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SMARTPHONE BASED MOBILE MAPPING FOR GEOSPATIAL DATA ACQUISITION

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Abstract: The expansion of technology and the use of mobile phones has created new opportunities for surveyors, especially for those who could not afford expensive professional equipment.
Smartphones are already used today as a mapping tool. Modern smartphones or handsets on the market today are able to achieve a very impressive quality, both in static or kinematic positioning. The aim of this paper is using different mobile mapping applications in order to measure two properties (immovable) that have materialized geometry in the Office of Cadastre and Land Registration Caraş-Severin database and compare the results obtained.
The improvement is also allowed by the quality of GNSS signals, the modern infrastructure dedicated to GNSS positioning and by the growing interest due to the user communities for the use of these technologies for high quality positioning. Certainly, by combining smartphones with external Bluetooth devices, the performance obtained could be better.
Keywords: mobile mapping GNSS, positioning, GIS, geospatial data.

1. INTRODUCTION

Precise positioning at the centimetre level cannot be achieved with GNSS signals alone. In addition, magnification systems are required. They consist of a network of base stations that continuously collect data to produce corrections in satellite orbit, satellite clock and atmospheric delay, which they transmit to GNSS receivers. [1] These corrections are indispensable for obtaining 3D positioning coordinates at the centimetre level. These augmentation services are often offered commercially on a subscription basis. GNSS positioning at the centimetre level can be achieved by many magnification methods, including real-time kinematics (RTK), network RTK (NRTK), precise point positioning (PPP) and PPP-RTK. RTK operates a network of base stations from which corrections are calculated and transmitted to subscribers [2].

Mobile mapping (location mapping), automatic machine guidance and other dynamic applications use Global Navigation Satellite System (GNSS) receivers for positioning [3]. In order to obtain positioning accuracies at the centimetre level, augmentation services are required to correct atmospheric signal disturbances, clock errors and satellite orbit deviations. A major limitation of many solutions is that accuracy comes at the expense of long convergence times, which prevents use in high-precision dynamic applications.

For dynamic applications, corrections must be available instantly (in real time) to the GNSS receiver. Phase-based PPP is a well-appreciated solution among surveyors, but one of the limitations of its use on mobile platforms is that it can take half an hour or more to obtain stable and reliable 3D coordinates. This means that dynamic applications require short convergence times. They also require services to increase and transmit low-bandwidth correction data (Figure 1). The large amount of data required by RTK and NRTK limits communication through ground stations and therefore the size of the service area. The idea of instant processing of corrections requires a global network and the transmission of corrections via communication satellites, but they have low-speed data channels, which limits the volume of data [4].

	RTK	Network RTK			Phase-based	Code-based	PPP-RTK
	RS	FKP	MAC	VRS/PRS	PPP	PPP	
Errors Corrected	Orbit error, Clock error, Bias, Ionospheric delay, Tropospheric delay				Orbit error, Clock error, Bias, Iono/Tropospheric delay (PPP-RTK)		
Approach	Observation State Representation (OSR)				State Space Representation (SSR)		
Accuracy	cm				< dm	~3dm	< dm
Mean convergence time	< 5s				20min	< 1s	< 5s - 1min
Largest service area	Local	Regional			Global	Global	Global
Double frequency	Yes				Yes	No	Yes
Required bandwidth	Medium	Medium	High	Medium	Low	Low	Low to Medium
CORS network density requirement (km)	20 - 50	70 - 100	70 - 100	70 - 100	1,000+	1,000+	100+

RS: Reference Station; FKP: Flächen-Korrektur-Parameter (Area Correction Parameters); MAC: Master Auxiliary Concept; VRS: Virtual Reference Station; PRS: Pseudo Reference Station; CORS: Continually Operating Reference Station .

Figure 1. RTK corrections particularities (Source: PPP-RTK market and technology report, European GNSS Agency, 2019) [5]

2. ACTUAL TRENDS OF MOBILE MAPPING

Mobile mapping systems (MMS) are widely used to create high-precision 3D maps and spatial data for different applications, infrastructure maintenance, and road and tunnel inspections [6]. An eloquent example is represented by an application developed by the Japanese association Dynamic Map Platform Co. which traced all 29.205kilometers of highway in Japan using the Mitsubishi Electric MMS (Figure 2). With an accuracy of 25cm, the resulting 3D maps are used for automatic driving.

The association is run by a government fund, and Mitsubishi Electric is supported by investors from all major Japanese car manufacturers, as well as by companies that use cartographic solutions. The

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images from the point cloud created by MMS allow operators to visually identify which roads need maintenance (Figure 3).

Figure 2. Mitsubishi Electric mobile mapping system [7]

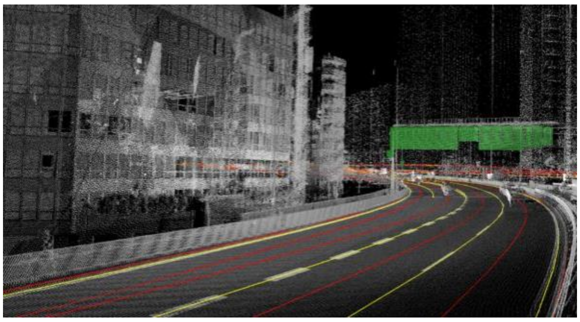

Figure 3**.** Example of geospatial data collected to create a 3D map of Japan's highways

GNSS systems offer the possibility to measure the area as accurately as possible from a technological point of view, the only problem being the high price of the necessary equipment.

The big change came as smartphones began to be increasingly modernized. The situation has changed drastically. Mobile application creators have offered a variety of productivity tools, including for measurement. Tasks that could only have been done by specialized equipment or geodetic engineers can now be easily done by smartphones. Smartphones have become our daily helpers. Daily tasks are facilitated by the huge variety of mobile applications, especially the usual applications. However, their growing assortment makes the choice increasingly difficult.

The expansion of technology and the use of mobile phones has created a new branch of possibilities for users. Especially for those who could not afford expensive professional equipment for such tasks, such as measuring large areas.

Modern mobile phones already have many of the important features that need to be used as mapping tools. However, it depends not only on the built-in sensors, but also on the available computing power, RAM and data storage capacity.

For data acquisition, a smartphone usually has two or three cameras, a GNSS sensor, an acceleration sensor and a gyroscope for positioning the system in 3D space. In addition, a smartphone has a magnetometer that displays the north orientation or direction through a compass and a barometer for measuring altitude. Current generation smartphones have built-in RGB cameras of up to 108MP to take high-resolution photos. However, it is debatable whether so many pixels are generally required for mapping applications.

Smartphones are already used today as a supporting mapping tool for controlling other sensors and measurement systems, such as terrestrial laser scanners, total stations and also unmanned aerial systems (UASs or "drones"). The technological development of smartphones continues at a fast pace and we can expect a reasonably priced performance and more accurate sensors in the future. However, the use of smartphones as a professional mapping tool is undoubtedly increasing.

This is an excellent time for location applications, as technological hardware standards and Android application programming interfaces (APIs) evolve simultaneously to allow for improved location accuracy, which was not previously possible when using smartphones.

It can be seen that the location of the phone seems to be more accurate when the person using it is in malls and office buildings than a few years ago. With each version of the location provider, there has been a steady improvement in Android algorithms and machine learning for Wi-Fi locations.

There are still improvements and it will be possible to observe an internal accuracy better than 10meters, but the return time (RTT) is the technology that will take us to one meter.

As for the accuracy of outdoor GNSS technology, they haven't changed much in recent years. Outside in the open air, the accuracy of the phone is about five meters and it has been constant for some time. But with raw GNSS measurements from phones, this can be improved now, and with changes to satellite and receiver hardware, the improvements can be considerable.

For the inner routing or the type of navigation in the car, a much better accuracy is needed than the outer one: an accuracy of one meter is needed, because the inner features such as obstacles or the aisle are only a few meters. Even for the most beloved outdoor applications, such as map directions and finding alternative routes in traffic, you could benefit from greater accuracy than there is now.

3. DIFFERENT MOBILE MAPPING SOLUTIONS

UTMGeoMap is a simple Android application that enables work implying coordinates, maps, GIS and spatial analysis. Created by geodetic engineers with decades of experience in the world of digital mapping, UTM GeoMap can meet the professional needs of mapping applications and has a friendly interface for ordinary users (Figure 4).

Figure 4. UTM Geo Map application menu

MapCoordinates is a map with real-time coordinates displayed at the bottom of the screen. These coordinates will change dynamically following the movement of the cursor on the map. The coordinates presented are Latitude, Longitude, UTM (Universal Transverse Mercator), MGRS and all the most used coordinate reference systems in the world (Figure 5).

Figure 5. Displaying coordinates in UTM Geo Map application

This module can also be used as a tool to search for location based on coordinates (from various coordinate reference systems), recording points that will be automatically stored in a complete database with coordinate data (Figure 6). Each point can be manually tagged with a unique tag / notes, photo added etc.

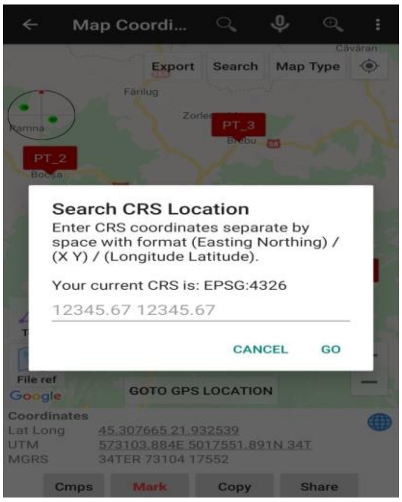

Figure 6. Coordinates insertion menu

Offline GPS is a simple GPS module designed to get offline coordinates (without internet access). By using the built into the device GPS, this module will display Latitude, Longitude, UTM, MGRS and all coordinate reference systems used in the world simultaneously and in real time (Figure 7).

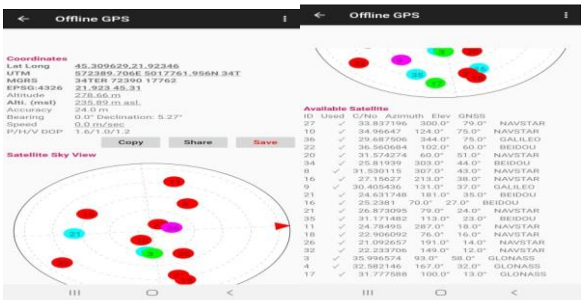

Figure 7. Satellites used to determine the position when internet connection is unavailable

AreaDistanceMeasurement is a complex module that can be used to measure areas and distances, record lines and polygons with advanced tools as well as custom colouring (line and polygon), labelling / notes and the ability to do simple GIS analysis. This module is also equipped with automation algorithm to record lines and polygons from a set of marker data automatically and tools to generate and calculate the travel distance between 2 locations (Figure 8).

GPS FieldAreaMeasure is also useful as a map measuring tool for outdoor activities, applications for sports activities such as cycling or marathon. It is useful when exploring the golf area, identifying a course, practical for measuring the area of pasture in the field, useful in the garden and for agricultural work, excellent for keeping track of the area. It is excellent for identifying a construction. This application is practical even for installing the solar panel, estimating the roof area or planning trips.

Figure 8. Surface and distance measurement menu

The operation of this application may sound technical, but it has been simplified by using a lucid interface. This application can also be used by a beginner. Google Maps integration is crucial, and developers have used maps in the most efficient way. Each location in the area measurement can be accessed.

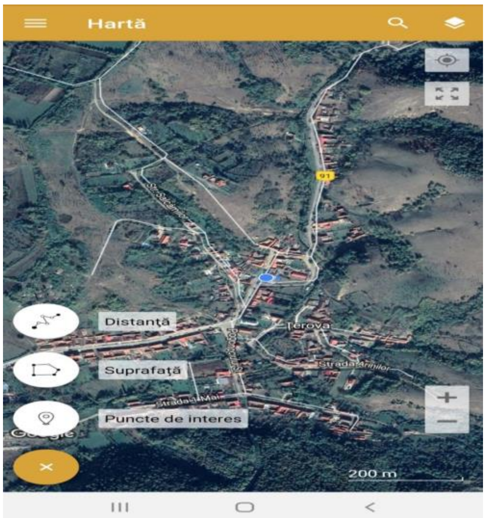

Figure 9. GPS FieldsAreaMeasure application and its measurement options

The basic operation of GPS FieldsAreaMeasure revolves around measuring land such as agricultural land [8] or planning a hiking trail. The measurements performed can be saved in a designated group. Similarly, several groups of measurements can be created related to a specific idea or region.

The measurements can be expressed using several units of measurement. As the units differ from country to country, the developers have made sure to incorporate most of the units systems for extensive use of the FieldFieldArea GPS application. Smart Marker mode is able to identify the exact location on the map.

The GPS FieldsAreaMeasure app is compatible with all types of Android devices, such as smartphones and tablets. The only requirement is that these devices be integrated with Android 4.1 or later. To improve the ability to use the app, it is available in over 30 languages such as Hebrew, Serbian, Spanish, Korean, English, Chinese (Simplified), Dutch, and more.

This measuring application (Figure 10) has the highest accuracy on the market, which is the main reason why it is the most important measuring application among construction sites, construction contractors and farms.

Users of the application include people who build roofs, buildings and roads, farm owners [9] who spray, fertilize, sow or harvest. It is useful for cycling or travel planning.

This application is also used by people who raise animals, the application is useful for measuring and planning fences. [9] Pilots can also use this application while flying in the fields. Administrators and contractors who exploit agricultural work for farmers can use this application to highlight planted fields. The fields are displayed in Google Maps.

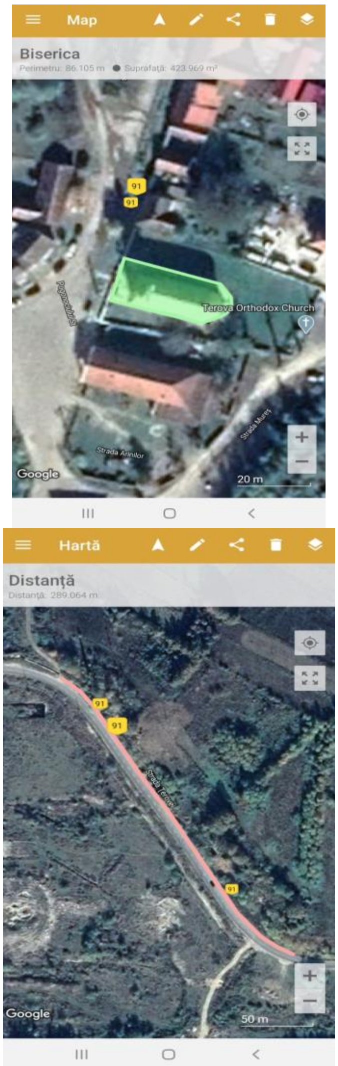

Figure 10. Area and distance measurement menu

To obtain the highest accuracy, it is recommended to connect an external GPS receiver (Figure 11) while using the application. The smartphone's internal GPS cannot guarantee the accuracy of a real GPS system, but it can be obtained with this small supplement.

Figure 11. Garmin external GPS receiver

4. STUDY CASE – SMARTPHONE BASED MOBILE MAPPING IN RESITA MUNICIPALITY, ROMANIA

The case study implies using the two applications described above (UTM Geo Map and GPS FieldsAreaMeasure) in order to measure two properties (immovable) that have materialized geometry in the Office of Cadastre and Land Registration Caraş-Severin database and compare the results obtained.

The immovable with cadastral number 39164 (Figure 12) is located in Ţerova, a district of Reşiţa Municipality, in Caraş-Severin County. It is located at the entrance of the locality, on the left side and has access to the main road of the locality. The property is located in a mountain area, so the land is rugged.

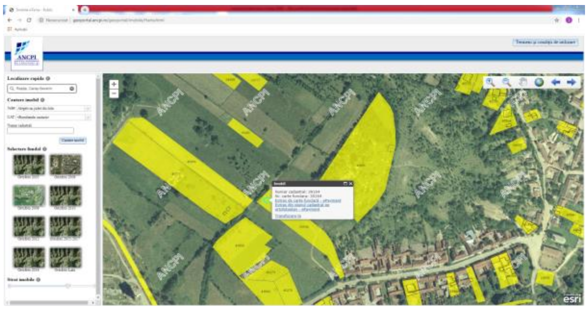

Figure 12. The immovable with cadastral number 39164 identified in the NACLR (National Agency of Cadastre and Land Registration) Geoportal

The immovable (Figure 13) is identified in the built-up area and outside the built-up area of the locality, having the same land book number. In the land book annex are highlighted the two plots, one in the built-up area and the other outside the built-up area.

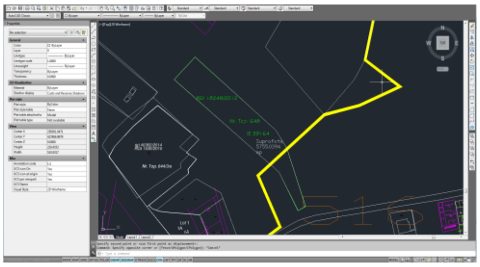

Figure 13. DXF format of the immovable with cadastral number 39164

We measured the surface of the 39164 immovable using UTM Geo Map and GPS FieldsAreaMeasure mobile applications by using the command "Manual measurement" (Figure 14).

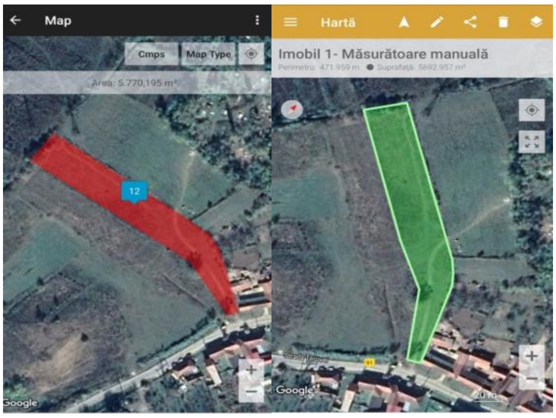

Figure 14. Measuring 39164 immovable’s surface with UTM Geo Map (left) and GPS FieldsAreaMeasure (right) mobile applications using the command "Manual Measurement"

The "Manual measurement" command involves marking points on the smartphone’s display representing the limit of the desired area.

Using UTM Geo Map application, the surface of the immovable with cadastral number 39164 resulted in 5770,195m^2 while using GPS FieldsAreaMeasure application, the surface of the same building resulted in 5692,957m^2. The real area of the 39164 immovable is 5755,0394m^2. From the resulting data, one can see a better accuracy obtained from using UTM Geo Map application. The difference between the real area and the measured area in the first case is 15m^2, and in the second case 62m^2.

FieldsAreaMeasure GPS application also has the command "GPS measurement" which involves marking points on the application’s map where the phone is currently located (Figure 15).

Figure 15. Measuring 39164 immovable’s surface with GPS FieldsAreaMeasure mobile application using the command "GPSMeasurement"

Using this command, because of the rugged terrain, unfavourable weather conditions and the absence of a Bluetooth GPS device to improve accuracy, the surface of the immovable resulted in 5230,034m^2, showing a great difference from the actual surface of the immovable under study.

Same procedure was repeated for another immovable, also located in Țerova (Figures 16 and 17). The immovable with cadastral number 41860 is situated about 200meters from the village's entrance, on the left, next to the main road of the locality, but cannot be directly accessed because of the land's afforestation.

Figure 16. The immovable with cadastral number 41860 identified in the NACLR (National Agency of Cadastre and Land Registration) Geoportal

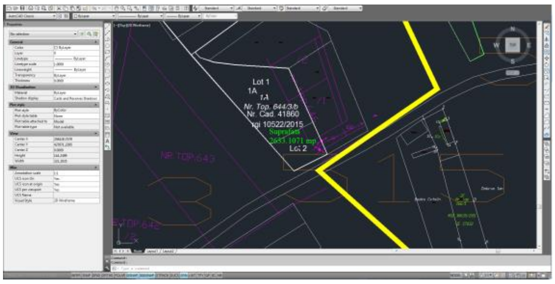

Figure 17. DXF format of the immovable with cadastral number 41860

Using the UTM Geo Map application, the surface of the immovable with cadastral number 41860 resulted in 2667,035m^2. Using the FieldsAreaMeasure GPS application, the surface of the same immovable resulted in 2630,795m^2. The real area of the immovable is 2633,1071m^2 (Figure 18).

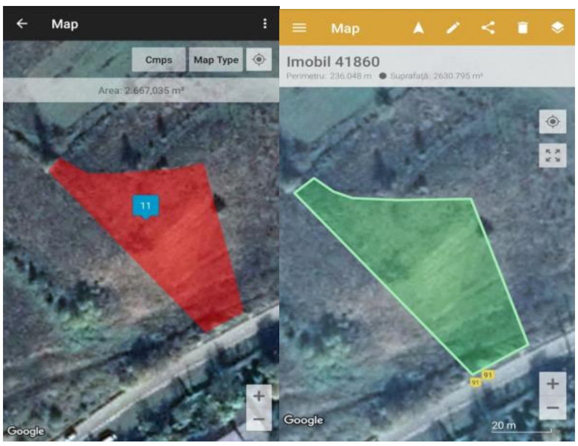

Figure 18. Measuring 41860 immovable's surface with UTM Geo Map (left) and GPS FieldsAreaMeasure (right) mobile applications using the command "Manual Measurement"

From the resulting data we can see a better accuracy is obtained from the use of the FieldsAreaMeasure GPS application. The differences between the real area and the measured area in the first case is 34m^2, and in the second case 2m^2.

Having considered an immovable with smaller area provided the possibility of zooming in the image which led to the materialization of the points much closer to reality.

In conclusion, our opinion is that the UTM Geo Map mobile application is much more user-friendly and useful for large area measurements, while the FieldsAreaMeasure application can be further improved to offer higher accuracy in the future.

5. CONCLUSIONS

The expansion of technology and the use of mobile phones has created new opportunities for surveyors, especially for those who find themselves at the beginning of their carriers and could not afford expensive professional equipment.

Smartphones are already used today as a mapping tool. Modern smartphones or handsets on the market today are able to achieve a very impressive quality, both in static or kinematic positioning.

The improvement is also allowed by the quality of GNSS signals, the modern infrastructure dedicated to GNSS positioning and by the growing interest due to the user communities for the use of these technologies for high quality positioning. Certainly, by combining smartphones with external Bluetooth devices, the performance obtained could be better.

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