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Integrated presentation of navigational data in a mobile navigation system for inland waters with the use of HUD

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Abstract

Mobile devices are increasingly popular among recreational water users and for navigational purposes. Making full use of the possibilities they offer requires a navigational system to be designed and built for mobile devices which make use of mobile cartography. A dynamically adaptive mobile presentation model offering various display possibilities may be an appropriate example of such a system. The navigational purpose of the system, however, requires that the main navigational data presented are integrated in one place, in a so-called conning display. These data should be easily accessible to the user, which is not always the case with mobile devices. The idea of using a Head-Up Display (HUD) as a conning display in a mobile navigation system arose from these considerations. The current paper presents research on implementing a HUD into a mobile system. First, the idea of mobile cartographic presentation is discussed, then the navigational data available in the system are presented. Finally, the concept of using a HUD is explained, a HUD presentation model is shown and technical aspects of HUD integration are described.

Introduction

Inland shipping is a dynamically developing branch of transport. The characteristics of inland waterways and the specifics of navigation on inland waters have brought about the development of dedicated technological solutions, of which Inland ECDIS, Inland AIS or Inland ENC are examples, as are river information services (RIS). These technologies aim at providing information about fairways and traffic image for both on-board and on-shore users. These technologies, however, are designed for professional users and often require the purchase of specialised equipment or software. The availability of such solutions is thus restricted to a selected group of users, leaving room for a tool designed to meet the needs of touristic users in inland shipping.

Navigation on inland waters has issues in common with both marine and road navigation. It is performed on a body of water; however, the configuration of an inland water fairway network is often more like that of a road network, for which mobile solutions are typically used and in which dynamic changeability and the adjustment of presentation to user needs play key roles. Thus, a tool designed for inland recreational shipping should address both requirements. An example of such a solution, which is a development of the road navigation concept for inland shipping, is MOBINAV (MObile INland NAVigation), a system developed by Marine Technology Ltd. in a R&D project financed by the National Centre for Research and Development under the LIDER IV programme. The main aim of the project is the development of mobile inland navigation technology. A technology demonstrator has been prepared for touristic users of inland waterways.

One of the key elements of the project is the elaboration of mobile cartographic presentation. This is understood as a set of dynamically changing geocompositions (GCPs) viewed by the user in a so-called geovisualisation window. The second key aspect is spatial data, including navigational data. These can be divided into static data, gathered in numerical charts, and dynamic data from inner sensors in the mobile device and external sensors mounted on board. Navigational data are a core element of any cartographic presentation in a navigation system and should be clearly and properly visualised in the system. One popular approach used on ships is the so-called conning display, which combines and presents in one place the most important data for making decisions. A similar approach may also be used in a mobile system. Thus, one of the cartographic presentations elaborated in the project was designed for the integration in some kind of conning display of information crucial for navigation. This presentation is designed for a HUD device, a type which is becoming more and more popular in road navigation.

The paper is divided into three parts. In the first, the assumptions of the project are presented, as well as the data gathered by the system and how those data are integrated in navigational and cartographic presentation. In the second part, the technological aspects of HUD integration in mobile devices are given. In the third part, information about the elaborated cartographic presentation of integrated navigational information for a HUD is given. Finally, presentation examples and conclusions are given.

Mobile navigation system for inland waters

The mobile inland navigation system MOBINAV is a product of an interdisciplinary R&D project combining aspects of the fields of cartography, geoinformatics and navigation. The scope of the project was the elaboration of techniques and methods for the efficient management and integration of spatial data, as well as their analysis and visualisation. The research hypothesis is that the combination of mobile technology and the methodology behind mobile cartography for inland navigational data will allow the development of innovative technology for recreational users of inland waters. The idea is to provide technology dedicated to water touristic purposes and thus fill the gap between professional systems such as ECDIS and available car navigation systems.

MOBINAV is, in fact, an example of a GIS system designed for the needs of a selected group of users. The system assumptions include not only the development of a dedicated model of mobile cartographic presentation, but also the provision of a suitable set of spatial analyses. The basic tasks for both are selected from spatial data and imported from commonly available sources such as Inland ENC or topographical geodatabases.

The main features of the system may be summarised as follows:

- import and integration of selected spatial data from available databases, according to a developed dedicated data model;
- visualisation of spatial data according to a developed dedicated mobile cartographic presentation model, including a model for HUD;
- implementation of a spatial data analysis designed for users;
- supporting navigation by presenting crucial information on a conning display;
- implementation of route management;
- implementation of route assistance;
- management of own user data;
- integration of internal and external navigation sensors;
- sharing of information via social portals;
- personalisation of application.

The visualisation module is key to the design. Its role is to visualise spatial data and additional information according to a mobile cartographic presentation model. It has been developed based on modifications of the achievements of mobile cartography.

Mobile cartography

Nowadays, almost everyone has a smart device such as a smart TV, smartwatch or smartphone. Every average class smartphone has a built-in GPS module and by using a specific map application, the user can easily view the map of the specific area, find interesting places and plan the best route to reach them. Although mobile cartography derives from the traditional methodology of cartography, it is much more complicated. Mobile cartographic presentation changes dynamically and is accurate only at the moment of use. Every change of map aspect, zoom-in/zoom-out, route planning and so on provokes changes in the geovisualisation on the screen of the mobile device (Meng, Zipf & Reichenbacher, 2005).

The MOBINAV model of cartographic presentation has been designed on the basis of the mobile cartographic model presented in (Gotlib, 2010).

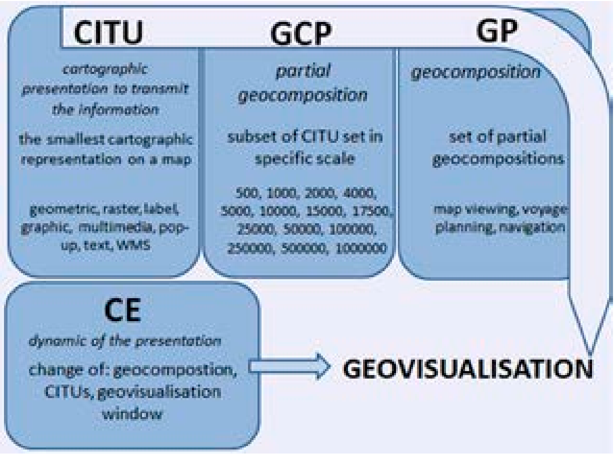

Figure 1. Model of mobile cartographic presentation in MOBINAV

It has been neatly modified and oriented to water navigation purposes. The MOBINAV model of cartographic presentation is shown as a schema in Figure 1.

MOBINAV geovisualisation is divided into five GCPs in line with the application's usage criteria. The authors have established five criteria types: viewing the map, planning the route and three types of navigation: in open areas, on rivers and in harbours. It is obvious that there is no need to present information strictly related to navigational procedures when the user wants to view the map and prepare his journey. The mobile cartographic presentation in MOBINAV can be defined as a set of a certain number of cartographic presentations which the application is triggered to display, automatically or manually, in various conditions.

Every cartographic presentation is composed of several partial GCPs. A partial GCP is nothing but a GCP on a specific scale and consists of a set of Cartographic Information Transmission Units (CITUs). The number and type of CITUs varies with the scale and usage criteria.

A CITU is the smallest basic element used in cartographic presentation to transmit information and visualise it on the screen by means of a geovisualisation window. It can be, for example, a representation of a class from a source database (such as water areas, land areas or vegetation); an object label (road names, bridges or depth points); a pop-up (more information about the object); raster (pictures); or audio signals (alerts or messages). The authors of MOBINAV have defined seven types of CITU:

- geometric – such as building areas, vegetation, harbour areas, land, water, etc;
- label – names of piers, building areas, roads, depth point values, etc;
- raster – images of objects, some bridges and buildings;
- graphic – route assistance;
- audio – route assistance, triggered alerts and incoming messages, etc
- pop-up – for more information about some objects, for touristic purposes, etc;
- WMS (Web Map Service) – as a map background, satellite view.

The dynamic of geovisualisation is steered by cartographic events (CEs), which induce changes in the mobile map visualised on the screen. The authors have prescribed five types of such changes (Bodus -Olkowska, Kazimierski & Zaniewicz, 2016):

- changing the GCP – switching mobile maps between different criteria of usage, styling to day/night visualisation, or scale management;
- changing the visualisation window – orientation changes or switching between 2D/3D view;
- changing the CITU – analysis results or viewing warnings or messages;
- changing the audio CITU – route assistance and navigation procedure monitoring;
- changing the object.

To sum up: the MOBINAV cartographic model is a modification of a mobile cartographic model presented in (Kazimierski, Harasymczuk & Bodus -Olkowska, 2016). It is enhanced by many aspects closely related to inland water navigation and touristic usage.

The MOBINAV cartographic model has been designed and elaborated with about 180 different CITUs and has been used in more than fifty partial GCPs, comprising the five main GCPs which make up the mobile geovisualisation steered by more than fifty CEs.

Navigational information in MOBINAV

Navigational information may be defined as the information required or desired in the process of navigation. This includes information about the area and the environment as well as information about the movement of the user's own vessel and images of the traffic around it. From a system point of view, the information has been divided into three categories, namely static data, dynamic data received from the inner sensors of the mobile device, and dynamic data received from external sensors. All of these have been examined in earlier works (Włodarczyk-Sielicka, Kazimierski & Marek, 2014; Zaniewicz, Włodarczyk-Sielicka & Kazimierski, 2014; Wawrzyniak & Kazimierski, 2016) and thus a suitable data model

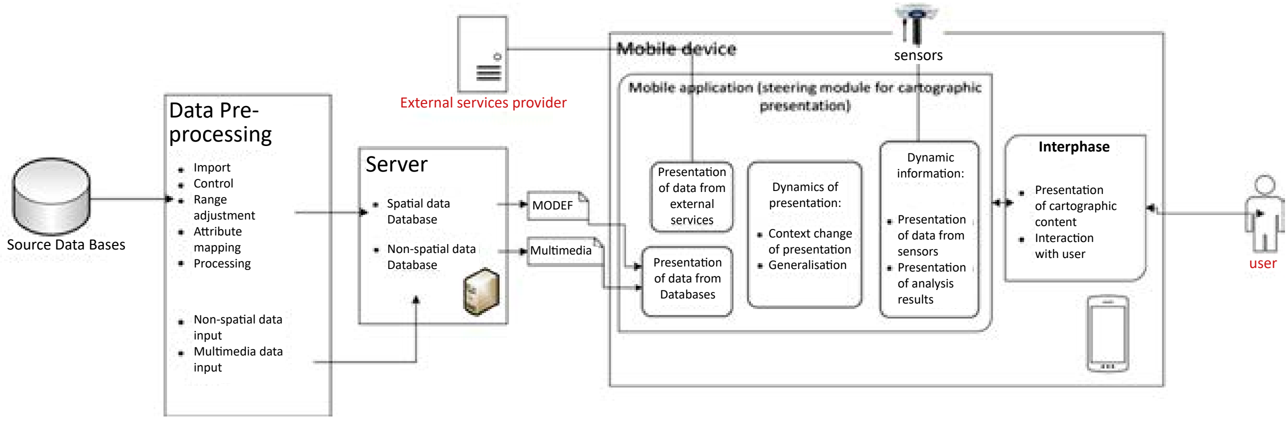

Figure 2. Data flow model in MOBINAV system

for each has been created. The data are gathered and processed in the system according to the data flow model presented in Figure 2.

The first stage is the preparation of data, which means importing static data from source databases and processing them to fit the desired model. The data are then transmitted to the mobile device, where they are properly visualised. Static data are enhanced with dynamic information from the inner sensors of a smartphone or tablet. The device might be also connected to external sensors, as in one of the models described in (Zaniewicz, Kazimierski & Bodus-Olkowska, 2016).

Static data

In MOBINAV, static data covers all the information about the fairway and environment which can be fixed in a navigational chart. Spatial data are the basis of any GIS system. The functionality of all systems often depends on the quality and reliability of spatial data. Preparation of suitable data and a proper data model are therefore crucial to the entire project. As regards MOBINAV, an analysis of available sources has been made and the results are given in (Zaniewicz, Włodarczyk-Sielicka & Kazimierski, 2014). As a result, the authors' own data model was proposed due to the inconsistency of existing databases. The idea was to integrate data from many sources to provide one source for a mobile application. The main data source was Inland ENC, which was enhanced by BDOT10k (a Polish database with topographical data) and open-source data in OpenStreetMap. Selected data were imported into the authors' own model, called MODEF (MObinav Data Exchange Format). It is also worth mentioning that vector data gathered in MODEF are also supplemented in the system by raster orthophotomaps for selected regions and with various Web Map Services.

Dynamic data – inner sensors

Nowadays, almost every mobile device, such as smartphones or tablets, has a set of inner sensors embedded in it. These are usually position sensors but a large variety of others are also used. These data are very likely to be used in such a system as MOBINAV as they are relatively easy to integrate. Research has also shown that their accuracy in areas within GSM range is comparable to typical recreational solutions (Zaniewicz & Sawczak, 2014).

The analysis performed in the project showed that there are two kinds of embedded sensors. The first group covers raw sensors, which allow data to be read directly from hardware sensors built into the device, while the second group includes so-called derived sensors that offer processed and fused data coming from a few raw sensors at once and forming different information for the system user. It was decided that both groups are interesting as regards MOBINAV and, finally, the sensors presented in Table 1 were included in the system.

Table 1. Internal mobile device sensors used in MOBINAV

Sensor	Role in MOBINAV
Geolocator	Ship's position and COG
Compass (derived sensor)	Heading
Device Orientation (derived sensor)	Vertical/horizontal mode of device
Ambient Light	night/day colour scheme

Inner sensors, although relatively easy to implement, do not cover all the requirements of the system. Thus, the additional effort was made to integrate external navigational sensors as well.

Dynamic data – external sensors

The use of external sensors in the system greatly expands the scope of its possible usage. The key

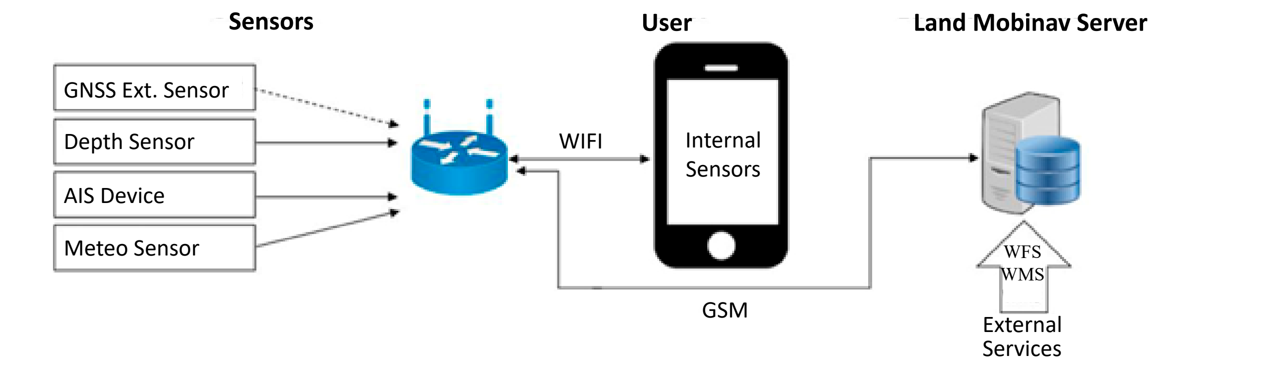

Figure 3. The schema of external sensor connection in MOBINAV (Zaniewicz, Kazimierski & Bodus-Olkowska, 2016)

aspect in their integration is, however, the creation of a transmission platform capable of wireless communication of NMEA strings from any external devices. Wireless transmission is here made necessary by the assumption of the mobility of the systems. Such a communication platform has been proposed in the project, together with possible extensions to a geoinformatic Sensor Observation Service (Zaniewicz, Kazimierski & Bodus-Olkowska, 2016). A typical configuration on board pleasure craft in inland waters would include several sensors. The main information required by the user is geographic position and course over ground. Most users, however, are also interested in weather information, bathymetry and traffic data. All these data can be transmitted in the NMEA sentence and displayed in the user interface. The proposed solution therefore included AIS sentences (*VDO*), depth below the transducer (*DBT*) and wind information (*MWV*). The set can easily be supplemented by other information, such as meteorological data. The connection schema of the external sensors in so-called direct connection is given in Figure 3.

The solution presented, based on a WIFI module, is principally useful for a mobile device user because of its mobility. The sensors can be mounted at any place in the boat and the user can read the data on a smartphone. The key aspect here is the proper visualisation of the information. Practice also shows that, nowadays, the selection of which crucial data are to be visualised is even more important, as a great deal of additional information is available on board which is of little importance. The idea of presenting key information in a HUD arose from this consideration.

Head-up Display in MOBINAV

HUD technology is still relatively new, although already quite popular in the luxury car sector. The concept itself is derived from military applications and may be considered as an introduction to virtual reality.

Basics of HUD technology

HUD technology began just after World War II. The first prototypes were assembled in military aircraft. They displayed the main flight parameters and supported the process of shooting. Technological

Figure 4. Examples of HUD usage (DRIVE2, 2016; LEDs MAGAZINE, 2016)

developments allowed the display of a larger amount of necessary data, including what was needed to carry out a safe landing. Commercial aircrafts have been equipped with HUD displays for many years, and the first car was equipped in 1988 (Pauzie, 2015).

An HUD device is used to display data from board instruments or other information at the eye level of the driver or pilot so that their attention is not deflected from the direction of the vehicle. Examples are given in Figure 4.

The data from the projector are displayed on the sloping area of flat glass or directly on the windshield. HUD systems are divided into four sources of image generation: CRT, LED, optical waveguides and laser scanner (Verma et al., 2015)

HUD as a conning display

One common feature in HUDs is the extraction of the most important information and its visualisation in a separate display. This meets some of the requirements set by the International Maritime Organization (IMO) for conning displays in navigational systems. According to the IMO, a conning display is an additional display (monitor) which presents crucial information from nautical equipment – the so-called required information for conning. Given this, both features – a HUD and a conning display – play the same role in the process of navigation. It was therefore proposed to treat a HUD as a conning display in MOBINAV. All the important information for navigation was to be gathered in this screen; however, due to the restricted size of the display, it was necessary to devise a suitable presentation.

The first step was to define the information to be presented in the HUD. After research based on the authors' own experience, enhanced by a questionnaire, it was proposed that the following information be included in the HUD presentation model:

- own ship position;
- route parameters – waypoint positions, route legs;
- route assistance – course to steer, distance to next waypoint, next course, cross-track error;
- route assistance messages.

The basic requirement was that the HUD presentation should be as simple as possible and that the main graphical variable should be colour.

Cartographic presentation model for HUD

The very first step in the cartographic presentation model for designing the HUD was setting all the recognisable CITUs that would be visualised. From the start, the authors needed to think about what information should be viewed. The designers established seven CITUs: start point, waypoints, final point, current route, next route, the vessel's actual position and a background, which was an orthophotomap from WMS services.

After determining the CITUs, the next step was to put them into the specially prepared application, namely MONAKO, which works as a plug-in software for QGIS (Quantum GIS). The following step

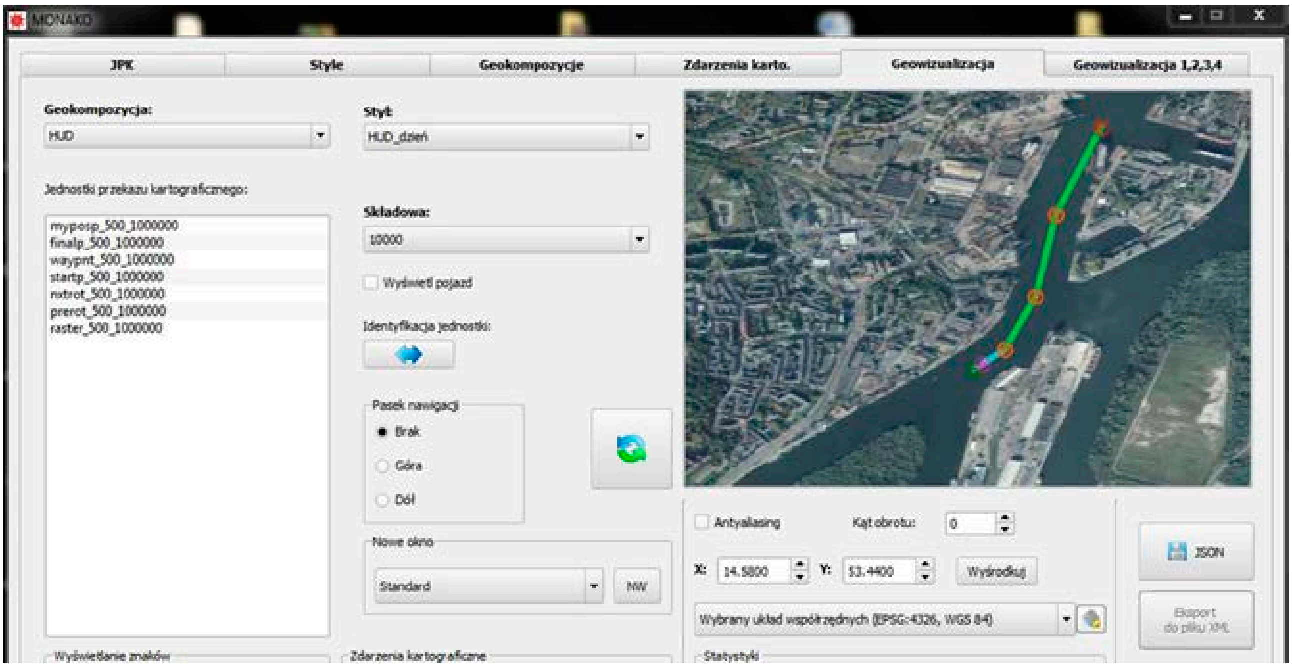

Figure 5. HUD cartographic presentation in MONAKO: daylight style, 1:10000 partial GCPs, 7 CITUs

was to style the CITUs in terms of colour selection, icon selection for point-based CITUs, and line-style for line-based CITUs. The next step, after styling, was to set the HUD's partial GCPs. The authors composed seven partial GCPs: 1: 50000, 1:25000, 1:17500, 1:10000, 1:7500, 1:5000 and 1:2000. The following step was to fix the CITUs and arrange them in appropriate order in each partial GCP. The last step was to establish any CE that could possibly have an influence on the dynamics of HUD visualisation. The cartographic presentation for HUD GCP is shown in Figure 5.

Survey of technical aspects of HUD integration in MOBINAV

Three devices underwent tests as part of the testing of HUD technology. Two of these are universal and portable HUD displays and the third was a mini projector. In selecting equipment for the MOBINAV project, the authors were guided mainly by mobility HUD devices and the techniques of image transmission between the mobile device and the projector. All these devices can transmit data via a direct HDMI cable connection or Miracast wireless technology.

First, the portable HUD used, a Springteq iHUD Headup Display, was made by a R&D team in Taiwan. It is designed to display an image on the windshield of the vehicle in which the device is mounted. A special film of semi-permeable foil should be stuck to the windshield of the vehicle. The virtual image is reflected on the film without restricting the view of the operator of the vehicle.

The device's Springteq presented a poor-quality display, which depended on the angle of the curvature of the film. The focus of the image capture in two strengths of external lighting was also problematic. Advantages and disadvantages of the device are listed below.

Advantages:

+ wireless Miracast connection;
+ power brightness setting;
+ several possibilities of cable connections.

Disadvantages:

– difficulty in adapting to the curvature of the glass;
– the lack of an integrated space for the displayed image;
– the problem with the image at high levels of environmental brightness;
– requires usage of additional films.

The second portable HUD is recPOP, a product mainly available on the French market. The device's main feature is the integration of the surface display with a projector, meaning there is no need to adjust the position of the projector to the curvature of the windshield.

This device gave good results for the display of images from the mobile device. Its main advantages are the sharpness and detail of an image. A satisfactory result was achieved by displaying the image in horizontal layout, which was stretched to the limits of the built-in "display". The advantages and disadvantages of this device are listed below.

Advantages:

+ integrated screen for the displayed image;
+ wireless Miracast connection;
+ power brightness setting;
+ a large combination of cable connections.

Disadvantages:

– the problem with the image at high levels of environmental brightness.

The last device to be analysed was a Philips PPX4350W. This device is a typical mobile projector. It does not belong to the class of HUD devices but the use of appropriate permeable films allows the image to be displayed on the glass.

Under laboratory conditions the device showed a high quality of image . The image required the use of a special film projection on the glass: without the use of foil, the image could not be displayed. Unfortunately, the source of light shining from behind the film (glass) causes difficulty in projecting the image.

Figure 6. HUD devices tested in the research (Springteq, 2015; road-eyes, 2015; PHILIPS, 2015)

Advantages and disadvantages of the device are listed below.

Advantages:

+ small dimensions;
+ wireless Miracast connection;
+ image focus setting;
+ a larger diagonal image.

Disadvantages:

– the problem with the image at high levels of environmental brightness;
– foil on the windshield required;
– no external power supply.

The analysis proved the second device to be the best, principally because of the integrated display and image quality. Below, a figure from the test in real conditions, with the device mounted on the boat, is presented.

Figure 7. View of tested HUD during real-environment tests on a boat

According to those who tested the system in real-life conditions, the use of a HUD display does not limit the helmsman's field of view. The proposed GCP displayed the transparent information which is required for safe navigation on waterways.

Conclusions

This paper has presented issues concerning the integration of a HUD as a conning display in mobile navigational systems for inland waters. The concept of a mobile cartographic presentation model was presented in general and a HUD model was described in detail. The research also included technical aspects of HUD devices, of which three types were analysed. Two were typical HUDs while one was a small portable projector. In general, all analysed devices have proved their ability to work as a part of a mobile set using Miracast technology. However, the results in the displaying of cartographic presentation were various and relied to a significant extent on the environmental light conditions.

The major findings are:

- all the tested equipment was able to display a picture from an external mobile device in real-time on-line mode;
- the major advantage of the selected equipment was the possibility of wireless transmission of a live picture, which is crucial for a mobile system;
- the main disadvantage of HUD technology is its low resistance to a high intensity of external light, such as the sun;
- a separate dedicated cartographic presentation for a HUD is necessary, as the characteristics of this screen are different than those of a mobile device.

The research has shown that a HUD may be used as a conning display in mobile navigational system, provided that a suitable presentation is created. Future works will include the optimisation of a HUD presentation in the context of various external light conditions.

Acknowledgments

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