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# Is Neo-Cadastral Surveying on your Smart Phone Feasible?

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## ABSTRACT

At recent conferences (SSC2011, GeoNEXT2012), it has been suggested that cadastral surveys will be performed on a GPS enabled mobile phone in the near future. This is both a delicious prospect for the modern geospatial innovator and a galling, outrageous proposition for the cadastral surveyor. How far away from legally defining property boundaries with nothing but a mobile phone are we? This project will therefore undertake a small cadastral survey and investigate each step using all the latest information available in NSW to critically analyse the benefits and pitfalls encountered. In a partnership between the School of Surveying and Geospatial Engineering and LandTeam (Wollongong) a modest property was chosen and as many aspects of the survey as possible were carried out using an iPhone 4. This project seeks to investigate what benefits a modern smart phone can bring to the modern surveyor, but also to explain the limitations with reference to the legislation under which a Registered Surveyor is bound. Some comments about the future of such a proposition are also given.

**KEYWORDS:** Cadastral Surveying, GPS, GNSS, mobile phone

## 1 INTRODUCTION

The motivation for this paper was to investigate the assertion that crowdsourcing of spatial data and the range of new applications available on modern smartphones and internet devices will diminish the role of the cadastral surveyor (Van der Klugt, 2012).

Purchasing a house or land is the greatest single investment that most people will make. The World Bank has stated, "…between 50 to 75% of the Gross National Wealth in a developed country depends upon a secure system on land titling and ownership …".In Australia, most privately held land is owned under Torrens title or Strata title and guaranteed by the State. Different States and Territories have jurisdiction over their respective cadastral systems which differ slightly. Registered or Licensed cadastral surveyors are the only professionals who can legally determine the position of boundaries. A particularly contentious decision must be determined by the Courts. Surveyors therefore have obligations,not only to their clients but also to the State to maintain the integrity of the cadastre (Donnelly, 2012).

The fundamental role of the professional cadastral surveyor is to re-establish a property boundary as per the intent of the original surveyor or a recent modern survey. In modern, metropolitan areas, this is can be relatively straightforward if a recent survey has been conducted and sufficient infrastructure in the form of survey reference marks exist. The surveyor can simply check these marks are stable with regard to the most recent, modern survey and then re-establish the boundaries from these survey monuments. However in a rural location where the original survey may be over 100 years old; where original techniques of measurement were rudimentary;

and where no evidence of survey marks left by the original surveyor are evident, the judgement and expertise of the cadastral surveyor must be employed. Even with modern measuring techniques (EDM and GNSS), the principle of “monuments over measurements” still applies. That is, if an original plan measurement is laid out using a modern (superior) technique and an original survey monument is found at a different dimension, then it is the monument that takes precedence over the measurement when defining the boundary. The monument may be an original survey mark or more likely an old fence or other evidence of occupation of the original boundary, but the owner of the land will understand that this is their ownership as compared to some plan dimension or modern instrument observation.

Original surveys in Australia were laid out as quickly as possible to enable development of the new colony. The principle of “working from the whole to the part” was not observed initially and subsequent surveys to re-establish these original boundaries require some creativity for the modern cadastral surveyor (Roberts, 2006). As more modern surveys re-define original boundaries, the cadastral surveyors’ job becomes more straight-forward. Ultimately re-establishing boundaries will become a much simpler procedure.

In NSW, the Digital Cadastral Database (DCDB) was developed from Land and Property Information (LPI) paper maps and plans and is constantly updated based on registration of land transactions in NSW, as well as changes in administrative boundaries (LPI, 2012a). The DCDB has differing accuracy depending on the origins of the data. It has no legal status and is simply a geographical representation of the tenure.

This paper will therefore examine the proposition recently advanced that cadastral surveys can be performed using a modern GPS enabled smart phone. The author has coined the term “neo-cadastral surveying” derived from the term “neo-geography” which refers to geography performed by non-experts using modern tools (Wikipedia, 2012).

## 2 THE SURVEY

A small 2-lot subdivision in Shell Cove, Shellharbour, a metropolitan location, was chosen as a suitable case study for this paper. An iPhone 4 using the OS5 operating system was used throughout this project. It should be noted that this is actually a GNSS (Global Navigation Satellite System) enabled smart phone, as it uses a chip which tracks both GPS and the Russian GLONASS signals. GNSS is an umbrella term comprising all modern satellite positioning methodologies.

### 2.1 Office preparation

Preparation prior to such a project requires a survey search to locate the original plan and previous modern surveys that have defined the boundaries of the subject parcel. These survey plans are called deposited plans or DPs and each contain a unique number, plan dimensions with connections to survey marks, some notes regarding the subject property and importantly the signature of the Registered Surveyor who takes responsibility for the legal definition of these boundaries.

LPI have eased this search process using the Spatial Information Exchange (SIX) Portal. From here it is possible to conduct a Cadastral Record Enquiry (CRE) report where, by simply entering the lot and DP of the subject parcel, all neighbouring DPs will be listed in numerical order allowing the surveyor to decide which plans to order to aid the field survey.

Also within the SIX environment, it is possible to search for information about survey marks using the Survey Control Information Management System (SCIMS). It is possible to order sketch plans to assist with the location of marks in the field as well as the MGA coordinate information and details about the quality of the marks (class/order). Positional uncertainty is still not available (Roberts et al, 2009).

The Certificate of Title (CT) for the land can be ordered within SIX. The CT lists any easements or restrictions that may affect the land as well as the owners name and mortgagee. The

CT may also refer to other DPs associated with the creation of legal instruments which may affect the boundary definition.

Often a boundary “model” is created in the office before visiting the field. This model derives from the best combination of plan dimensions available from the search and is often uploaded to an instrument (total station or GNSS receiver) prior to fieldwork. It is used in conjunction with survey marks to assist in finding evidence to confirm the boundaries. For a modern survey this model will usually be quite accurate, however for an older, original survey, this model will often give the surveyor an indication only of where to search for boundary evidence.

As searching for evidence in the field requires digging, it is common practice for surveyors to conduct a “dial before you dig” search in the vicinity of the subject property to avoid disturbing any underground services.

The last task in the office is to use Google Earth, Street View or SIX to indicate the terrain, the tree cover, vehicular access and any other information that the surveyor might glean in order to expedite field operations.

### 2.2 Office preparation on the phone

Although many of the tasks listed in section 2.1 are more conveniently carried out on an office computer, all were attempted on the iPhone4. Connection to the SIX portal was straight forward and despite the small screen it was possible to zoom in to enable accurate navigation with the finger. The SCIMS search was not possible. The device stated that “SCIMS had been launched in another window”, but no window had been opened. This is possibly due to the SIX portal not being configured for use on mobile devices.

The CRE search was very straight forward on the phone. It was possible to zoom and scroll easily. The certificate of title was not searched using the phone. Similarly “dial before you dig” was registered and conducted on the phone. This is not always required for cadastral surveys.

Google maps were easily visible on the phone. Indeed this is a major feature of most modern smart phones.

Creating a model of the survey prior to visiting the field was less straightforward. Autodesk Inc. offer a free version of Autocad in the “Appstore” (Autocad, 2012). It has quite limited functionality, but is suitable for viewing files in the field. It is possible to produce a model in the office and email to the device, however the model is not linked to the GPS requiring the user to switch between the Autocad and GPS positioning map environment.

Also prior to leaving the office various applications (Apps) were investigated that could be of some assistance in the field. The App “GPS Receiver” was chosen as it displays UTM grid coordinates in the field and overlays saved points onto a background map (GPS Receiver, 2012). This is a very convenient feature for fieldwork. Importantly, any marks that are measured in the field can be saved as waypoints and emailed to an account as a text list, excel file or kml file to display on Google Earth. This App could be used in the office to manually upload coordinates of marks from the DPs to assist location in the field. Coordinates can only be uploaded as latitude and longitude. The “Theodolite” App was also installed for checking of angles as per the DP in the field (Theodolite, 2012). An iPhone cannot measure distances of several 100 metres directly.

### 2.3 Fieldwork

The biggest concern for the fieldwork was the telecommunications network connection for the smart phone. For most metropolitan regions this is not of concern and it should be noted that network connection is improving in most regional locations in Australia. Shell Cove had satisfactory coverage.

Based on the configuration of the job, location of control and constraints to access the subject property, a plan was devised to carry out the survey. Since GPS techniques were to be used, double occupations on all marks, as per the Surveyor Generals Directions # 9 (LPI, 2012b) were built into the plan. This included locating State Survey Marks (SSM) and Reference Marks (RM) with checks on measurements and placing and measuring new RMs with checks. At Shell Cove, drill hole and wing marks on concrete kerbing were used as RMs. Any fencing on or near the boundaries needs to be located including any fencing further along the street if relevant. The location of any improvements (buildings) within 1 metre of the boundary must also be measured. If a new dividing boundary is determined by walls of houses, they must be located (with gutters if necessary). Any services, or features, which require easements (eg driveway, inter-allotment drainage services etc) need to be located as part of the survey. Ultimately upon completion of all calculations the final boundary definition including new dividing boundaries must be pegged.

DP1155515 completed in 2011 was the original plan for this 2-lot subdivision survey. As this is a modern survey, no uploading of coordinates was required. RMs were drill hole and wing marks which are easy to find and therefore “dial before you dig” was also not necessary.

This survey had been completed previously using total station techniques. MGA coordinates were therefore available for all points. This survey was simply repeated using the iPhone4 and the GPS Receiver App. All points were double occupied and three SSMs were occupied as per regulations. A screen shot of the field work is shown below in Figure 1.

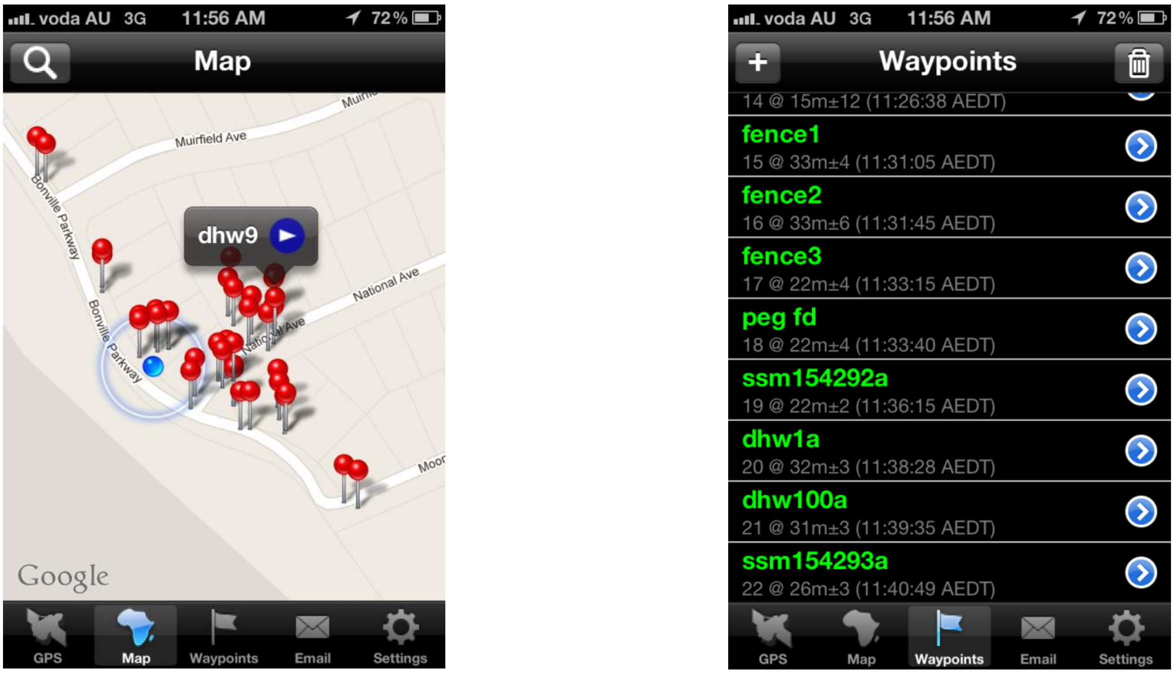


Figure 1 – Screen shots of the GPS Receiver App

The procedure after completing the survey fieldwork is to return to the office and perform calculations (usually using a CAD software) to confirm that the field work accords with the original survey plan and define the boundary. The GPS coordinates were therefore compared with the MGA coordinates derived from the previous conventional survey.

## 3 RESULTS

Table 1 details the points that were measured in the field. The column 2 (H error) refers to the real time error estimated by the GPS Receiver App in the field. This indicates to the user the approximate precision of the measurement at the time of observation. All points were measured twice separated by around 30 minutes to allow the constellation of satellites to move and therefore provide a more independent second observation. The third and fourth columns show the difference in easting and northing between the two observations. These can be cross-referenced with the estimation given in column 2. Multipath errors (see section 4.2) can be seen at fence1 and fence2. Columns 5 and 6 list the MGA coordinates computed by Paul Davis-Raiss (PDR) based on a total station survey. The final column shows the vector error between the conventional survey result (assumed to be correct at the 5mm level) and the average of the 2 GPS observations.

Table 1 – Results of smartphone survey MGA coordinates compared to conventional survey.

| Point | H error (m) | East Diff (m) | North Diff (m) | East PDR (m) | North PDR (m) | Vector error (m) |
|---|---|---|---|---|---|---|
| ssm154292 | 5 | -4 | 4 | 303085.363 | 6168836.704 | 8.501 |
| dhw1 | 5 | 0 | -2 | 303108.29 | 6168790.587 | 6.452 |
| dhw100 | 5 | 0 | -2 | 303124.693 | 6168763.774 | 5.235 |
| ssm154293 | 5 | 1 | 6 | 303146.949 | 6168746.674 | 2.796 |
| dhw3 | 5 | 3 | 0 | 303167.007 | 6168738.888 | 4.580 |
| dhw4 | 5 | 0 | 1 | 303169.023 | 6168744.655 | 4.891 |
| dhw5 | 5 | 1 | 2 | 303185.017 | 6168732.438 | 6.396 |
| dhw6 | 5 | -1 | 6 | 303187.268 | 6168738.211 | 7.015 |
| dhw7 | 5 | -3 | 2 | 303165.371 | 6168752.728 | 6.332 |
| dhw8 | 5 | -2 | 2 | 303159.622 | 6168755.306 | 1.736 |
| dhw101 | 5 | -1 | -4 | 303173.228 | 6168773.582 | 2.525 |
| dhw9 | 5 | 0 | -4 | 303185.653 | 6168775.073 | 3.279 |
| dhw10 | 5 | 0 | -1 | 303184.76 | 6168781.636 | 6.122 |
| ssm154294 | 10 | 6 | -3 | 303219.823 | 6168706.913 | 1.869 |
| fence1 | 5 | 14 | -10 | 303167.56 | 6168778.494 | 5.641 |
| fence2 | 10 | -1 | -10 | 303160.858 | 6168789.685 | 2.951 |
| fence3 | 5 | -5 | 0 | 303134.561 | 6168767.713 | 4.389 |
| peg fd | 5 | -5 | -2 | 303133.884 | 6168767.242 | 4.091 |

The average vector error between the conventional survey and the average of the GPS coordinates is 4.7m and ranges from a minimum of 1.7m up to 8.5m. Some additional concerns during the computations are that the coordinates from the device, despite displaying on the phone in grid easting and northing, are only available in the text and excel files in latitude and longitude. The latitude and longitude provided are given to 6 decimal places of accuracy with could indicate to a user that coordinates are accurate to the millimetre. This is clearly not true. Also the UTM coordinates shown are converted from WGS84. MGA coordinates are based on ITRF92 epoch 1994.0. WGS84 coordinates move with plate tectonics. The Australian plate moves at 7cm/yr to the north-east therefore in 2012 the difference in coordinates is approaching 1.3m (Stanaway & Roberts, 2009).

## 4 DISCUSSION

The Board of Surveying and Spatial Information is constituted under the Surveying and Spatial Information Act, 2002 to provide for the registration of land and mining surveyors, to regulate the making of surveys and to advise the Minister on spatial information (BOSSI, 2012). New regulations have been enacted and the Registered Surveyor is required to act within these regulations (Surveying and Spatial Information Regulations, 2012).

It is clear from the results section above that GNSS measurements from a mobile phone are very inaccurate and inappropriate for cadastral surveying. Some of the relevant regulations confirm this.

The Surveying and Spatial Information (SSI) Regulation 14 deals with equipment for measurement of surveys and states, “A surveyor must not use any equipment in making a survey unless the surveyor knows the accuracy obtained by its use.”

SSI Regulation 22 (Surveys using GNSS equipment), states, “When making a survey using GNSS equipment, a surveyor must use an approved technique that provides appropriate accuracy for the type of survey being undertaken.” This was attempted by performing double occupations (SSI Reg 25(1)).

However, SSI Regulation 25(2) precludes the use of GNSS from a smart phone. It states, "In making a survey, a surveyor must measure all lengths to an accuracy of 10mm + 50 parts per million or better at a confidence interval of 95%."

The current smart phone GNSS accuracy is of the order of 5 metres which far exceeds this limit. Indeed high precision, survey grade GNSS devices also exceed this regulation over short distances. An explanation of current GNSS positioning follows.

### 4.1 GNSS positioning

GNSS satellites transmit two observables on two frequencies[1] that are used for positioning: Code and carrier phase. Survey grade GNSS receivers can measure the two frequencies broadcast by satellites to increase productivity. Smart phones use only one frequency and an open code. The codes can be measured directly providing a range (or distance) between a known satellite position (also transmitted by the satellites) and the receiving antenna. This is called "code ranging" or "pseudo ranging". Combining a minimum of four such ranges in a receiver can resolve a 3D point position to around 5 m of accuracy depending on obstructions and satellite geometry. This process is called point positioning and is the original design of GPS. Smart phones currently use code ranging (ie point positioning) as their only means of computing position.

The codes cannot penetrate the Earth's atmosphere (NASA, 2012) so are modulated onto a carrier wave and demodulated at the receiving device, such as a smart phone. This carrier wave has a known wavelength. In the 1990s, engineers devised sophisticated methods to compute the number of carrier wavelengths (plus a fractional part) between a pair of receiving antennas and a pair of satellites thereby giving "carrier ranging" to mm-level (Hofmann-Wellenhof et al, 2008).

In order to exploit this high precision carrier ranging, a differential positioning mode is employed whereby two GPS receivers measure the same constellation of satellites simultaneously. A mathematical process called "double differencing" is used to cancel out common errors such as receiver/satellite clock bias and satellite orbit errors to improve positioning precision. For code only measurements (often called DGPS) this can improve positioning to sub-metre precision depending on the number of satellites and the distance between the receiving antennas.

When double differencing is applied to carrier phase measurements, the cancellation of the common errors and the accumulation of consecutive observation epochs seeds a process called "ambiguity resolution" (AR). That is, the ambiguous, unknown number of wavelengths between a receiving antenna and a satellite (plus any fractional extra part of the measurement) can be computed mathematically and verified with specific internal criteria in an algorithm. This process usually requires the user to accumulate epochs before an algorithm achieves AR. Initially this was performed in a post processing mode; that is observations were logged in the field, downloaded and combined later in the office. This is called "static mode".

Static GNSS surveying can resolve mm-level precision between points, but is labour intensive and time consuming. This is the process used by professional surveyors and geodesists for high precision control surveys. If a communications link between the receiving devices is included in the field, observations at the base can be sent to the roving antenna and the AR process can occur after just 30 seconds. This process is called "initialisation" and is fundamental to the high productivity procedure called real time kinematic (RTK) surveying. Due to the high productivity nature of RTK, the precision is often at the 10-20mm level for point positions even though it is almost identical to static positioning which achieves a slightly higher precision.

RTK surveying usually uses a base station at a fixed location and a roving station which computes positions with respect to the base. This requires surveyors to own at least two GNSS receivers. Recently, continuously operating reference station (CORS) networks have been

[1] The latest block IIF GPS satellites broadcast three frequencies: L1, L2C and L5

established by government and private companies to provide a networked base station configuration to allow users to only purchase one roving antenna and subscribe to a service to receive the base station data enabling RTK positioning within the network. These CORS networks additionally offer “Network RTK” (NRTK) services which enable high precision positioning over longer base/rover distances without sacrificing precision. CORSnet-NSW is an example of a CORS network (CORSnet-NSW, 2012).

Table 2 – GNSS positioning modes

| Method | Code | Carrier | Approx. Precision | Application |
|---|---|---|---|---|
| Point positioning | ✓ | × | 5 m | Smart phone, car navigation |
| Differential GPS | ✓ | × | Sub-metre | Precision Agriculture, GIS |
| RTK | ✓ | ✓ | 10-20 mm (hori) | Machine control, topographic surveying |
| SBAS | ✓ | ✓ | 50 – 1000 mm | Precision Ag, GIS, etc |
| NRTK | ✓ | ✓ | 10-20 mm (hori) | Machine control, precision Ag |
| Static | ✓ | ✓ | 5 – 10 mm (hori) | High precision control surveys |
| PPP static | ✓ | ✓ | 10 -20mm (hori) | Survey control in remote locations |
| PPP real time* | ✓ | ✓ | Decimetre level | Precision Agriculture |

* Still in research. Initialisation time is around 40 mins.

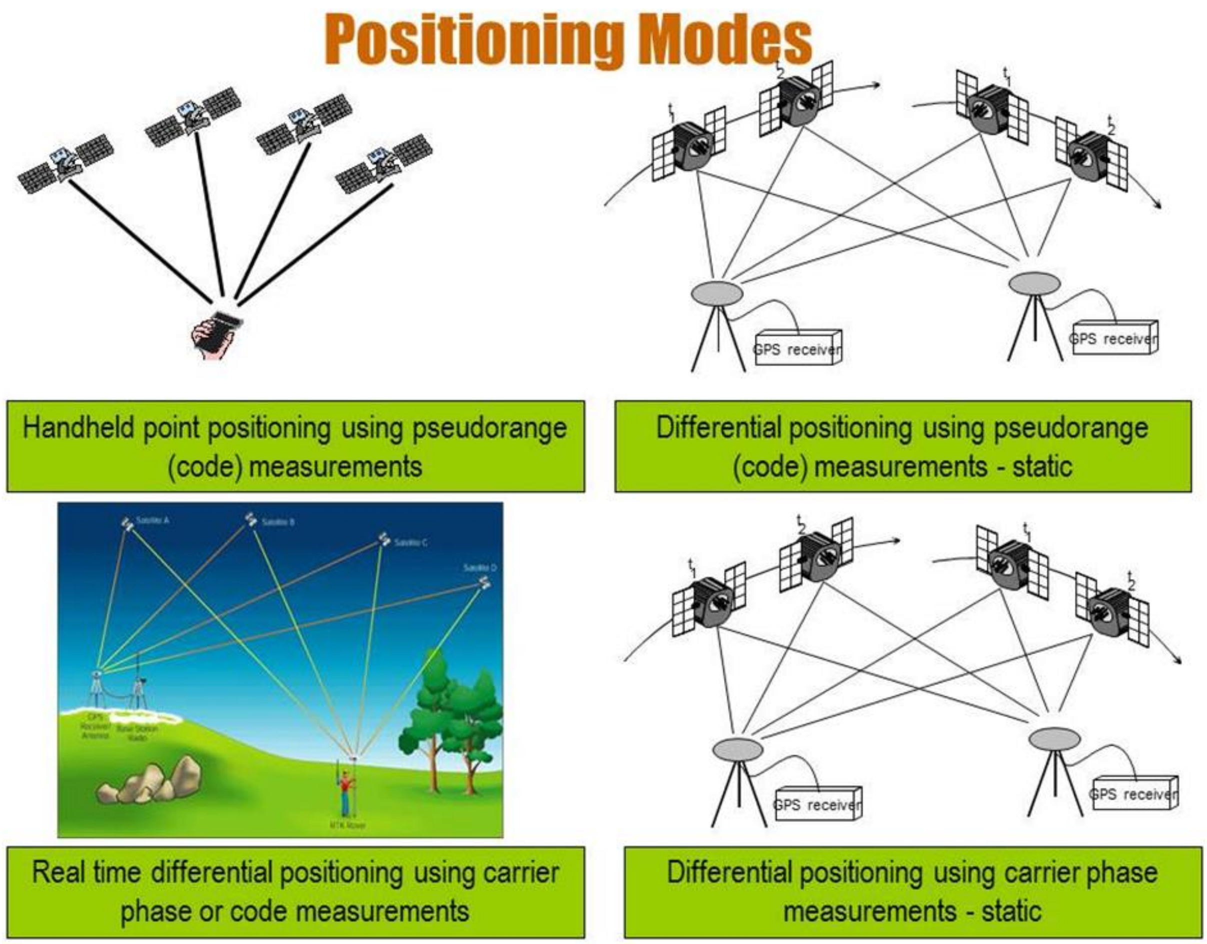


Figure 2 – The four basic positioning modes of GNSS.

The major reason point positioning precision is at the 5 m level is due to the quality of the broadcast orbits (1-2m) and the stability of GPS time which is received from the satellite clocks via the codes. In recent times, the International GNSS Service (IGS) have been providing free orbit and clock products online (IGS, 2012). Exploiting these new, near real time products, a new mode of positioning called precise point positioning (PPP) has evolved which offers post processed cm level positioning. Researchers are developing methodologies for real time PPP positioning, but at present this technique is not commercially feasible (Grinter & Roberts, 2011).

Satellite based augmentation systems (SBAS) are another form of GNSS positioning. They comprise a ground-based control segment which provides corrections which are broadcast to geostationary satellites which re-broadcast these corrections to users. It is a global, code ranging differential service. In the case of the US Wide Area Augmentation System (WAAS), geostationary satellites not only provide a re-broadcasting communications link over large portions of the USA, but they also broadcast an extra GPS signal with correction messages, based on their monitoring ground based network, modulated onto this broadcast message. Users with a WAAS enabled firmware upgrade of their device can receive essentially differentially corrected positioning to sub-metre precision within the coverage area (WAAS, 2012). This service is not available in Australia. Similarly EGNOS (EGNOS, 2012) and MSAS (only in limited regions in northern Australia) are also not available to Australian users (MSAS, 2012).

Two commercial services exist - namely Omnistar (Omnistar, 2012) and Starfire (Starfire, 2012). The high precision services offered by the commercial operators actually utilise the carrier phase measurement, but require an initialisation time of up to 15 minutes. The repeatability of this initialisation is less robust than using CORS or PPP techniques.

## 4.2 GNSS error sources

The major error source in GNSS positioning is receiver clock error. Point positioning overcomes this by observing four satellites to achieve 3D position and estimate the receiver clock error for every observation epoch thereafter. PPP improves positioning accuracy further by incorporating the IGS clock and orbit products to reduce satellite clock error and orbit bias.

Double differencing accounts for satellite/receiver clock errors and satellite orbits errors and is used for all differential positioning algorithms. The major error sources that remain are multipath and atmospheric bias.

When ranges are computed from GNSS satellites, it is assumed that the direct path between the satellite and receiver are measured. However if the signal reflects from another surface, then is it possible to measure the indirect path (ie the path of the signal including the extra distance from the reflecting surface to the antenna) which will bias the position. This is the multipath error. For code ranging this can be 10-20m of position error (Wells et al, 1987).

Numerous improvements of hardware technology mitigate the effects of code ranging multipath for survey grade equipment. However much of this is not applicable to a smart phone as the antenna is very small and the capability of the chip to include sophisticated signal processing algorithms to mitigate the effects of multipath is limited.

Multipath on carrier phase observations can be as much as 60mm, but more importantly can cause initialisation to resolve the incorrect ambiguities resulting in decimetre errors in positioning. At present smart phones do not measure carrier phase.

Atmospheric biases are caused by the GNSS signals being delayed predominantly by two layers of the Earth’s atmosphere: Troposphere (electrically neutral layer from ~0-50km above the Earth’s surface) and the Ionosphere (charged electrical layer from ~50 – 1000km above the Earth’s surface) (Hofmann-Wellenhof et al, 2008).

The troposphere is usually ignored for point positioning applications and for several differential applications under the assumption that the atmospheric delay at both receivers is similar and will not affect positioning accuracy or initialisation. For static, high precision GNSS positioning, a range of models available in software can be selected as part of the processing.

The ionosphere has a larger effect than troposphere and is corrected for point positioning using the Klobuchar model (Klobuchar, 1986). This model accounts for around 50% of the bias and is sent to receiving devices as part of the navigation message. Smart phones incorporate this into their positioning.

For highest precision positioning, GNSS surveyors utilise the dual frequency observations to eliminate ionospheric effects during post processing. Most RTK applications simply ignore ionospheric effects over distances under 10km. For longer distances and real time applications, network RTK algorithms within CORS networks "map" atmospheric biases providing 10-20mm positions for any point within the CORS network (Janssen & Haasdyk, 2011).

Most of the above error sources do not affect GNSS positioning on a smart phone as single frequency point positioning is used.

## 5 FUTURE POSITIONING ACCURACY FROM SMART PHONES

At present, positioning accuracy from smart phones is poor and not suitable for cadastral surveying purposes. However a smart phone is an internet device and incorporating the clock and orbit products from the IGS to produce a PPP solution would improve positioning significantly. Similarly no smart phone currently uses an SBAS mode to improve positioning accuracy.

The European Galileo GNSS currently has four satellites in orbit. Galileo transmits a new frequency called E5. The "chipping rate" on the code of this signal is 10 times higher than that of the GPS code. This means that the precision with which a receiving device can measure the code is higher thereby improving the code ranging and, therefore, positioning accuracy (Roberts, 2011). At present, no smart phones are capable of measuring this E5 signal. There is some concern about the added power consumption required to measure the E5 code (Dempster & Rizos, 2009).

In order to enable differential positioning using codes, the smart phone would need to be equipped to receive data from a base station (most likely a CORS station) and to be able to combine and process this data internally in the device.

All of the above advances would only resolve decimetre precision in the device which would not satisfy SSI Reg 25(2) requiring 10mm + 50ppm. In order to achieve this precision, a smart phone would require a chipset that is able to track and process carrier phase measurements as well as receiving carrier phase measurements from a CORS network and an efficient initialisation algorithm to resolve the ambiguities. This would have significant implications on the power consumption of the device and the design of the internal antenna.

Perhaps the bulk of the computational load for initialisation could be performed in the "cloud" with client software on the phone used to display the results for a user. Todd Humphrey, keynote speaker at the recent US Institute of Navigation 2012 Conference, (Nashville, Sept 17-21) was quoted as predicting, "By 2020 mobile phones will have RTK capability providing cm-level accuracy" (Humphrey, 2012).

Even if all of these improvements were possible, the problem of how to locate the device on the ground or over the mark at better than 10mm remains. Indeed this is a consideration for current surveyors when centring a tripod over a mark. A centring error contributes to the precision of the survey.

The new SSI Reg 25(2) is also unique in that is states specifically, "…10mm + 50 ppm or better at a confidence interval of 95%." When purchasing surveying equipment, the technical specifications show the precision of an instrument or device at one standard deviation (1σ) of the mean or a 67% confidence interval. A 95% CI implies an observation lies within ± 2σ of the mean. The new regulation is therefore far tighter than the previous regulation, which was 10mm +15ppm @ 67% CI. The implications of this new regulation for using GNSS for cadastral surveys is that any line shorter than approximately 100 metres must be verified by another means.

The regulation prior to 2006 in NSW was 6mm + 30ppm at 1σ. This meant that any distance shorter than 120m had to be verified by electronic distance measurement (EDM) (Roberts, 2005). This tightening has implications for boundary definition for any cadastral survey using GNSS whether it be with a high precision survey grade instrument or a futuristic carrier phase enabled smartphone. For surveys in urban environments where the distance between neighbouring marks is short, this regulation precludes the use of GNSS. In rural areas, where distances between marks is larger, GNSS techniques can be better accommodated.

## 6 CONCLUSION

Much of this paper has been devoted to explaining the range of GNSS positioning modes in the context of smart phones. There has been a focus on positioning accuracy. It is concluded that from an accuracy perspective, that current smart phones are nowhere near suitable for boundary determination purposes. Even with a carrier phase enabled smart phone which can perform computations in the cloud, mitigate multipath and interact with a CORS network, the survey regulations preclude the use of GNSS over short distances.

However the internet connectivity of smartphones can be a huge advantage to cadastral surveyors in the field. Information available on the internet can be accessed in the field and enable surveyors to remain productive in the case where new, unanticipated data is required.

The numerous mapping applications can really assist the surveyor when searching for evidence in the field. The ability to take photographs and document various aspects of the survey can be of great benefit later in the office when making professional judgements on the location of boundaries.

GNSS enabled smartphones certainly offer the modern cadastral surveyor many more options to assist with boundary definition, but most certainly do not replace the current measurement techniques used and certainly not with the new NSW SSI regulations to which the professional surveyor must adhere.

Basiouka & Potsiou, (2012) present a strong argument in favour of crowd sourcing techniques in support of the cadastre. They argue that the time taken to register existing parcels in Greece is too long, too expensive and consequently only 6.4% of the country is registered on the Hellenic Cadastre. They present two practical experiments using volunteered geographical information aimed at simplifying the processes needed for a cadastral survey, and to reduce time and cost. A similar argument is advanced by Van Der Klugt (2012). He questions if accuracy equals quality and counters that if clients can get less accurate data quickly, then this is enough for many users.

Anecdotally in Australia we see a move away from land purchasers requiring a boundary identification survey from surveyors and instead purchasing insurance to protect their interests in the case that there is some problem with the position of the boundaries at a later stage.

Dasgupta (2012) contends that precise surveying will remain fundamental for boundary determination. However it is clear there is a trade-off between timely imprecise information and high quality but delayed information. Increasingly land administration authorities are considering these less precise forms of data to support spatial data infrastructures.

Is Neo-Cadastral Surveying on your Smart Phone Feasible? Not yet, but watch this space.

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