

Linking GNSS Features Integrated in Smartphone to GIS and Google Earth Engine

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Abstract:

Background: This paper seeks to put a light spot on the Global Navigation Satellite System (GNSS) features coming with smartphones and, by consequence, relate them to Geographic Information System (GIS) and Google Earth Engine (GEE).

Materials and Methods: This is done through performing cadastre for a real dataset extending in area of about 400×260 m. The dataset consists of 6 tracks (about 130 m length for each) extending in East-West direction and 6 tracks (about 200 m length for each) extending in North-South direction. First, GNSS data for different tracks were collected utilizing SW Maps® smartphone application via moving along desired tracks at average speed of 1.5 m/sec.

Results: Then, polyline shape files generated by the SW Maps® application were manipulated by ArcMap®. The manipulation includes projecting coordinates on Universal Transvers Mercator (UTM) zone of the study area, point shape generation, line simplifying, creating modified kmz files. Moreover, raw kml and kmz files generated by smartphone along with kmz files modified by ArcMap® were linked to Google Earth® software.

Conclusion: The proposed study highlighted the significance of GNSS surveying using smartphone.

Key Word: GNSS; GPS; GIS; Google Earth Engine; Tracking Surveying; Routing Surveying; Smartphone Surveying.

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I. Introduction

The increasing development of smartphones boosted the aptitude of their usage for surveying applications. Today, three main positioning technologies are integrated as standard components in smartphones: Cell ID, WLAN, and GNSS (Küpper, 2005). The Cell ID positioning works as long as the smartphone is connected to available mobile network. The smartphone's position is obtained using the coordinates of the serving base station (Zandbergen, 2009). The WLAN (Wireless Local Area Network) positioning is based on measuring the proximity of a mobile device to wireless access points (AP) via the intensity of the received signal strength (RSS). Since this technology requires the availability of a wireless AP to register in, it is limited to densely populated areas (Küpper, 2005; Zandbergen, 2009). Finally, the GNSS (Global Navigation Satellite System) positioning is based on the GNSS signals that are received via the smartphone.

Today, all smartphones come with a built-in Global Navigation Satellite System (GNSS) unit. Additionally, plenty of softwares exist in the Play Store offering very helpful features for GNSS surveying. These GNSS hardware and softwares facilitate the GNSS surveying tasks that can be accomplished utilizing smartphone. Undoubtedly, the resulted accuracy obtained using RTK (Real Time Kinematic) GNSS positioning is better than that could be obtained using smartphone GNSS surveying. However, the smartphone GNSS surveying resulted accuracy is satisfactory for many applications such as routing, tracking, road's distress detection, etc. This paper introduces a study that emphasizes the importance of using smartphone GNSS cadastre. This is done through signifying different features of SW Maps® application (smartphone application available at Play Store) and, hence, linking the files created by the smartphone application to Geographic Information System (GIS) and Google Earth Engine (GEE).

The GNSS is satellite positioning systems that are already operating or planned to be operated [1]. Some of these GNSS provide global coverage of Earth such as GPS (United States), GLONASS (Russia), Galileo (Europe), and BeiDou (China). While, some other GNSS provide local coverage such as QZSS (Japan) and IRNSS (India) [2, 3]. The GNSS constellation consists of three main segments: space segment, control (ground segment), and user segment. The space segment consists of number of working satellites besides number of spare one traveling around Earth in number of orbits (for instance: GPS space segment consists of 24 satellites traveling in 6 orbits). The satellite system is designed to have at least 4 satellites in view anywhere and

anytime to the user on the ground. The satellites' signals are carried on frequencies differs from GNSS to another. For example: GPS frequencies are L1, L2, and L5 [4], whereas Galileo frequencies are E5a, E5b, L1, E6, and E2-L1-E1 [5]. The Control Segment is a set of ground stations responsible for operating and monitoring the GNSS satellites. For GPS, the main Control Center exits at Falcon Air Force Base, Colorado Springs, USA. Finally, the user segment includes both hardware and software used for the applications of positioning, navigation, and timing. The common types of GNSS receivers are RTK (Real Time Kinematic) receivers, hand-held receivers, and smartphones. The resulted positioning accuracy varies dramatically form GNSS receiver type to another. For example, the accuracy resulted from using RTK receivers reaches 1-2 cm [1], accuracy for hand-held receivers is around 1-5 m [6, 7], and GNSS smartphone's positioning accuracy is 3-15 m [8].

Recently, the applications GIS and GEE have been extended to many fields. GIS is used as a tool that is used for creating, editing, analyzing, visualizing, and managing the geographic information [9]. The GIS data consists of both spatial and attributes data. The spatial data are the vector and/raster data that represents the geometric characteristics of the geographic objects. Whereas, the attribute data are tables that describe the geographic objects. Among the various GIS softwares exiting in the market, ArcMap® is the most famous one that affords plenty of features that facilitates the manipulation of geographic features. On the other hand, GEE is a cloud-based computing platform, accessible through a web-based interface, for planetary-scale geospatial analysis [10]. GEE provides visual data includes remotely sensed imagery (including Landsat and Sentinel collections), geospatial and other environmental datasets [11]. This data (which is freely available worldwide for public users) is produced in file format that can be converted from/to other spatial softwares existing in market such as ArcMap®.

II. Related Work

GNSS positioning has been introduced in several researches. In [12], the authors introduced a comparison of Samsung Galaxy S™, Motorola Droid X™, and iPhone 4™ smartphones to compared to a vehicle tracker device. The results revealed the feasibility of using smartphones as an alternative vehicle tracker. The effect of weather conditions on GPS positioning error using two different smartphones was investigated by Kost and Brčić [13]. Positions were recorded during hours and analysis was performed to calculate the position deviations in all directions. The study emphasized the significance of taking space weather related error components into account. Bauer [14] compared the GPS based results obtained using nine different smartphone applications on a single smartphone for the same track of one kilometer in an urban area. The results showed that the deviations between distances and altitude measured by the applications were extremely high. Kim et al. [15] presented a smartphone-based technique for coastal monitoring. Moreover, the accuracy of acquired data such as images, three-dimensional coordinates, and attitude was evaluated. The authors stated that the proposed smartphone-based technique was suitable for coastal monitoring applications. A paper that applied the smartphone GPS tracking (SGT) on exploring the spatial distribution and density of recreational movement in multiple-use urban forests was introduced by [16]. The study involved a novel and cheap approach for participatory data collection utilizing smartphone's GPS receiver. The proposed study showed that the SGT methodology offered great opportunities for collecting helpful and up-to-date spatial information. In [17], an iPhone 6 was implemented using the Avenza software for gathering horizontal positions in an urban environment. The study included the time-effect within the year and day on the obtained results. The time of year did not affect the average error observed in horizontal positions when GPS-only (no Wi-Fi) capability was enabled, nor when Wi-Fi was enabled. On the other hand, the average horizontal position error got improved at afternoon during the leaf-off season. Additionally, during each season and during each time of day, horizontal position error got better during perceived high Wi-Fi usage periods.

Chena et. al [18] studied the function design and application effort using GPS and GIS in Shanghai Airport Pavement Management System. The results showed that involving GPS and GIS in the pavement system highly enhanced the overall performance. A library method including satellite data, GPS, and GIS was applied on modern agricultural systems by [19]. Results for two case studies in Khuzestan were presented. The data received from simultaneous control management of resources system was the main base for precision agriculture. In [20], the authors introduced a study that focused on real-time monitoring of the excavated coal quality using GIS and GPS integration. After conducting the GPS surveying, digital maps and attribute data were created and involved in the GIS environment by writing a Map Basic computer application using Visual Basic. A driver's navigation system that uses the GPS and Google Earth maps was presented by [21]. The proposed system was designed to continuously monitor the vehicle's track on PC with Google Earth Application. The basic elements of system were GPS, GSM (Global system for Mobile Communications), and MCU (Micro Controller Unit). In [11], the authors presented a study for the big geospatial data flows available to fluvial geomorphologists within the GEE data catalog. The study focused on approaches over which GEE analysis can be applied.

III. Material And Methods

The methodology obeyed in this research is described in this section. First, the smartphone GNSS surveying for the area in question is performed utilizing SW Maps® smartphone application. Then, the files generated via the application were uploaded to computer. Afterwards, the uploaded files were manipulated via GIS software (ArcMap®) along with Google Earth® software. Finally, Google Earth® software was interlinked to both SW Maps® smartphone application and ArcMap®. The methodology outlines are illustrated in **Figure no1**.

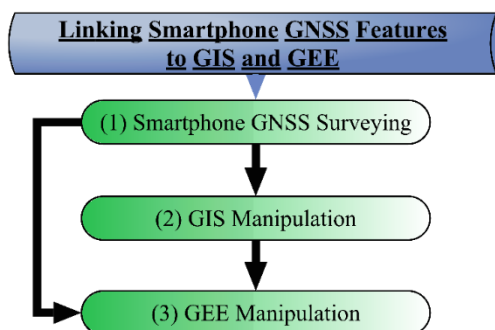


Figure no1: Research methodology outlines.

Smartphone GNSS surveying:

The GNSS surveying is conducted through observing the centerline of different tracks in the area under study using SW Maps® application installed on Samsung Galaxy Note 8 smartphone. A surveyor holds the smartphone with location and internet enabled and moves from the start point of track to end point at relatively low speed. Meanwhile, the "Record Feature" option is enabled in the SW Maps® application in order to record the coordinates of the centerline of track at a selected minimum recoding time interval and chainage. The "Geometry Type" for the recorded feature is selected as "Line". The geodetic reference datum is selected as WGS 1984 Ellipsoid. Nevertheless, the recorded coordinates can be transformed later to the desired geodetic reference or projection. For small distances, the surveyor can perform the GNSS surveying while walking. Whereas, a car moving at low speed can be exploited for long distances. The accuracy of spatial location of the smartphone is 3-15 m [8].

The smartphone application is rich with features that facilitate the surveying process. For instance, the application is provided with "Skyplot" option (**Figure no2**) to enables the user to monitor the observed GNSS satellites. Moreover, information about the observed point can be displayed through the "GNSS Status" option (**Figure no3**). This information includes the basic information such as coordinates, Ellipsoid height, speed, satellites in view, satellites in use, horizontal accuracy, and vertical accuracy. Furthermore, the application is provided with "Compass" option in order to assign the North direction for navigation purposes. The user has the ability to display the points' coordinates only with respect to (wrt) WGS 1984 Ellipsoid or UTM (Universal Transverse Mercator). In many other smartphone applications, the user is free to select among plenty of stored reference ellipsoids and projections. In addition, some applications allow the user to define his own proception. However, this issue is not a major drawback as the recorded coordinates can be transformed later using any computer software such as ArcMap®. The SW Maps® application creates number of output files in different formats such as: *.gpkg, *.kml, *.kmz, *.xls, *.ods, *.csv, *.geojson, *.prj, *.dpx, *.shp, and *.shx. These formats can be then read and processed by ArcMap® and Google Earth® softwares.

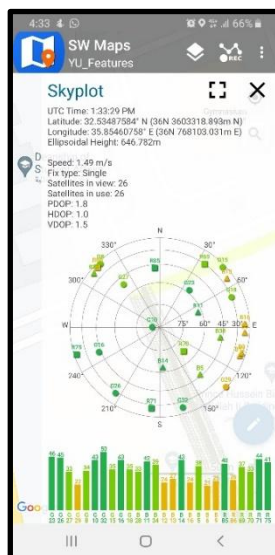


Figure no2: "Skyplot" option in SW Maps®.

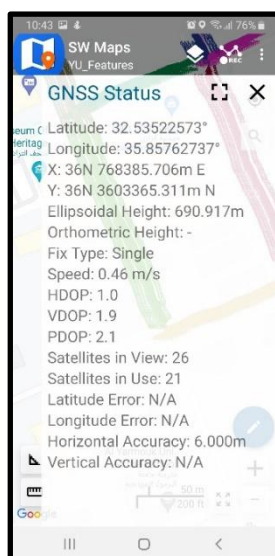


Figure no3: "GNSS Status" option in SW Maps®.

GIS manipulation:

The GIS manipulation is done using ArcMap® software. After uploading the *.prj, *.dpf, *.shp, and *.shx to computer, the data are processed via ArcMap®. The surveyed tracks' data are exported to ArcMap® software as "Polyline" shapefiles. The ArcToolbox is exploited for data processing. First, the "Data Management/Projections and Transformations/Raster/Project" is used to project the WGS 1984 coordinates created by the SW Maps® application to the desired projection. The mathematical equations that are used by ArcMap® software for projection can be found in [22]. Then, the "Data Management/Features/Feature Vertices To Points" is used to generate "Point" shapefiles for the vertices of the surveyed tracks. Additionally, the "Data Management/Features/Add XY Coordinates" is used to add the coordinates of generated points to the attribute tables. Furthermore, the "Conversion Tools/Excel/Table To Excel" is used to export the attribute tables to Microsoft Excel® software. Moreover, the "Editing Tools/Conflation/Generalize" is used to simplify (smooth) the surveyed tracks. This is done in order to exclude the outlier vertices of the surveyed tracks. Besides, the "Data Management/Projections and Transformations/Raster/Project" is used again to back-transform the simplified projected coordinates to the WGS 1984 Ellipsoid's coordinates. Finally, the "Conversion Tools/To KML/Layer To KML" is used to create the *.kmz for the manipulated data that could be opened and processed in Google Earth® software.

GEE manipulation:

This sub-section is dedicated to data manipulation using Google Earth Engine (GEE). The original data for the surveying tracks generated via SW Maps® smartphone application is exported to Google Earth® software. This data includes *.kml and *.kmz files generated by SW Maps®. Moreover, the *.kmz files for the data manipulated using ArcMap® software are exported to Google Earth® software as well. Google Earth® software is helpful for manipulating, visualizing, and refining the exported data.

IV. Result

The surveying data was gathered using Samsung Galaxy Note8 with SW Maps® smartphone application installed on it. The location and internet connection were enabled on the smartphone while measuring. The study area (lies inside Yarmouk University, Irbid, Jordan) extends for about 400 m in the North-South direction and about 260 m in the East-West direction. The dataset was divided into 12 tracks. Six of these tracks (Track01 to Track06) extend in the East-West direction with an average length of 130 m, whereas the other 6 tracks (Track07 to Track12) extend in the North-South direction with an average length of 200 m (see **Figure no4**). The properties of different surveyed tracks are illustrated in **Table no1**. The measurements were conducted in May, 2018 at time from 4:00pm to 6:00pm. A surveyor carried the smartphone and walks at an average speed of 1.5 m/sec through the tracks in question. In average, 26 GNSS satellites were observed (see **Figure no2**). The "Record Feature" option in the SW Maps® application was utilized for recording the coordinates of the centerline of tracks. The minimum recoding time interval and minimum chainage interval were set to 0.1 sec and of 10 m, respectively. The "Geometry Type" for the recorded feature was selected as "Line" and geodetic reference datum was chosen as WGS 1984 Ellipsoid. The smartphone application generated a bundle of output files in different formats. Some of these formats are compatible with ArcMap® software such as After uploading the *.prj, *.dpf, *.shp, and *.shx. While, the others are compatible with Google Earth® software such as *.kml and *.kmz. The total Cholesterol level reduced by -14.71%, 17.35%, -11.63%, respectively.

Table no1: Properties of surveyed tracks.

Track ID	Length (m)	Direction
Track01	127.0065	East-West
Track02	142.3911	East-West
Track03	137.5283	East-West
Track04	134.3571	East-West
Track05	136.6575	East-West
Track06	129.2119	East-West
Track07	213.5623	North-South
Track08	204.6784	North-South
Track09	193.8333	North-South
Track10	1999.7037	North-South
Track11	226.4949	North-South
Track12	207.5634	North-South



Figure no4: Surveyed tracks on SW Maps®.

After generating shapefiles (*.shp) for the surveyed tracks, they were uploaded to ArcMap® software (**Figure no5**). The type of the generated shapefiles is "Polyline". Then, ArcToolbox was utilized for data processing. At the beginning, the "Data Management/Projections and Transformations/Raster/Project" was used to project the WGS 1984 coordinates to the 36N UTM projection (the UTM zone at which the study area lies in). Next, the "Point" shapefiles for the vertices of each of the 12 surveyed tracks were generated using "Data Management/Features/Feature Vertices To Points". The generated points (vertices) of Track01 are illustrated in **Figure no6**. The "Data Management/Features/Add XY Coordinates" was exploited to include the coordinates of generated points to their attribute tables. The coordinates of some points (vertices) of Track01 (as a sample for the generated projected 36N UTM coordinates) are demonstrated in **Table no2**. Moreover, the attribute tables were exported to Microsoft Excel® software utilizing the "Conversion Tools/Excel/Table To Excel". Additionally, the outlier vertices were omitted through performing line simplification utilizing the "Editing Tools/Conflation/Generalize" tool. The value of tolerance (the maximum allowable offset between points on original line and simplified line) was set to 3m. The blue line in **Figure no7** represents the original line of Track01, whereas the red line represents the simplified one. Afterwards, the "Data Management/Projections and Transformations/Raster/Project" was used again for back-transforming the simplified projected coordinates to the WGS 1984 Ellipsoid's coordinates. Finally, the simplified tracks were exported to Google Earth® software in *.kmz format using the "Conversion Tools/To KML/Layer To KML" tool. On the other hand, the raw *.kml and *.kmz files generated by SW Maps® were exported to Google Earth® software for better visualization and more manipulation (see **Figure no8**).



Figure no5: Surveyed tracks on ArcMap®.

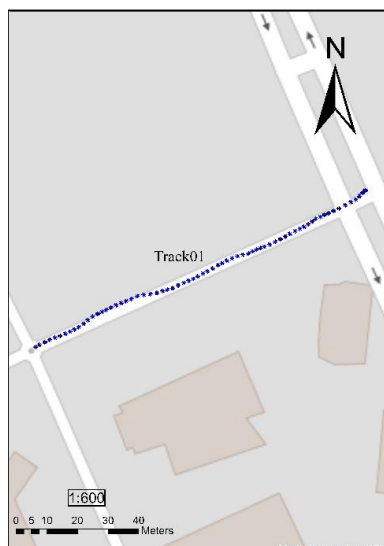


Figure no6: Vertices of Track01 on ArcMap®.

Table no2: The 36N UTM coordinates for some vertices of Track01.

Point ID	E (m)	N (m)	Z (m)
0	768244	3603375	657
1	768244	3603375	657
2	768243	3603374	657
3	768242	3603373	657
4	768241	3603372	657
5	768239	3603371	657
6	768237	3603370	657
7	768235	3603369	657
8	768234	3603368	657
9	768232	3603368	657
10	768231	3603367	657
11	768229	3603366	657
12	768228	3603366	657
13	768227	3603365	657
14	768225	3603364	657

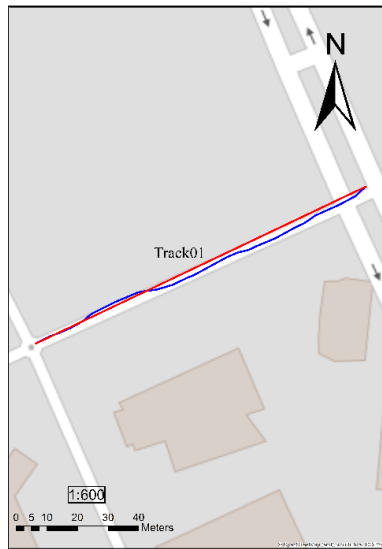


Figure no7: Original line vs. simplified line of Track01 on ArcMap®.

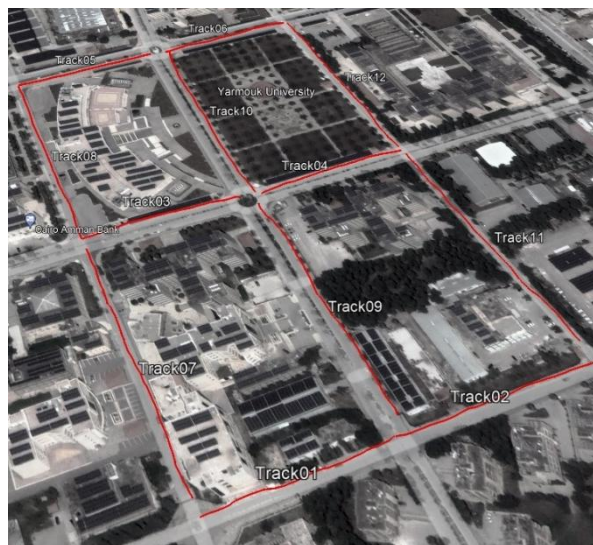


Figure no8: Raw surveyed tracks on Google Earth®.

V. Conclusion

This paper introduced a study to investigate the GNSS features embedded in smartphones and linked them to GIS and GEE. After, making the GNSS surveying utilizing SW Maps® smartphone application, the output generated files were uploaded to ArcMap® and Google Earth® softwares for processing and refinement.

The experiments showed the power and efficiency of linking the GNSS data produced by smartphone to GIS and GEE. In addition, the output files generated by smartphone were compatible to the famous softwares existing in market.

Future work will focus on enhancing the efficiency of the process through designing a complete system for data processing. Moreover, a developed code is intended to be added to the system in order to detect the outlier observation.

Disclosures

The authors have no relevant financial interests in the manuscript and no other potential conflicts of interest to disclose.

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