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ACCURACY OF GEOLOCATION SERVICES AND USE OF GPS-COORDINATES: WEB-QUEST-BASED RESEARCH

Introduction

The aim of this study is to assess the impact of external factors on the operation of the geopositioning system. Today, GPS is widely used in many industries of mankind, such as military, aviation, maritime, navigation of ordinary users. Significant spread of this technology is observed in many geographical areas, such as cartography, geodesy. Issues related to the use of geolocation systems for research have interested many scientists. [1] The main factors of such rapid development of this system are its high accuracy and ease of operation. Therefore, the study of the influence of external factors on the accuracy of the geolocation system is currently relevant.

The Global Positioning System (GPS) is a surveying method used to precisely locate a three-dimensional position (latitude, longitude, and elevation) anywhere on the surface of the Earth. The system can be used at any time under all weather conditions. The GPS has replaced traditional survey methods as a low-cost, high-accuracy technology. It is also a very quick survey method to use, which on hazardous waste sites, serves to minimize personnel exposures to a variety of potential hazards.

One example of the use of GPS is a variety of navigators, which have become quite popular. They are used when traveling by transport and when walking. A characteristic of many movements is the distance traveled. The formula for its calculation is usually one: the sum of the distances between all points on the path. But sometimes some points can quite distort the overall look of the route. This is because the determination of geographic coordinates depends on many factors, such as: the presence of WiFi hotspots nearby, mobile network coverage, altitude, high objects nearby. Therefore, it was decided to investigate this problem in more depth in order to draw conclusions about the accuracy of algorithms that determine the position of the device on the surface of the globe. The urgency of geolocation accuracy research is due to the significant spread of applications that use geographic data devices [10].

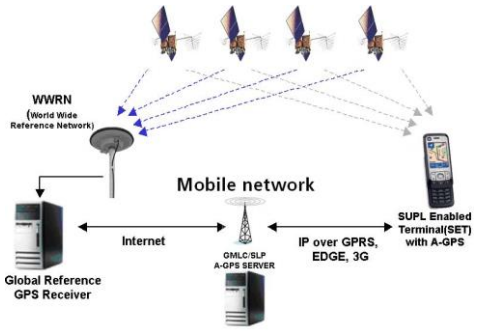


Fig.1 – The principle of GPS functioning [10].

Currently, there are many software developments that use user geographic data. For the most part, they are mobile games. The most popular products were reviewed during the study.

1. Pokémon Go - a multiplayer augmented reality (AR) role-playing video game from the Pokémon series. Developed by Niantic and originally released in the US,

Australia and New Zealand on July 6, 2016 for iOS and Android mobile devices. A feature of Pokémon GO is the overlay of virtual images on real-world images.

2. Shadow Cities is an early location-based augmented reality game created by the Finnish company Gray Area. The game took place in a "parallel world", using the physical location of the GPS of the player on the game map, fighting with other players nearby.

3. Ingress (or Ingress Prime) is an augmented reality mobile game developed and published by Niantic for Android and iOS devices. Ingress uses GPS to find and interact with "portals" that are in close proximity to the player's actual location.

4. Parallel Kingdom is a mobile multiplayer game based on location, which placed the player in the virtual world on top of the real world, based on the player's GPS location.

All these software products have their own characteristics. Most of them do not take into account the error of determining the geographical coordinates, so often players have problems with interaction with the elements within the game. Thus, the task of assessing the impact of external factors on the operation of the geolocation system using the Android Location API is relevant and important.

The study did not aim to develop a system of web-quests, but after conducting a series of experiments, it was found that it will be much more convenient to represent it in the form of an application.

After analyzing the tasks to be implemented by the module, a list of them was compiled:

- saving data on experiments to determine the accuracy of geolocation services;
- interface for data entry, processing;
- user-friendly interface for data interaction [8].

Thus, it becomes obvious that the possibility of implementing these tasks directly depends on the quality of design and optimal choice of technologies for geolocation and database implementation.

Given the above, the purpose of this study is to assess the impact of external factors on the accuracy of the geolocation system.

Accuracy of geolocation services and use of GPS-coordinates on the example of web-quest

Android Location API technology was chosen for software implementation of the research. The API defines the functionality provided by the program (module, library), while the API allows you to abstract from how exactly this functionality is implemented.

Software components interact with each other using the API. In this case, the components usually form a hierarchy - high-level components use the API of low-level components, and those, in turn, use the API of even lower-level components [8]. Google APIs are a set of application programming interfaces (APIs) developed by Google that allow you to interact with and integrate with Google Apps. Examples - Search, Gmail, Translation, or Google Maps. Third-party applications can use these APIs to use or extend the functionality of existing services.

APIs provide features such as analytics, machine learning as a service (forecasting API, or access to user data (when permission is granted to read data). Another important example is Google's built-in map on a website, which can be achieved with the static API Maps, Places API or Google Earth API [11].

To invoke a Google API feature provided in the Google Play services library (such as Google Sign-in and Drive), it is necessary to create an instance of a single API client object that is a subclass of GoogleApi. These objects automatically control the connection to Google Play services, process requests offline and execute them in the

order when the connection is available [6].

GoogleApiClient object can be used to access Google APIs provided in the Google Play library (such as Google sign-in, games, and disk). The Google API client provides a common access point to Google Play services and manages the network connection between the user's device and each Google service [6].

Once connected, the client can call the features of the API services for which the application is authorized, as specified in the API and in the areas added to its GoogleApiClient object.

A formula for the relative estimation of the accuracy of geolocation algorithms is also derived. The formula takes a value from 0 to 100: 0 means that at this distance to the test point, the accuracy is too low, and for 100 - that in this case, the accuracy can be ignored. For ease of calculation, 2 concepts were introduced: **radius rad** - *if the point where the user is in the circle of such a radius, then the accuracy should be calculated, otherwise - no, then the estimate of relative accuracy is zero*; **radius perrad** - *if the point where the user is in the circle of such radius, then the relative accuracy estimate is 100, while perrad is always less than or equal to rad.* The explanatory figure to the formula is shown in Fig. 2.

Therefore, the final form of the formula is as follows:

$$mark = 100 - ((\frac{dist}{rad - perrad}) * 100), \quad (1.1)$$

where mark is the relative score; dist is the distance from the point where the user is located relatively to the examined point. This distance is calculated in the built-in Android Location API. One of its variants is the formula of haversinus:

$$haversin\left(\frac{d}{r}\right) = haversin(\varphi_2 - \varphi_1) + \cos(\varphi_1)\cos(\varphi_2)\, haversin(\lambda_2 - \lambda_1), \quad (1.2)$$

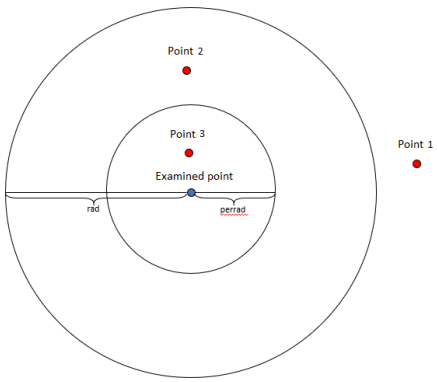
where d is the distance between two points (according to a large circle of the sphere), r is the radius of the sphere

- the latitudes of point 1 and point 2
- the length of point 1 and point 2

From here we deduce d:

$$d = 2r \arcsin\left(\sqrt{sin^2\left(\frac{\varphi_2 - \varphi_1}{2}\right) + \cos(\varphi_1)\cos(\varphi_2) sin^2\left(\frac{\lambda_2 - \lambda_1}{2}\right)}\right), \quad (1.3)$$

Both formulae are only approximate if we take into account that the Earth is not an ideal sphere: the radius of the Earth R varies from 6356,752 km at the poles to 6378,137 km at the equator. Moreover, the radius of the earth's curve drawn from north to south at the poles (≈6399,594 km) is 1% larger than at the equator (≈6335,439 km) - so the haversinus formula and the cosine theorem cannot be guaranteed to be more accurate than 0, 5% [11].



Possible cases of placing the coordinates of the user's point relative to the examined point:

1. Point 1 lies behind a circle of radius **rad**;
2. Point 1 lies in a circle of radius **rad**;
3. Point 1 lies in a circle of radius **perrad**;

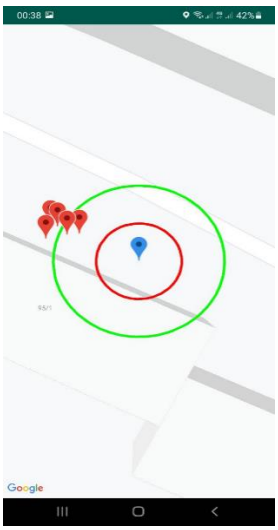


Fig.2 – Determining the distance from the point where the user is located to the examined point

Fig.3 - Screenshot of the results of the mobile application for an experiment to assess the impact of external factors on the operation of the geopositioning system

Using the developed mobile application, experiments were performed to assess the influence of external factors, such as the model of the device using which the study was conducted; its Operating System; WiFi point nearby; Bluetooth enabled; Mobile Data enabled; the floor on which the user is located during the experiment and cloudiness, the results of which are shown in Table 1. Figure 3 shows a screenshot of the results of the developed mobile application to conduct experiments for assessing the impact of external factors on the geolocation system using Android Location APP.

Model of device, operation system	Wi-Fi	Bluetooth	Mobile Data	Floor	Cloudiness	Coordinates in the app	Number of satellites	Assessment of the quest
1	2	3	4	5	6	7	8	9
Samsung Galaxy M20, Android 9	+	+	+	4	low	49.4365334, 27.0120489	9	100
Samsung Galaxy M20, Android 9	-	-	+	1	low	49.436552, 27.012048	8	70
Samsung Galaxy M20, Android 9	+	-	-	4	low	49.4365457, 27.0120476	9	100
1	2	3	4	5	6	7	8	9
Samsung Galaxy M20, Android 9	-	+	-	1	low	49.436747, 27.012059	4	0
Samsung Galaxy J7 2016, Android 8.1	+	+	-	4	low	49.436502, 27.0120723	9	85
Samsung Galaxy J7 2016, Android 8.1	-	-	-	1	low	49.436791, 27.012340	3	0
Samsung Galaxy J7 2016, Android 8.1	+	-	-	3	low	49.436500, 27.012063	8	100
Samsung Galaxy J7 2016, Android 8.1	-	+	-	2	low	49.436623, 27.012270	3	0
Doogee X5MAX PRO, Android 6.0	+	+	-	4	high	49.436572, 27.012173	8	40
Doogee X5MAX PRO, Android 6.0	-	-	-	3	high	49.436690, 27.012228	2	0
Doogee X5MAX PRO, Android 6.0	+	-	-	1	high	49.436501, 27.012093	7	97
Doogee X5MAX PRO, Android 6.0	-	+	-	2	high	49.436702, 27.012231	2	0

Table 1 - Data table with the results obtained during the experiment

Conclusions

The aim of this study was to assess the impact of external factors on the operation of geopositioning system. An experiment with the use of developed mobile application based on Android OS and using static map API, Places API or Google Earth API was conducted [6].

The input data for the experiment for assessing the impact of external factors on the operation of the geolocation system are the device model, its operating system, the

presence of a nearby access point, Bluetooth enabled, mobile data enabled, the altitude of user's location and cloudiness. Research on the accuracy of geolocation services plays an important role in creating applications that use user geographic data, because a small error with a large amount of data can greatly distort the end result, for example, when calculating the cost of a taxi route. If the error is ignored, the overpayment can be up to 400% percent, so there is always a need to take into account the fact that certain geographical coordinates may differ from the actual, because the determination of latitude and longitude depends on altitude, cellular coverage, WiFi points nearby and many other factors.

The practical significance of the conducted research is that it can be used for:

1. Improving the automated system of taxi drivers (taximeter) to reduce the mileage of the car, as well as time and financial costs to find the right location;
2. In game development industry for mobile devices, while developing mobile games such as web quests, in which the accuracy of the GPS system is crucial.

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