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EXAMINING THE ACCURACY OF POSITIONING USING SELECTED SMARTPHONE APPLICATIONS

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Summary

The paper presents the results of situational measurements of 6 points of a test grid in two-dimensional space. Measurements were made using 8 selected smartphone applications: Precise GPS, MapIt, Turbo GPS, Coordinator +, GPS Test, Precision GPS Free, GGRS87, and Mobile Topographer. Based on the Δx and Δy values obtained as differences in measurement results and reference coordinates, it was possible to determine that the mean values of these differences remain at the level of ± 2 m, although individual differences assume smaller and larger values. One of the applications generated the results classified in the error theory as errors of gross type.

Keywords

GPS phone applications • accuracy of positioning • satellite navigation

1. Introduction

The major role played by satellite navigation in the modern world also brings many questions related to, for instance, the viability of its application for the performance of specific tasks. The turbulent development of mobile communication technology has resulted in the emergence of smartphone applications, which make it possible, among other things, to determine the location of the given phone device in the global spatial reference system with a specific degree of accuracy.

There are a large number of (both fee-based and free-of-charge) navigational smartphone applications, offered by various developers and providers. In most of the names of these applications, the GPS acronym is included. The questions about the accuracy of determining the position, and about the reliability of the given application, seem to be pertinent. The subject has an aspect of novelty, which is confirmed by the lack of available literature referring thereto.

2. Satellite Navigation System with a single receiver L1. Study method

Global Satellite Navigation Systems (GNSS) cover the entire Earth with their range. One of these is the most popular American (US) GPS system. The receiver registers signals from a minimum of 4 satellites, whose positions are well known. Thanks to the software, it is possible to determine, in real time, the position of the receiver, and to adjust its clock.

GPS signals are transmitted on the basic carrier wave frequencies L1 and L2. The receiver placed in the smartphone determines its position on the basis of the C/A code, L1 frequency, and the support system, for instance, the EGNOS. The horizontal accuracy of position determination ranges from a few to a dozen or so meters with a confidence level of 95% [Kruszewski 2016].

From among numerous free smartphone applications offered on the market for test measurement, 8 were selected. Test grid consisting of 6 points was measured using the static GPS method, in relation to the KRAW reference station in the ASG – EUPOS system. The accuracy of these points is determined to be ±2–3 mm. Coordinates x, y of these points were found to be error-free with respect to the accuracy of determining the position of the said points by means of smartphone applications.

3. Field measurements

Measurement conducted using smartphone applications took place on 5 November 2016, between 11:00 and 13:00. At the time it was sunny, with temperature around 12°C. The Lenovo TAB 2 A7 tablet with Android was used for the purpose. 6 points (2041, 2042, 2043, 2044, 2045 and 2046) of known coordinates were measured using eight applications, that is: Precise GPS, MapIt, Turbo GPS, Coordinator+, GPS Test, Precision GPS Free, GGRS87, and Mobile Topographer. Each single measurement lasted about 1 minute.

3.1. Description of the area

The measured points (Fig. 1) are located on a grassy meadow at the Faculty of Environmental Engineering and Geodesy of the University of Agriculture in Krakow, at Balicka street, number 253C. The area on which the points are located is slightly ridged, but it is not difficult to measure.

Source: Geoportal, http://mapy.geoportal.gov.pl/imap/?gpmap=gp0&actions=acShowWgButtonPanel_kraj_ORTO]

Fig. 1. Location of the points

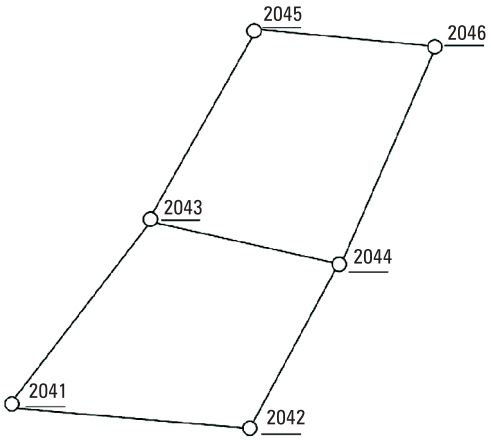


Fig. 2. Distribution of the points

The points form a shape approximating a rectangle (Fig. 2). They have been placed fairly evenly throughout the given area.

Table 1. Measurement of the coordinates using GPS

Point number	B			L		
	[°]	[‘]	[”]	[°]	[‘]	[”]
2041	50	4	57.461682	19	51	9.105473
2042	50	4	56.372201	19	51	15.318107
2043	50	5	1.988256	19	51	11.790754
2044	50	5	0.326484	19	51	17.082849
2045	50	5	6.451985	19	51	14.436776
2046	50	5	4.292838	19	51	18.852632
Point number	***X* [m]**			***Y* [m]**		
2041	5550241.150			7417879.597		
2042	5550205.595			7418002.582		
2043	5550380.174			7417935.124		
2044	5550327.221			7418039.537		
2045	5550517.268			7417989.839		
2046	5550449.218			7418076.596		

Source: data made available from the University's resources

The data obtained (Table 1) for the B and L coordinates of the points were measured using GPS technology by relating to the ASG-EUPOS KRAW reference station. Then they were transposed in the Transpol v 2.06 software to the "2000" layout. Their accuracy remains within the range of 2–3 mm.

3.2. Characteristics of selected applications, and presentation of measurement results

All applications come from the Google Play store, and they are free for all users.

3.2.1. Precise GPS

The application increases the precision of coordinate measurement by repeatedly activating the sensor in order to balance the received data. In order to achieve better accuracy, at least 30–50 independent measurements should be taken. Depending on the type of GPS sensor and satellite system, the results obtained may vary [https://play.google.com/store/apps/details?id=precise.GPS.free&hl=en]

Table 2. Measurement of the coordinates using the Precise GPS application

Point number	B			L		
	[°]	[‘]	[”]	[°]	[‘]	[”]
2041	50	4	57.461688	19	51	9.10800
2042	50	4	56.42400	19	51	15.30000
2043	50	5	2.06412	19	51	11.83212
2044	50	5	0.40812	19	51	17.08200
2045	50	5	6.51588	19	51	14.40000
2046	50	5	4.40988	19	51	18.90612
Point number	***X* [m]**			***Y* [m]**		
2041	5550241.156			7417879.647		
2042	5550207.201			7418002.246		
2043	5550382.504			7417935.982		
2044	5550329.742			7418039.558		
2045	5550519.254			7417989.139		
2046	5550452.818			7418077.714		

Table 2 presents the measurements made using the Precise GPS application in the form of coordinates B, L then transformed into *X*, *Y* coordinates in the "2000" system, also shown.

3.2.2. MapIt

MapIt is an application whose task is to assist in collecting GPS data, such as for instance satellite status, or location. It can also be used to measure and calculate distance or area size. It is possible to import and export data [https://play.google.com/store/apps/details?id=com.osedok.gisdatacollector&hl=en]

Table 3. Measurement of the coordinates using the MapIt application

Point number	B			L		
	[°]	[‘]	[”]	[°]	[‘]	[”]
2041	50	4	57.4608	19	51	9.1080
2042	50	4	56.4240	19	51	15.3000
2043	50	5	2.0652	19	51	11.8332
2044	50	5	0.4380	19	51	17.0748
2045	50	5	6.5148	19	51	14.4000
2046	50	5	4.4088	19	51	18.9072
Point number	***X* [m]**			***Y* [m]**		
2041	5550241.122			7417879.646		
2042	5550207.201			7418002.246		
2043	5550382.538			7417936.005		
2044	5550330.668			7418039.429		
2045	5550519.220			7417989.138		
2046	5550452.784			7418077.735		

The table 3 above shows the measurements made with the MapIt application in the form of coordinates B, L then transformed to the coordinates X, Y in the “2000” system.

3.2.3. Turbo GPS

This particular application makes it possible to determine the position, and it provides the so-called street view. In addition, it can support an external Bluetooth GPS, and it contains maps with directions. It is possible to import and export files [https://play.google.com/store/apps/details?id=com.turboirc.tgps.v2015&hl=en]

Table 4. Measurement of the coordinates using the Turbo GPS application

Point number	B			L		
	[°]	[‘]	[”]	[°]	[‘]	[”]
2041	50	4	57.4608	19	51	9.1080
2042	50	4	56.4240	19	51	15.3000
2043	50	5	2.0652	19	51	11.8332
2044	50	5	0.4380	19	51	17.0748
2045	50	5	6.5148	19	51	14.4000
2046	50	5	4.4088	19	51	18.9072
Point number	***X* [m]**			***Y* [m]**		
2041	5550241.122			7417879.646		
2042	5550207.201			7418002.246		
2043	5550382.538			7417936.005		
2044	5550330.668			7418039.429		
2045	5550519.220			7417989.138		
2046	5550452.784			7418077.735		

Table 4 presents the measurements conducted using the Turbo GPS application, in the form of coordinates B, L then transformed to coordinates *X*, *Y* in the “2000” system.

3.2.4. Coordinator+

This is an application created by a Turkish company. The software allows the user to measure coordinates in the selected coordinate system. In addition, it provides information about the distance, as well as the difference between the points on the map. It also makes it possible to convert coordinates from one coordinate system to another [https://play.google.com/store/apps/details?id=com.suleymaner.coordinatorplus&hl=en]

Table 5. Measurement of the coordinates using the Coordinator+ application

Point number	B			L		
	[°]	[‘]	[”]	[°]	[‘]	[”]
2041	50	4	57.461988	19	51	9.108000
2042	50	4	56.424000	19	51	15.300000
2043	50	5	2.063976	19	51	11.831976
2044	50	5	0.438000	19	51	17.075988
2045	50	5	6.515988	19	51	14.400000
2046	50	5	4.409988	19	51	18.905976

Point number	*X* [m]	*Y* [m]
2041	5550241.159	7417879.647
2042	5550207.201	7418002.246
2043	5550382.501	7417935.980
2044	5550330.668	7418039.453
2045	5550519.257	7417989.139
2046	5550452.821	7418077.712

Table 5 presents the measurements conducted using the Coordinator+ application, in the form of coordinates B, L then transformed to coordinates *X*, *Y* in the "2000" system.

3.2.5. GPS Test

This application shows the current location in text format as well as visually on the map; it also shows GPS signal in the form of a bar graph, the placement of satellites in the sky, the current altitude, location and speed, and the current GPS reading time [https://play.google.com/store/apps/details?id=com.chartcross.gpstest&hl=en]

Table 6. Measurement of the coordinates using the GPS Test application

Point number	B			L		
	[°]	[‘]	[”]	[°]	[‘]	[”]
2041	50	4	57.427	19	51	9.141
2042	50	4	56.425	19	51	15.300
2043	50	5	2.069	19	51	11.832
2044	50	5	0.407	19	51	17.010
2045	50	5	6.422	19	51	14.442
2046	50	5	4.404	19	51	18.905
Point number	***X* [m]**			***Y* [m]**		
2041	5550240.067			7417880.286		
2042	5550207.232			7418002.247		
2043	5550382.655			7417935.983		
2044	5550329.730			7418038.127		
2045	5550516.341			7417989.929		
2046	5550452.636			7418077.689		

Table 6 presents the measurements conducted using the GPS System application, in the form of coordinates B, L, and transformed coordinates *X*, *Y* in the "2000" system.

3.2.6. Precision GPS Free

The application uses a GPS sensor in order to determine the exact position. It calculates the weighted average for a given measurement. The longer the measurement takes, the better accuracy is obtained. It is not possible to record points [https://play.google.com/store/apps/details?id=com.sciencewithandroid.precisiongpsfree&hl=en]

Table 7. Measurement of the coordinates using the Precision GPS Free application

Point number	B			L		
	[°]	[‘]	[”]	[°]	[‘]	[”]
2041	50	4	57.4070	19	51	9.1094
2042	50	4	56.4200	19	51	15.0000
2043	50	5	0.3189	19	51	17.0836
2044	50	5	2.0600	19	51	11.8300
2045	50	5	6.4730	19	51	14.3577
2046	50	5	4.4000	19	51	18.9000
Point number	***X* [m]**			***Y* [m]**		
2041	5550239.459			7417879.649		
2042	5550207.169			7417996.281		
2043	5550326.986			7418039.548		
2044	5550382.378			7417935.939		
2045	5550517.942			7417988.278		
2046	5550452.514			7418077.588		

Table 7 presents measurements made with the Precision GPS Free application in the form of B, L coordinates as well as transformed *X*, *Y* coordinates in the "2000" system.

3.2.7. GGRS87

The GGRS87 application is designed to increase the accuracy of GPS. It provides the function to record points, and to calculate the area size. It allows the user to export files [https://play.google.com/store/apps/details?id=gr.stasta.egsa&hl=en]

Table 8. Measurement of the coordinates using the GGRS87 application

Point number	B			L		
	[°]	[‘]	[”]	[°]	[‘]	[”]
2041	50	4	57.786672	19	51	9.1080
2042	50	4	56.424000	19	51	15.3000
2043	50	5	2.064012	19	51	11.8332
2044	50	5	0.402000	19	51	17.0748
2045	50	5	6.497988	19	51	14.4000
2046	50	5	4.409988	19	51	18.9072
Point number	***X* [m]**			***Y* [m]**		
2041	5550241.122			7417877.231		
2042	5550207.201			7418002.246		
2043	5550382.538			7417935.980		
2044	5550330.668			7418039.556		
2045	5550519.220			7417990.800		
2046	5550452.784			7418077.712		

Table 8 presents measurements made with the GGRS87 application in the form of B, L coordinates as well as transformed *X*, *Y* coordinates in the “2000” system.

3.2.8. Mobile Topographer

This application, by calibrating the map, the weighted average, as well as calibrating the devices on the map, aims to increase the accuracy of GPS. In addition, it provides the ability to convert data into various coordinate systems. It shows the position of the satellites in the sky as well as their signal strength. It guides the user to the selected location, and also enables the calculation of area size and ellipsoidal height [https://play.google.com/store/apps/details?id=gr.stasta.mobiletopographer&hl=en]

Table 9. Measurement of the coordinates using the Mobile Topographer application

Point number	B			L		
	[°]	[‘]	[”]	[°]	[‘]	[”]
2041	50	4	57.456012	19	51	9.065988
2042	50	4	56.424000	19	51	15.300000
2043	50	5	2.064012	19	51	11.832012
2044	50	5	0.402000	19	51	17.082000
2045	50	5	6.515988	19	51	14.436792
2046	50	5	4.409988	19	51	18.906012
Point number	***X* [m]**			***Y* [m]**		
2041	5550240.986			7417878.809		
2042	5550207.201			7418002.246		
2043	5550382.501			7417935.980		
2044	5550329.554			7418039.556		
2045	5550519.246			7417989.870		
2046	5550452.821			7418077.712		

Table 9 presents the measurements made using the Mobile Topographer application in the form of B, L coordinates and the transformed X, Y coordinates in the “2000” system.

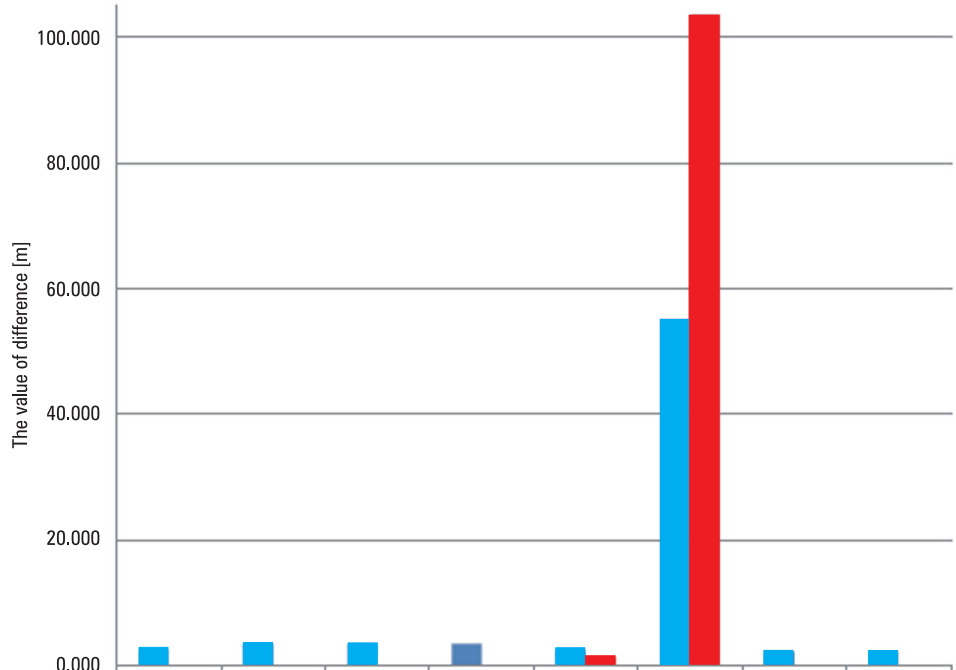
3.3. Comparison of data from GPS measurement with smartphone applications

Measurements made using various applications have been compiled with the available coordinates that had been obtained using a static method (Table 1). In the present study, only an sample set of results for one of the designated points will be presented, as well as averages for 6 points of the *X* and *Y* coordinate difference values for each of the 8 tested applications.

3.3.1. Presentation of the value of difference at point 2044

At point 2044 (Fig. 3), the tested applications reached the values of the difference from approx. 0.020 m to approx. 104.000 m. For *X* coordinates, GGRS87 and Mobile Topographer applications presented the smallest values of differences (2.333 m). The GPS Test obtained an accuracy of 2.510 m, and Precise GPS, 2.522 m. Coordinator+ reached the value of 3.447 m difference, with MapIt and Turbo GPS at 3.448 m. The biggest difference was observed in the Precision GPS Free application. For *Y* coordi-

nates, the smallest difference was 0.019 m, which was recorded for the GGRS87 and Mobile Topographer applications. The applications, which also obtained the values of the difference below one meter, include: Precise GPS (0.022 m), Coordinator+ (0.083 m), MapIt, and Turbo GPS (0.107 m). The worst accuracy was obtained by Precision GPS Free, at 103.598 m. As demonstrated, the best results were obtained from the GGR87 application and the Mobile Topographer application, and the worst results came from the Precision GPS Free [Kuboń 2017].



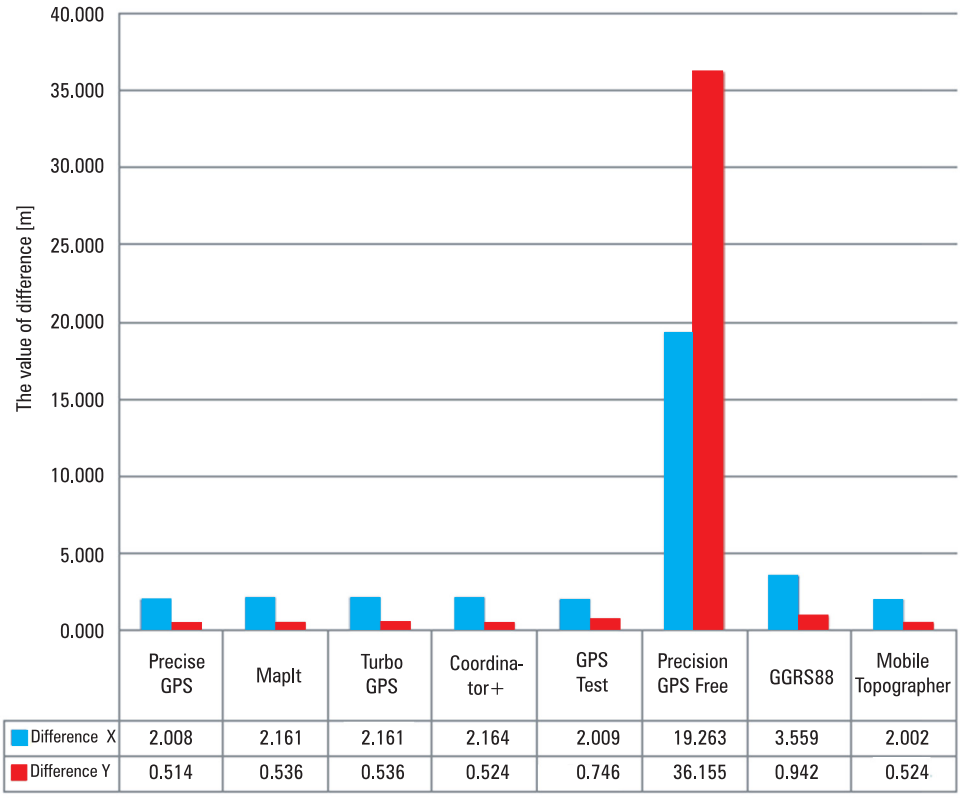
	Precise GPS	MapIt	Turbo GPS	Coordina-tor+	GPS Test	Precision GPS Free	GGRS87	Mobile Topographer
Difference X	2.522	3.448	3.448	3.447	2.510	55.157	2.333	2.333
Difference Y	0.022	0.107	0.107	0.083	1.410	103.598	0.019	0.019

Fig. 3. Differences in measurements at point 2044

3.3.2. Presentation of the mean value of differences in the measurements

As follows from the diagram (Fig. 4), the largest mean differences occur on the *X* coordinates. They range from about 2.000 m to as much as 19.300 m. The best result was achieved by the Mobile Topographer application (2.002 m). The next best results came from the Precise GPS (2.008 m) and GPS Test (2.009 m) applications. MapIt and Turbo GPS applications obtained the same values at 2.161 m, and Coordinator+ appli-

cation followed them by three millimetres (2.164 m). The Precision GPS Free application obtained the worst result at 19.263 m. The mean differences on *Y* coordinates fell within the range of 0.500 m to 36.115 m. The Precise GPS application presented the best result at 0.514 m. Coordinator+ and Mobile Topographer applications have reached values equal to 0.524 m, MapIt and Turbo GPS applications, 0.536 m, and GPS Test application, 0.746 m. The worst result was obtained using Precision GPS Free application, at 36.155 m.



	Precise GPS	MapIt	Turbo GPS	Coordinator+	GPS Test	Precision GPS Free	GGRS88	Mobile Topographer
Difference X	2.008	2.161	2.161	2.164	2.009	19.263	3.559	2.002
Difference Y	0.514	0.536	0.536	0.524	0.746	36.155	0.942	0.524

Fig. 4. Mean difference in the measurements

4. Conclusions

Smartphone applications make it possible to determine the position of the phone device with the same accuracy as the manual GPS receivers, i.e. with the accuracy of ±(1–3) metres. Thanks to this, we can effectively find objects whose coordinates are known.

This statement is based on the information in Figure 4, and the numbers contained in its lower section.

Evidently, one of the applications (Precision GPS Free) shows considerable deviation from the others, in terms of large values of coordinate differences – also shown in Figure 4. We might say that these observations constitute outliers, and in accordance with the rules of the adjustment calculus they should be rejected when calculating average values – that is, the latter should be calculated only for the remaining pairs of differences.

Another conclusion related to this application is the recommendation to make a measurement check (control test) for coordinates at a reference point (or points) whose coordinates are known exactly. The result of that control measurement should verify the correct operation of the application.

An application that has passed such a control test can also be used in measurements for GIS purposes, among other things.

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