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MOBILE NAVIGATION FOR SPORT'S PILOTS

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Abstract: Today, global object-positioning is accomplished very precisely by GPS satellite technology. Access to this information is provided globally by widespread mobile devices with integrated GPS receivers from everywhere also from airplane. This paper presents a mobile device using GPS receiver to be used by mobile navigation for sports pilots. In fact, the mobile navigation is a mobile application running on Android. Thus, the current position of the airplane is indicated on the GoogleMaps and compared with the planned direction of the flight by the pilot. In addition, this mobile application could also serve flight instructors when tracking student pilots by first independent flights. The proposed solution has shown in practice to be the cheapest substitute for expensive professional navigation devices.

Keywords: mobile navigation, Android, GPS, mobile network.

1. Introduction

Nowadays mobile devices play an increasingly greater role in everyday life and they are useful in most areas of human activity. Navigation is the process that directs people along a route between two points and can determine their positions at each moment (Prasad and Ruggieri, 2005). Navigation on the Earth is based on the use of maps, different signals along a route and human senses, for orientation. The first tool for navigation was developed for naval navigation regarding security. A typical example of naval navigation infrastructure is certainly the beacon that illuminated paths into ports at the time of the Roman Empire 2000 years ago.

When Christopher Columbus was discovering America, most of his sailors calculated the position of their ship based on the journey plan and the direction from a known point. Later they started using sextants that can measure the heights of celestial bodies above the sea's horizon, i.e. the vertical angle between the celestial body and the point on the horizon. Accurate clocks are also needed when using sextants. For example, knowing what time is it in London whilst at the same time measuring the height of the sun in the sky, latitude can be determined. The longitude can be calculated from the exact height of the sun at noon.

The appearance of the first global positioning system (GPS) based on satellite navigation in 1960 proved, that history repeats itself (Dierendonck, 1996). That system is based on knowledge of the exact positions of the reference points, represented by GPS satellites that circulate along the Earth's orbit. The GPS receiver needs distance to at least four points of reference to determine its own position on Earth (Agnew and Larson, 2007).

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Today there are three major global positioning systems:

- Global Positioning System (GPS),
- GLObalnaya NAvigatsionnaya Sputnikovaya Sistema (GLONASS) and
- GALILEO.

GPS stands for global positioning system and was created in 1960 under the aegis of the U.S. Army. As a counterbalance, the Soviet Union developed the GLONASS system during the Cold War. The idea of the GALILEO system was formed in 1990 within the fields of production, transport, control and service under the aegis of the European Union. It is led by the Directorate for Energy and Transport, and is of a completely nonmilitary nature.

GPS has become an invaluable tool for navigation regarding sports aviation. Most modern airplanes have a GPS receiver built-in as standard. With its help, the sports pilot can always obtain information on the screen about his or her position. The problems occur mainly in older airplanes that do not have these devices. In the event of a side wind, it may lead to the occurrence of a drift, when the airplane starts to fly in a different direction than planned. In that case, the pilot must rely primarily on his or her own experience. Thus, he or she can be guided by basic navigation tools, like aeronautical calculators, compasses, analog clocks, etc.

Smart-phones have emerged as a result of the development of ubiquitous computing, which provides information anytime from anywhere. These devices have a GPS receiver built-in as standard and at the same time are connected to a mobile network. The advantage of smart phones is that they have operating systems, which allow the development of mobile applications. In line with this, a lot of mobile application has been emerged. For example, the mobile application for detecting the drafting conditions in Ironmans has been proposed in (Fister, 2011; Fister and Fister, 2011). Moreover, this system has been connected with the EasyTime measuring system (Fister et al., 2012) capable for measuring time in sporting competitions (Fister et al., 2011a; Fister et al., 2011b).

These mobile applications can also be used to solve the problem of navigation in sport's airplanes with the help of GPS devices that indicate the current positions of airplanes on Google Maps, and compares then with the planned directions of the flights. Although a similar solution is already offered on websites (Aviation mentor, 2012), the advantage of the presented application is that on the one hand it is written for the open-source Android platform (free platform), whilst on the other hand it allows various extensions useful for either sport's pilots or their instructors (Android, 2012). For instructors, the analysis of a flight-path that a student pilot has taken during the instructor's absence is very useful. The flight-path is automatically created on the mobile device.

The structure of this article is as follows: in the second chapter authors deal with the basics of sport's aviation. The third chapter describes how to solve sports navigation problems using mobile application. The fourth chapter covers the testing, and the analysis of the results. In conclusion, a summary of the work done is provided and a set of directions for further development.

2. Sports Aviation

Despite the fact that Slovenia, due to its small geographical size, has never become an airline superpower nevertheless from a historical perspective represents a bright star in its tracking of technical innovations throughout the world. The Rusjan brothers were the first Slovenians to work on their own construction of an engine plane in 1909. The first flying clubs in Ljubljana and Maribor were founded in the period between the two World Wars. After World War II sports aviation in Slovenia began to develop rapidly. Today there are already 13 airports, 36 runways and about 59 landing-places. There are 14 aeroclubs dealing with sports aviation with more than 1500 members. The Slovenian airline fleet has almost 1000 aircraft, i.e. engine, glider and ultra-light airplanes. Some of the smaller airports, like Murska Sobota, have also a few para-gliders.

The remainder of this chapter introduces the basics of air navigation, continues navigation within sports aviation in practice, and concludes with the GPS's role in sports aviation.

2.1. Basics of Air Navigation

Air navigation enables pilots to guide the airplane from one point in an area to another. In doing so, it must continuously determine and verify the position of the airplane, flight direction, and flown distance. Although initially air navigation inherited many things from sea navigation, after the World War I it soon began to develop independently, mainly as an aid for long distance flights. Several types of navigations have been arisen during the development of technology - such as:

- visual navigation: orientation with the help of a map and a comparison with visual orients on the surface,
- computational navigation: calculating and measuring the basic navigational parameters,
- radio navigation: guiding the airplane with the help of radio,
- inertial navigation: guiding the airplane with the help of devices that operate on the principle of measuring the acceleration and deceleration by taking time into account,
- satellite navigation: guiding the airplane with the help of GPS.

The basic navigation elements are: the direction of flight, altitude, speed, and time. In regard to air navigation, speed as a vector variable was considered in two ways: as air-speed, i.e. the speed of the airplane depending on the air-mass, thorough which if moves and as ground-speed, i.e. the speed at which the airplane is moving depending on the Earth's surface. The wind can have an influence on the direction and movement in the sense of travel-speed, which can cause a so-called drift. Drift is the phenomenon, when an airplane is come beyond the planned flight-path because of side-wind. Drift depends on the wind's speed and the direction. Ideally, when the wind is blowing straight towards the airplane, there is no drift. Strong side-wind can drift an airplane far from the planned flight-path. An additional aggravating circumstance is that this change cannot be detected using a compass because it only provides information about the aircraft compass heading.

In practice, when there is a strong wind, the pilot uses visual navigation to guide the airplane towards the selected target, i.e. by comparing navigational charts and visual orients on the path, such as highways, power lines, rivers, lakes, etc. If the approximate wind-direction and speed are known, the so called drift angle α can be calculated, i.e. the difference between planned and actual directions of the flight with the help of an aeronautical calculator, expressed by the equation of drift angle (Eq. (1)):

$$\alpha = v_w \times \frac{60}{v_i} \qquad (1)$$

where α indicates drift angle, schematically shown in Fig. 1, v_w stands for wind-speed and v_i for the air-speed of the airplane. Fig. 1 shows a drift angle, indicating it as α, while v_w stands for wind-speed blowing from the side, v_p the planned-path and flight-speed and v_r the actual-path and flight-speed.

It can be seen from Fig. 1 that the drift-angle depends on wind's speed and direction, i.e. if the wind-speed is higher and blows more from the side, the drift angle is greater. The greatest drift angle, as expressed in equation of drift angle, is obtained if wind blows perpendicularly to the flight-path.

2.2. Navigation in Sports Aviation

Each flight over the controlled airspace of Slovenia has to provide a flight-plan in advance for air traffic control. This flight-plan needs to contain data such as: identification and type of airplane, takeoff and landing airport, departure time, flight speed and altitude, the scheduled length of the flight, the flight direction, etc. The flight direction is determined using so-called way-points. Way-points are usually visual orients in surface and are recorded on navigational map by markings. At these points the pilot contacts selected air control regarding his or her positioning report via radio transmitter. This report should contain the following information: time and altitude of the flight, scheduled time of arriving at the way-point, and confirmation of the next way-point.

Before each flight the sports pilot makes a flight plan. This can be done manually using navigation maps or automatically with the help of a computer (Fig. 2). A feature of the navigation map is that it is already labeled with: way-points, airports, restricted areas, etc. Navigation maps can be stored

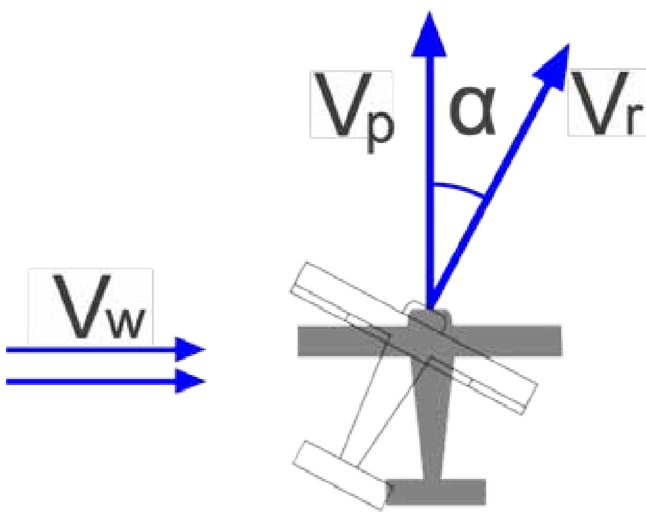

Fig. 1.
Drift Angle and Components
Source: Dušan Fister

on computers. Based on the selected way-points the direction of the flight can easily be determined so that corresponding points can be connected with each other using straight lines. Then the way-point's coordinates are recorded in a flight notebook for ease of flight tracking during the flight. The flight notebook is automatically collated by a computer program.

If the wind-direction and the speed along the scheduled route are known, the directions needed to fly by means of a magnetic compass can be calculated, so that an airplane can fly on the chosen path at the selected ground speed. In the event that conditions vary during the flight because of the side-wind, an adjustment to the flight is made with the help of navigation triangle speed.

Classic navigation requires a lot of effort from the pilot and that is why he can help himself by using additional navigational equipment and methods, if they are available on the airplane. Often, the following two additional navigational systems are used:

- Very High Frequency Omni-Directional Radio Range (VOR) and
- Automatic Direction Finder (ADF).

VOR is a radio navigational system for airplanes. The earth station emits high-frequency radio data signals, from which the receiver on the airplane calculates the direction of the airplane to the station in relation to true north, which is determined by the Earths' axis. The magnetic compass on the airplane measures so-called compass north, which differs from the true north for size of the deviation and variation (Willits, 2007). All ground stations show the direction of the airplane's regarding the true north and with the airplane form a straight line, the so-called radial. The intersection of radials taken from two different ground stations specifies the exact position of the airplane.

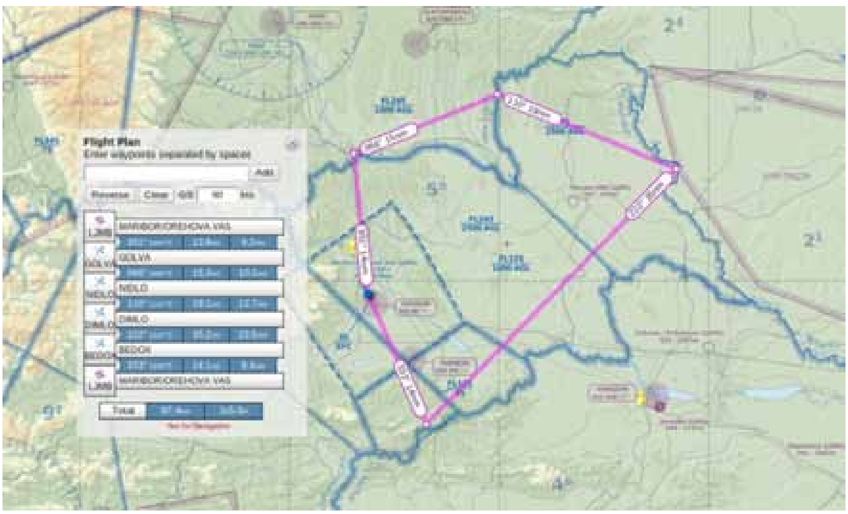

Fig. 2.
Creating the Flight-Plan by Computer
Source: www.skyvector.com

ADF is a sea and air radio navigation instrument that automatically and continually indicates the relative direction to corresponding non-directional beacon (NDB). Normally, the frequency of this beacon is 190-535 kHz. The pilot sets the receiver automatically towards the direction of the transmitter. The pilot can guide the airplane straight to the transmitter, or calculate the direction from the transmitter and take this into account during the flight.

2.3. GPS's Role in Sports Aviation

The Global Positioning System, or GPS for short, can also be used in mobile navigation. The GPS system is based on a set of broadcast satellites that serve as reference points when calculating the positions of objects on Earth. For correct calculation the receiver on the Earth requires a connection with at least four GPS satellites to determine the distance to the object, and on the basis of mathematical operations triangulation (Žalik, 2005) calculates its position.

The GPS system consists of three segments: space, user and control. The space segment consists of 24 to 32 satellites that orbit the Earth at an altitude of about 20 km (Vincenty, 1975). The user segment represents those GPS receivers that are usually held in hands or are secured in a vehicle. The control segment is responsible for the proper operation of satellites. The GPS position is represented by the longitude, latitude and altitude. The system provides for two operating modes: Standard Positioning System (SPS) and Precise Positioning System (PPS). The standard mode, intended for wider-usage, enables accuracy to within 20 m, whilst the precision, which is mainly used for military purposes, enables exact accuracy of up to within several centimeters. Accuracy is calibrated according to the number of satellites, which means that the accuracy is greater with a larger number of satellites (Misra and Enge, 2010). In sports aviation, the GPS system is not yet fully established, mainly due to outdated airplane fleets. In modern airplanes it simplifies the navigation, since it can predict position regarding to the airport. It also automatically calculates the airplane's ground-speed, which is unavailable within the airplane, and shows its exact altitude.

3. Mobile Navigation on Android

The rapid development of mobile devices has not only brought great progress to telephony, but also extended their applicability in new areas of activity. Today's mobile devices including smart phones, in addition to telephony, allow connecting to the network connections. These devices are equipped with additional hardware components such as: cameras, exposure meters, compasses, distance meters, accelerometers, thermometers, GPS receivers, etc.

Various operating systems are run on mobile devices (for example Windows Mobile, Mac OS X, Android, etc.). In order to protect the operating system the mobile device, the system is closed to the user, which means that the user interacts with the operating system via the applications. With the development of new mobile applications, the additional flexibility of mobile devices is enabled (Darcey and Conder, 2011). The development of these applications is done via application frameworks, which are integrated into the appropriate mobile platform. Today, the most important platforms are: Windows Mobile, iPhone and Android. Mobile devices connect to Internet using the mobile network (Fling, 2009). Linkage between web servers and mobile devices is mostly implemented with the help of web services.

Android is an open-source operating system for mobile devices developed in 2008 under the auspices of Google. The core of the operating system is written in the C programming language and graphical interfaces mostly in Java. As developing tools for development of new mobile applications, Google has developed a development tool the Android Software Development Kit (Android SDK) (Brunette, 2010). Android SDK is used in conjunction with a variety of development frameworks such as: Eclipse and Netbeans. In both frameworks the programming language is Java (Bell, 2010), which makes it easier to modify applications and enhance their portability. Mobile navigation is an application that was developed on the Android platform. For this development Eclipse, which is associated with Android SDK via plug-in for Android, was used. The concept of the application is explained in more detail below.

3.1. The Concept of Mobile Navigation on Android

Developing the mobile navigation on Android was built from two requirements, i.e. enabling of the following two functions:

- tracking: display the actual movement of an airplane within a virtual navigation map on a mobile device and
- navigation: offer the user the best possible navigational information about the flight (direction, speed, estimated time of landing).

The tracking function serves light-airplane's instructors as a means of controlling their student pilots during independent flights. In the event that an airplane flies near an airport, where the wireless signal is usually strong enough, the movement of the airplane on-line can be displayed. This means that the instructor at the airport monitors the student pilot using a virtual navigation map with a web-browser in real-time. The event that

Fig. 3.
The Concept of Mobile Navigation on Android
Source: Dušan Fister

access to the network is disabled, application must allow to record the airplane's actual movement and an off-line display of this on the visualiser.

In the first stage, the function must enable the creating of a flight plan on the mobile device, and during second phase display a movement-curve of an airplane on a virtual navigation map by means of a mobile device, together with the planned curve-movement. In addition, there is need to monitor data on a mobile device about flight direction and speed, and the estimated time landing. In this case, a real-time display via the internet network is not required, but it is desirable to archive movement for off-line display on the visualiser.

If it is assumed that the mobile device can:

- provide a virtual navigation map with the help of Google Maps product (Google Maps, 2012),
- monitor the movement of an airplane using the airplane's positions obtained from the GPS receiver and then drawing these positions as points in Google Maps,
- determine the direction and speed from data obtained from the GPS receiver and
- calculate the estimated time of landing by the current speed and location of the aircraft,

then the concept of mobile navigation as represented in Fig. 3 is easy to set. From this figure it can be seen that the mobile device carried by a pilot in an airplane's cabin, is connected to a satellite GPS system via a GPS receiver and communicates with the online network over a wireless network. When tracking the mobile device determines the current position of the airplane. The sequence of the positions provides a flight-curve that is displayed on the virtual navigation map provided by Google Maps. When navigating, the mobile device also displays a curve of flight plan, in addition to the curve of the actual flight. In this way, on the mobile device it can be, at any time, monitored the difference between the planned and actual curve of the flight and, according to the perceived deviation, taken appropriate action.

4. Testing and Results

The purpose of testing on the Android mobile navigation was to ascertain whether the mobile device can be successfully used for navigation during sports aviation. To this end, authors carried out several test flights to examine the behaviour of mobile navigation regarding tracking and navigation.

Fig. 4 displays the user interface for tracking. In order to emphasize that the mobile device is ready for tracking only when connected to GPS, the current location of the airplane (airplane icon) is displayed on the virtual map Google Maps. For the initial display, the virtual map Google Maps needs to be connected to a wireless network. This is then loaded into the cache memory of the mobile device.

When tracking, the application displays the actual flight-curve. At the same time it forms the GPX file type, which records the current positional points during the flight. These files can be displayed on visualisers.

Fig. 5 represents curve of the actual flight, which was obtained from tracking by mobile navigation on Android. From this figure it can be seen that the pilot took off from his home airport in Murska Sobota, did traffic pattern and then flew to the northwest, i.e. across the border with Austria in the direction of Leibnitz. He returned to Slovenia through

Fig. 4.
Tracking on the Android Mobile Device
Source: Dušan Fister

Fig. 6.
Creating the Flight Plan on the Mobile Device
Source: Dušan Fister

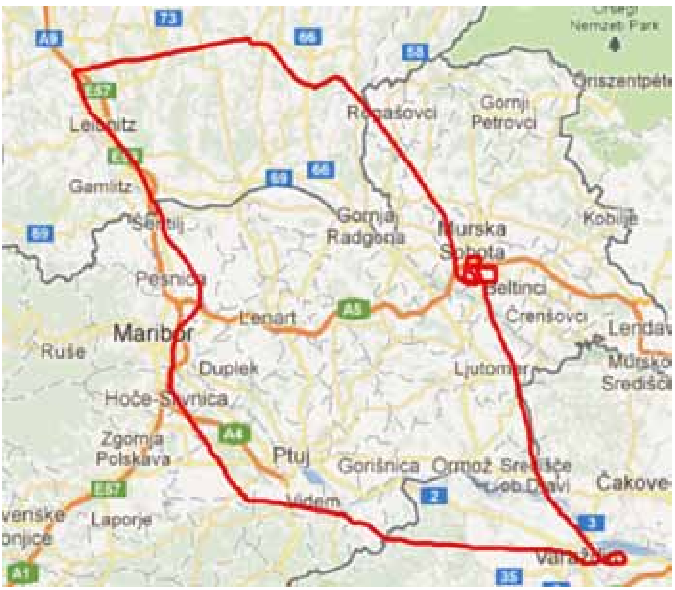

Fig. 5.
An Example of Tracking Device Using the Android Mobile
Source: Dušan Fister

Šentilj, avoided the city of Maribor and nearby Slovenska Bistrica changed direction towards Croatia. Above Varaždin he then made another traffic pattern and returned back to Murska Sobota. Fig. 6 shows a graphical interface for creating a flight-plan. Graphical interface allows the selection of individual waypoints in two ways: by pressing the point on a virtual navigation map or selecting a point stored in the archives. When a flight is in a planning phase, each item can be added by simply clicking the button to desired destination on the virtual navigation map. The second mode is the desired waypoint selected from the archive and added to the virtual navigation map. If necessary, the last waypoint from the virtual navigation map can be deleted.

Fig. 7 displays the navigation paths of the planned and actual flights using mobile navigation, where the planned flight is marked in green, and the actual in red. From Fig. 7 can be seen that the intended flight included the following waypoints: Murska Sobota-Lenart-Maribor-Slovenska Bistrica-Kamnik and landing at Lesce airport. The return flight was via Kranj-Brnik-Celje-Slovenska Bistrica-Ptuj and landing at the home airport Murska Sobota.

It can be seen from the actual path that the flight was at a shorter route than planned. Flying a shortcut, that must be approved by air traffic control, requires from a pilot the calculation of a new flight direction and the time to the waypoint so, in this case, the use of Android mobile navigation was very welcome.

The tests revealed a number of problems that need to be considered when implementing Android mobile navigation in practice. The biggest problem is downloading Google Maps within the cache memory, because there is need to connect to a wireless network. On the other hand, Google Maps are not real navigational charts, but general maps. This calls for a fixed loading of the correct navigational maps on Android, which are not free of charge. Another problem is the large power consumption of mobile devices. This problem was partially solved by turning off the mobile network after the map had already been stored on the mobile device. A complete solution to this problem would be to use airplane's electrical system as a power source, for which an appropriate adapter would be needed.

Fig. 7.
Navigation Using the Mobile Device
Source: Dušan Fister

5. Conclusion

The use of Android mobile navigation in practice has, despite the initial difficulties, fulfilled expectations, i.e. it is useful for tracking and navigation, and the solution is relatively cheap. On the one hand it eases student pilot's work regarding navigation when entering the world of aviation, and on the other hand, can serve as a tool for the instructor either when monitoring their first solo flights, or simply for the analysis of navigation.

In the future authors intend to use fixed maps loaded on the mobile device, rather than Google Maps, which require connections to the servers. For this purpose there are especially suitable OpenStreetMap maps (OpenStreetMap, 2012), which eliminate most of the legal and technical restrictions when using the existing maps. In addition, authors want to improve navigation by the use of additional graphical elements such as: calculating and displaying the actual directions and wind-speeds, calculating the plane's drift and the necessary corrected direction, see the trend vector paths, calculating the airplane's airspeed depending on the altitude of the flight, etc.

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MOBILNA NAVIGACIJA ZA SPORTSKE PILOTE

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Sažetak: Globalno pozicioniranje objekata se danas veoma precizno postiže primenom GPS satelitske tehnologije. Pristup ovim informacijama je globalno omogućen pomoću rasprostranjenih mobilnih uređaja sa integrisanim GPS prijemnicima koji se mogu nalaziti bilo gde, pa tako i u vazduhoplovima. U ovom radu je opisan mobilni uređaj sa GPS prijemnikom koji se može koristiti za mobilnu vazduhoplovnu navigaciju za potrebe sportskih pilota. Suštinski, mobilna vazduhoplovna navigacija predstavlja aplikaciju koja koristi Android operativni sistem. Na taj način, moguće je prikazati trenutnu poziciju vazduhoplova pomoću GoogleMaps u odnosu na zadatu liniju puta. Pored toga, ova mobilna aplikacija takođe može da posluži instruktorima letenja u praćenju prvih letova učenika pilota. Predloženo rešenje u praksi može naći značajnu primenu kao najjeftinija zamena skupim profesionalnim navigacionim uređajima.

Ključne reči: mobilna vazduhoplovna navigacija, Android, GPS, mobilna mreža.