The Smart Phone as a Surveying Tool

Oluropo OGUNDIPE, (United Kingdom)

Key words: smartphone, GPS, surveying, crowd source

SUMMARY

The development of mobile phone technology has enabled African countries to break out of the limitations of poor national telecoms infrastructure development and to leap forward by several developmental stages and in the process generating a strong mobile technology economy. Smart phone technology is increasingly becoming pervasive in every society across the globe. These mobile platforms carry an array of sensors such as GPS receivers, accelerometers, digital compass, and camera. These connect to a fast multi-core CPU of speeds in excess of 1GHz. This paper assesses the capability of the smart phone to be used as a topographic survey tool. It provides an analysis on the level of accuracy that can be achieved using such a technique. An Android application is developed for data collection, filtering and display. Data filtering is performed by integrating both GPS and inertia sensor data. In addition a method for data correction by calibrating on a known point is proposed. A comparison survey using survey grade Total Station and GPS is conducted and used as a comparison benchmark.

The Smart Phone as a Surveying Tool

Oluropo OGUNDIPE, United Kingdom)

1. INTRODUCTION

The processing capability available on today's smart phones has almost doubled over the past few years. For example the Apple 3GS iPhone uses a 600Mhz CPU 256MB of RAM ARM chip, while the iPhone 4 uses the A4 chip which runs at 1GHz. With the introduction of multi-core phones in late 2010 mobile software can take advantage of increased speed and performance. Many of 2010's top smart phones had a 1GHz processor - devices such as Apple's iPhone 4, HTC's Desire HD and the Windows Phone 7 handsets that arrived towards the back end of 2010. After this dual-core phones such as the LG Optimus 2X came on the market. The 2X has a Nvidia Tegra 2, 1GHz processor - a dual-core system-on-a-chip based on ARM architecture. The Tegra chip still promises 1GHz of processing power however, dual-core chips enable more power to be squeezed out of the processor because the chips contain two 1GHz cores - meaning there are two 1GHz processors that can be used in parallel to speed up performance, provided the mobile software has been optimised to take advantage of the parallel processing power. Dual-core chips should enable a noticeable speed and performance increase, particularly when it comes to multitasking. In 2013 the latest smart phones feature multi-core processors with dual and quad-core processors available.

This availability of increased processing power coupled with smart phones that have numerous inbuilt sensors such GPS positioning sensors, Wi-Fi, Bluetooth, camera, pressure, temperature, humidity, light and inertia sensors such as digital compass, accelerometers and gyros, has created a powerful tool which can be used for surveying and geographical information data collection. In addition many top end smart phones are starting to use multi-constellation GNSS chips for example the iPhone 4S, iPhone 5 and Samsung Galaxy Note use a GPS+GLONASS GNSS chipset. This hardware does not exist in isolation but benefits from advances in computer science, in particular the emergence of Web 2.0, as well as the availability of broadband and 3G communication networks. Smart Phone platforms such as Apple or Android provide an API for developers to write their own software with additional APIs in Android to utilise Google maps. There are also APIs available for use with Open source maps such as OpenStreetMap.

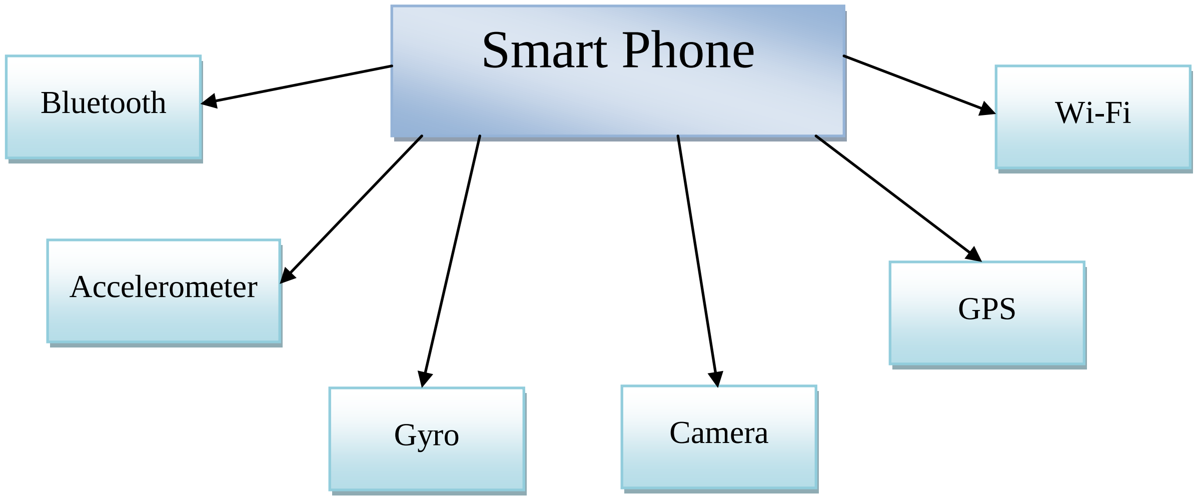

Figure 1: Key Smartphone Sensors

At the end of 2011 there were 5.6 billion mobile phones around the world with an increasing proportion being smart phones. Smart phone use is growing exponentially with an estimated 1 billion active users around the world. According to a report by Strategic Analytics this value is estimated to increase by another 1 billion by 2015.

With the increasing availability of low cost navigational devices in the form of smart phones and GPS data loggers, the area of volunteered geographic information and crowd sourcing of geographical data has grown significantly. Crowd sourcing in a geospatial context refers to data collection by a large and varied group of interested people who generally do not have any surveying training and who do not have any involvement with the subsequent data processing and integration (Heipke, 2010).

A number of crowd sourcing geospatial projects have been established in recent years. Some of the well known ones are OpenStreetMap and Wikimapia which produce openly available data as well commercial systems such as Google Map Maker and TomTom's HD Traffic™ real-time traffic information. Waze™ is a community based traffic and navigation app available on iPhone and Android. It utilises information gathered from its large user base to provide alerts on accidents, road hazards and traffic jams (http://www.waze.com/). There are also online tools and platforms such as Ushahidi (http://ushahidi.com/) which came to prominence during the aftermath of the Haiti earthquake in 2010 where it was used for mapping and tracking spatial related information such as food and water needs, missing children, and more. Another community based mapping platform is Taarifa. It is an open source web application for information collection, visualization and interactive mapping. It enables people to post reports which are geographically tagged. These can then be followed up on while engaging citizens and communities (http://taarifa.org/).

Figure 2: Taarifa User Mapping and Reporting a Sewerage Problem in Dar es Salaam

As crowd sourced data is largely from untrained users with low cost equipment the issue of the data quality arises. Many of these datasets such as OpenStreetmap have facilities for reporting map errors. However the key issue is 'fitness for use' (Heipke, 2010). Is the data quality appropriate for the application required? While crowd sourcing utilises the untrained user with their smart phone for data collection, can this new tool with its many sensors be utilised by the trained surveyor/GIS specialist in collecting and analysing geospatial data. Can the use of simple algorithms and filters, as well as the integration of the various sensors enable improved positioning accuracy and data collection. In this paper different tests and analysis were performed in order to try to address these questions.

2. SMART PHONE APPLICATION

An android based smart phone app was created in order to enable the use of a smart phone as a surveying tool. Figure 3 below shows a screen shot of the user interface. The user interface is simple and enables the user to record GPS data, store it in a text file on the SD card, filter the data, add descriptions and attribute information, and take a geo-tagged photograph. GPS data for these tests were colleceted using a Samsung Galaxy S and a HTC Wildfire Android smart phones.

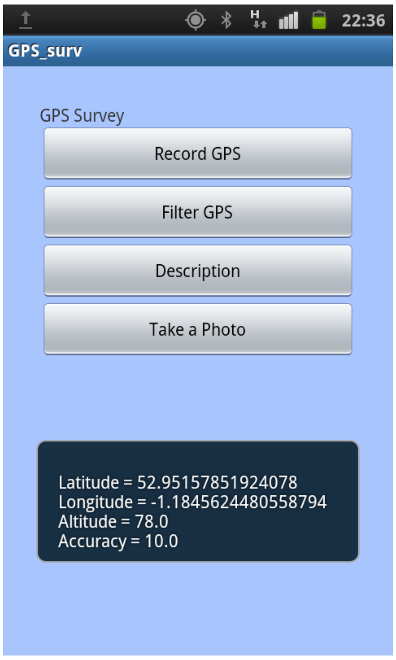

Figure 3: GPS Survey Application Front Screen

The GPS Survey app will also enable the measured data to be overlaid on Google Map background enabling the user to see their data in relation to the surrounding landscape and features.

3. DATA FILTERING

The GPS data collected on the smart phone will contain errors from different sources including atmospheric and multipath errors, as well as measurement sensor noise. In addition to this there is the effect of the number of satellites visible and their geometry in the sky. The effect of the satellite geometry known as dilution of precision has a multiplying effect on the position accuracy. Some of these errors such as multipath from a passing vehicle can momentarily reduce the quality of the observation causing large errors. Therefore some means of quality control is required to remove outliers from the data collected. The data filtering techniques used by this tool are as follows:

- Using the data quality indicator provided by the Android API from the GPS engine to set a threshold for identifying outliers.
- Averaging of data on static points
- Using comparison with accelerometer data to identify and remove gross errors.

In writing the app the user can request that the 'position accuracy' be provided in the output strings as well as the position coordinates. A extract of the data file stored is shown in Table1 below. The column highlighted in red is the position accuracy provided by the smart phone GPS engine. A threshold of 12m was set with positions with accuracy values above this value excluded from further processing.

Table 1: Extract of recorded GPS positions with the position accuracy highlighted

13,1362668566797,1362668606000,**52.95159101486206,-1.184425950050354,100.0,16.0**,
14,1362668567798,1362668607000,**52.951757311820984,-1.1840826272964478,78.0,24.0**,
15,1362668568799,1362668608000,**52.951762676239014,-1.184098720550537,76.0,8.0**,
16,1362668569799,1362668609000,**52.951762676239014,-1.184104084968567,78.0,6.0**,

It should be noted that some smart phones perform some level of internal filtering of sensor data which is largely undocumented. Tests conducted by the author on an iPhone 4 show some characteristics which may suggest internal filtering (Ogundipe, 2012). Observing the data from the HTC Wildfire in particular when the phone is stationary suggests that some internal filtering may be performed as there is very little random noise component in the coordinates when static. For some applications this internal filtering may not be beneficial as the position solution may be 'boot-strapped' to a poor quality value.

Data from the 3 axis accelerometer on the smart phone was also recorded. The combined acceleration vector was computed according to Equation (1).

$$A = \sqrt{((A_x)^2 + (A_y)^2 + (A_z)^2)} \qquad \text{Equation 1}$$

Where A_x, A_y and A_z are the acceleration in the x, y and z axes respectively.

This was then double integrated to give the change in distance every second. The change in distance based on the GPS coordinates from consecutive epochs was also computed. If this change was greater than 3 times the change in distance from the accelerometer data then that GPS position record was flagged but not removed.

4. DATA CORRECTION

The low-cost GPS sensors on smart phones does not provide the user access to the raw GPS pseudo-range or carrier phase observables. Therefore techniques such as RTK, DGPS or even post processing of single point positioning cannot be performed in order to correct or mitigate the error in the observables which translate to a positioning error. In seeking to use the smart phone as a surveying tool the data quality and reliability is of importance. Therefore a simple correction methodology was tested. This method required that the user survey and record position data at a point with known coordinates which is in the same area as the features to be surveyed. A correction factor is then computed by subtracting the difference between the true and observed values at the known point. This is then applied to the coordinates of the features that are surveyed in that session. The assumption behind this method is that within the same environment the tropospheric and ionospheric errors are similar and change slowly. And that the multipath environment is also similar. However the reality is that the ionospheric errors can sometimes change very rapidly due to scintillation effects. Scintillation refers to short-term rapid fluctuations in the amplitude or phase of the GNSS signal. Amplitude fading and phase scintillations can cause cycle slips or even cause the receivers to lose lock on the GNSS signal (Kintner et al., 2009). This scintillation effects are more prevalent around the solar maximum period and affect largely the equatorial and high latitude areas. Mid latitude areas such as the UK are not as strongly impacted by scintillation effects. The other challenge to the assumption is multipath as depending on the user location and other transient effects like passing vehicles, this will vary as well. Nevertheless if the difference in multipath environment does not dominate, there should be some common error that this techniques may be able to assist in correcting.

A test was conducted on the Jubilee Campus of the University of Nottingham. The survey marker NGB12 was surveyed for 1-2 minutes using the HTC Wildfire Android smart phone. The data was recorded in a log file on the SD card. Using the software Grid Inquest the geodetic WGS84 coordinates were converted to Ordnance Survey OSGB36_(02) coordinate system. Table 1 show the error of the average coordinates.

Table 2: Comparison of smart phone GPS result with known coordinates at NGB12

	Easting	Northing	Height
Smart phone Av	454911.928	339680.128	39.682
Known NGB12	454914.208	339679.717	29.898
Diff	**-2.280**	**0.411**	**9.784**

This error values were applied as correction parameters to the average value of the coordinates collected at NGB11 which is located about 30m away.

Table 3: Applying correction to NGB11 smart phone GPS results

	Easting	Northing	Height
Smart phone Average	454876.698	339692.636	61.452
TRUE NGB11	454893.289	339700.255	30.796
Error	**-16.591**	**-7.619**	**29.631**
Error Vector	**34.808**		
Corr from NGB12	2.280	-0.411	-9.784
Corr Coords	454878.978	339692.225	50.643
New error	**-14.311**	**-8.030**	**19.847**
New Error Vector	**25.752**		

It can be seen in Table 3 that the simple correction method provides improvements in the position solution with significant improvements in the height in the order of about 10m and some improvement in the east direction in the order of about 2m. however the accuracy of the northing component was degraded by about half a metre. The error vector was used to assess the overall improvement in accuracy. Improvement in the error vector from 34.8m to 25.8m can be seen.

A test was conducted where the smart phone was used to survey a road which had been previously surveyed using RTK GPs and Total station. The aim was to compare the level of accuracy that could be obtained from using the smart phone as a topographic survey tool. Figure 4 shows an extract of an AutoCAD drawing. This shows the smart phone surveyed and corrected data in relation to the high accuracy surveyed road segment. The white line is an attempt to smooth the smart phone data by applying expert knowledge. This includes smoothing the lines and also applying the knowledge that a road generally maintains a constant width.

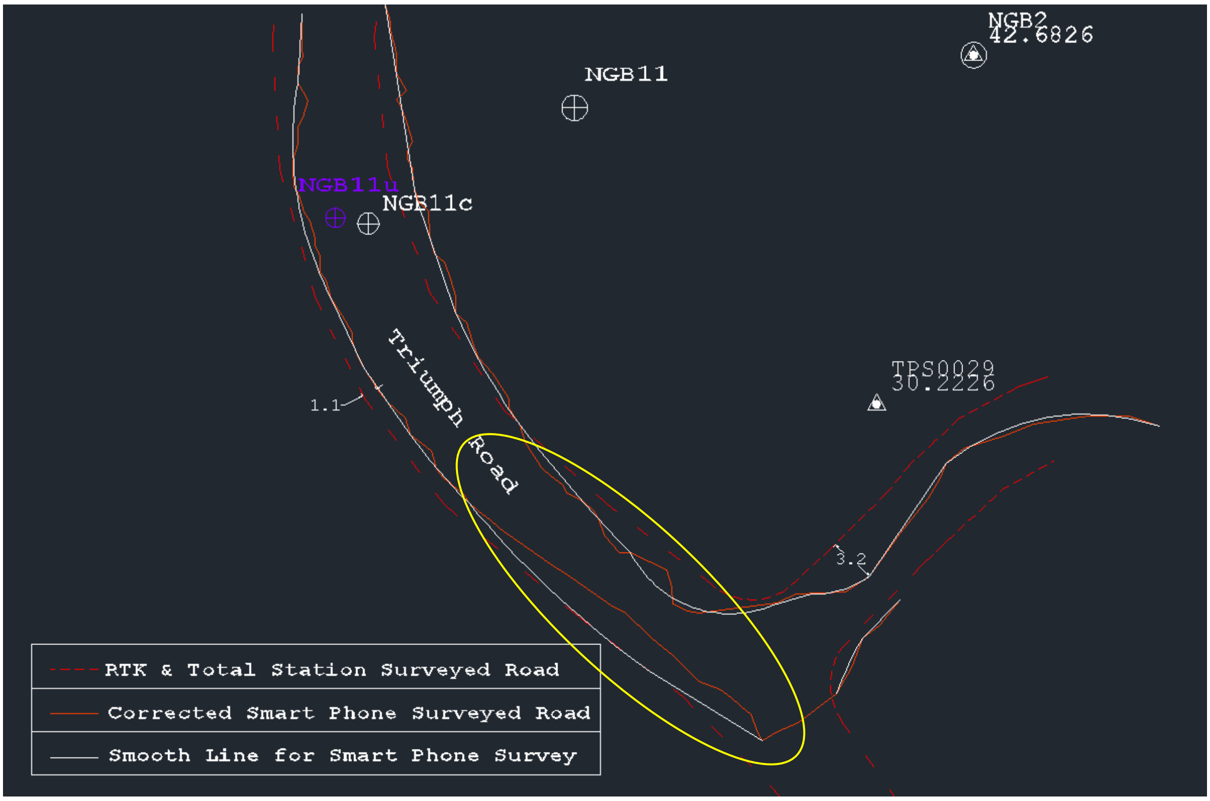

Figure 4: Road Survey Using Smart Phone GPS Compared with High Accuracy Surveying.

It can be seen from Figure 4 that deviation from the correct plan position vary from about 1m to 3.2m with exact matches in some locations. The yellow segment highlighted experienced large deviations. Looking at Figure 5 which show a photograph of the area, it can be seen that there are several buildings on both sides of the road. Moving between these buildings will generate variations in the multipath signature and it is likely that in that area the multipath signature was significantly different to that of the calibration point, hence the large deviation.

Figure 5: Photograph Showing the Road Segment and Surrounding Buildings

5. CONCLUSION

The increasing ubiquity of smart phones with its numerous sensors provides a tool that is increasingly being utilised for geospatial data collection. Crowd sourced geospatial maps like OpenStreetMap are producing feature rich maps collected by enthusiasts. Though currently crowd sourced maps tend to be feature rich in developed countries but sparse in poorer countries with less contributors. However as smart phone become increasingly pervasive this can be a low-cost survey tool if utilised appropriately. It will not be suitable for all applications, for example in the setting out for road construction where centimetre level accuracy is required. However for many applications it can be a useful survey tool. Applications such as planning, topographic survey reconnaissance, geological surveys, epidemiological mapping and much more, where accuracy at the 1-3m level is adequate can benefit from the use of the smart phone. The app created provides the ability to add description to the position stored, as well as attaching a photograph. Such a functionality is useful to many applications including environmental monitoring and forest management.

In traditional surveying methods a traverse is surveyed in order to establish some known points. A detail survey is then conducted by setting up the total station on those known points. Also in precise GPS techniques like Differential GPS utilise a base station with known reference coordinates. The correction technique tested attempts to utilise that same approach in correcting the smart phone GPS data. The filtering techniques implemented though simple, help to improve positions. Correction on a calibration known point also helps to an extent but this degrades over time and also degrades as the multipath environment changes from that of the known point used to calibrate.

REFERENCES

http://www.cbsnews.com/8301-205_162-57534583/study-number-of-smartphone-users-tops-1-billion/ (Accessed March 2013)

http://www.silicon.com/technology/mobile/2011/01/12/dual-core-smartphones-the-next-mobile-arms-race-39746799/ (Accessed April 2011)

Heipke, C., (2010) *Crowdsourcing Geospatial Data*. ISPRS Journal of Photogrammetry and Remote Sensing 65 (2010), pp. 550–557.

Kintner, P. M., Humphreys, T., Hinks, J., (2009) *GNSS and Ionospheric Scintillation, How to Survive the Next Solar Maximum*. InsideGNSS, July/August 2009, pp.22 – 30.

Ogundipe, O.; (2012) *Assisting the Visually Impaired Using Smart-Phone Sensors*. Coordinates, May 2012, Vol. VIII, Issue 5, pp.18 – 26.

BIOGRAPHICAL NOTES

Oluropo Ogundipe is a Research Fellow at the Nottingham Geospatial Institute, University of Nottingham. She has a PhD on the topic of "The Use of Real Time Kinematic GPS on Construction Plant" from the University of Nottingham. Her current research focus includes the use of GNSS in forestry accreditation, indoor positioning for the blind, software receiver validation and the use of GNSS for bridge monitoring. Her research interests also include multipath mitigation, RFID positioning, augmented reality and Network RTK GPS. She has also had industry experience in the GNSS and Geomatics sector working for a GNSS equipment manufacturer and as a Land & Engineering Surveyor.

CONTACTS

Dr Oluropo Ogundipe
University of Nottingham
The Nottingham Geospatial Building
Triumph Road
Nottingham
UNITED KINGDOM
Tel. +44 (0)1158232752

Web site: www.nottingham.ac.uk/ngi