rapid wear-and-tear.

Fig. 3. General view of UPP-1E vehicle. Source Delta Prototypes

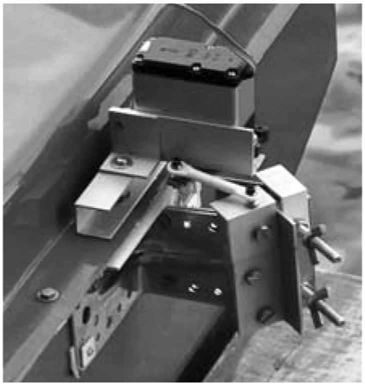

Fig. 4. Steering mechanism

Fig. 5. Propeller, diameter of 9 cm

Fig. 6. Control software screen shot

Fig. 7. Batteries compartment

On Fig. 5 the propeller is shown, just under the main hull. It is going to be the most exposed part of the entire vehicle. We expect it to be replaced fairly often (more than 6 times in a season). As for now, a 9 cm diameter is used. After initial trials, we may change it for a slightly bigger one.

On the last picture (Fig. 7), the batteries compartment can be seen. As for now, only five units are used (for testing purposes). For real-world use, there is space provided for 15 more. Our aim is to be able to have at least 8 hours of continuous operation. The maximum speed of the vehicle is set to be about 2 m per second, but for nominal measurement conditions, it shall be no more than approx. 1 m per second (as the echosounder gives up to 5 pings a second, it should be more than enough for most of applications).

The UPP-1E vehicle is meant to be able to replace the large boats (like UŚKA) as bathymetric (meaning like depth measurements) platforms. Our vessel shall be much cheaper to procure, easier to maintain and be able to do much more research, even in adverse conditions. There shall be no crew on water, much longer measurement passes are possible, the draft will be minimal.

There is, however, a problem with boat stability. Larger vessels, as a rule, offer a much more stable platform against waves than the smaller ones. For echosounder measurements, it is a difficult problem. If the sound beam emitted from the transducer is skewed (as happens when a wave rolls a boat), the resulting water depth value is bad – much bigger (30% or even more relative to the "true" value).

The UŚKA vessel is 8 meters long, 2.5 meters wide with draft of 40 cm. It is possible to record bathymetric measurements (using stabilized transducer firmly attached to her side) for up to approx. 20 cm of wave heights. Achieving the same feat with a much smaller boat is a challenge. To overcome this, we are proposing a three part solution:

1. Software. Using white noise statistical function, some impact of wave rolls can be eliminated during post-processing of the obtained data.
2. Passive wave dampening. This will be done by using two additional hulls, attached to the sides of the main one, forming a trimaran configuration. The auxiliary hulls will be much smaller, but nevertheless, shall offer some stabilization.
3. Active wave dampening. A device (under development) to actively dampen the rolling of the boat.

The anti-roll system – active and passive, integrated with steering and propulsion system – is currently under development and preparation for obtaining a Patent protection.

The entire system (even in its current configuration) is meant to be as rugged as possible. We are currently testing it to see what can be improved to be able to do work even in the most adverse conditions. Trying to assess the progress of a new technology, National Aeronautics and Space Administration (NASA) Technology Readiness Level can be utilized. Using this scale UPP-1E vehicle in its current shape is on the TRL 6 – "Prototype demonstration in relevant environment" [4].

The vehicle is still under development (working prototype 1E), but it can easily be used in its current state, albeit with some limitations (mostly concerning surface wave impact dampening, man-machine interface and firmware issues).

4. Example of use

The UPP-1E vehicle was used for determination of the layout for the planned development project (called Mała Wenecja) on Dunajec River in the city of Nowy Sącz. The river in this particular location is rather dangerous to cross, water velocity may be well above 3 m/s. There was no easy way to get the shape of the river bed there, as the use of classic geodesics method allowed to obtain only a few measurements.

However, using the UPP-1E vehicle, it was possible to get +200 measurements. A bottom map has then been made, greatly easing the design process of the future development.

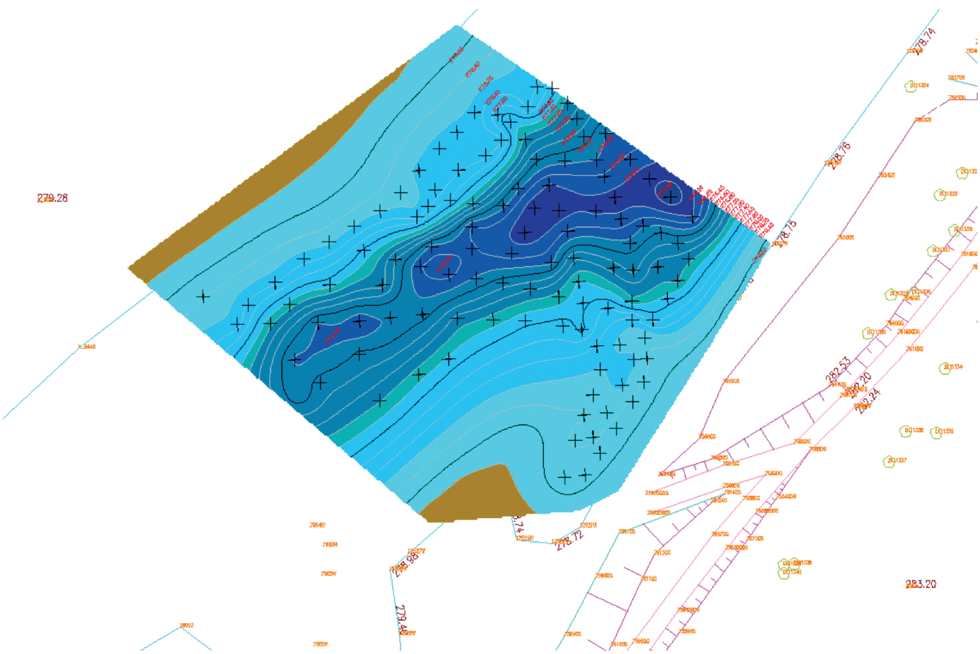

Fig. 8. River bed model for Mała Wenecja development project, Dunajec river

5. Conclusion and the way forward

The UPP-1E vessel is meant to be able to replace large boats as bathymetric (depth measurements) platforms. This vessel shall be much cheaper to procure, easier to maintain and able to perform much more research, even in adverse conditions. There shall be no crew on water, much longer measurement passes are possible, the draft will be minimal.

There is, however, a problem with boat stability. Larger vessels, as a rule, offer a much more stable platform against waves then smaller ones. It is a difficult problem for echosounder measurements. If the sound beam emitted from the transducer is skewed (as happens when a wave rolls a boat) the resulting water depth value is incorrect – much higher (30% or even more then the "true" value).

Ultimately, to overcome this, we are proposing a three-part solution:

1. Software. Using a white noise statistical function, some impact of high wave can be eliminated during post processing of the obtained data.
2. Passive wave dampening. This will be done by using two additional hulls, attached to the sides of the main one, forming a trimaran configuration. The auxiliary hulls will be much smaller, but nevertheless, shall offer some stabilization.
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The vessel is still under development (working prototype 1E), but it can easily be used in its current state, albeit with some limitations (mostly concerning surface wave impact dampening, man-machine interface and firmware issues). After it is completed, it can be a game-changer for the industry.

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