Accuracy in the Hands of the Workforce:

Portable GPS Devices Prove Central to Accurate Solutions

Executive Overview

The casual use of satellite-based positioning has proliferated, with GPS now readily available in mobile phones and cars. Most GPS receiver chips in such devices can achieve an accuracy of just two to three meters, which is far less accurate than professional-grade devices. Consumer-grade devices lack the ability to provide quality assurance details or metadata about position so that you can't be sure with confidence that the positions that you collected are correct. When lower-end accuracy is used for data collection, what also gets lost is the utility of high-accuracy position, and the kinds of insight that are revealed only at higher accuracies.

Businesses increasingly understand that spatial awareness of workers, assets and processes can lead to much greater efficiencies. But the best enterprise-wide information system can be sabotaged by data that is not accurate enough. The bottom line of 'garbage in, garbage out' is as relevant today as it was when the first database was invented. Poor positional accuracy, and in some cases wrong positions, degrade the utility of your systems, and can even result in costly errors.

Given the benefit of greater accuracy, the trend across the GIS and mapping arena is toward higher accuracy data collection. This began with aerial and satellite imagery as pixels the size of a meter squared rapidly improved to the 50 cm range. Similarly, we have high-speed LiDAR collection tools that capture large areas at 5 to 10 cm accuracy. We're now entering a realm where highly portable handheld devices can achieve accuracy that was once only possible with survey-grade tools.

The improved portable high-accuracy capability is potentially a game changer. It puts high precision into the hands of a greater percentage of the workforce, which can improve the quality of spatial information in an organization to unlock new efficiencies and insight.

Introduction

Among the positioning community, accuracy is a moving feast. There are plenty of applications where accuracies of a few kilometers have been deemed adequate, while there are others where a few millimeters are not accurate enough.

Historically, precise measurement required more care (so more time), required higher quality (so more expensive) instruments and led to the generation of more data (so bigger data sets). This last is not a trivial consideration, since the size of spatial data sets can multiply exponentially as more accurate recordings of position are taken. This in turn set off a new round of expenditure on hardware to store the data, and software to process and interpret it.

The exciting news is that this situation has changed. The latest range of equipment now available is incredibly accurate, and lower in price, more reliable and easy to use. On today's work sites, people with many different skill sets, not just surveyors, can be involved in collecting high resolution data. And, they often integrate it with other kinds of geospatial data to gain increased value.

The role of professional surveyors is increasingly centered on designing data collection methodologies, building databases and ensuring that the data that is being generated by the system is fit for use by the people who are going to use it.

This had led surveyors and other generators of spatial data to considerations of two closely related concepts: 'fitness for purpose' and 'return on investment' .

The concept of fitness for purpose supposes that, for any given spatial problem, an experienced professional can develop metrics that say: 'this problem can be solved with data that has these characteristics'. That may be a statement about accuracy. So for instance, an engineering surveyor considering the position of piles for a new bridge may find positions plus or minus 10 mm hard to live with. An asset manager, on the other hand, who is hunting for an existing sewer main with a backhoe, might think that any accuracy within the size of the bucket of the backhoe (say a meter) is good enough. And an environmental manager making an inventory of trees might think that plus or minus five meters is perfectly adequate.

But increasingly, the solution is more than accuracy alone, since accuracy is now so easy to achieve. Instead, the shift is toward adding value that leads to higher return on investment.

A data acquisition plan must be developed that balances costs against the potential uses of the data. Can the end users be clearly defined? In some cases, the answer will be obvious. In others, it will be less clear. A balance between accuracy, time and cost in relationship to value-added use provides important guidance. And when considering use, the growing trend is toward understanding and estimating the entire data delivery ecosystem — including storage and delivery.

This new approach ought to include a mechanism for introducing risk management related to the value of the data. How much will it cost me if the data is wrong? How much re-work will I have to do? What impact will accuracy have on staff productivity? How do we expect the data to perform in crisis situations where poor accuracy could mean loss of life?

A further consideration concerns the management of the data is whether data collected for one purpose can be used for others? Might collecting data at higher accuracy mean that it is fit for more than one purpose? If so, does this change how much I am prepared to pay for it?

New positioning technology is helping to solve parts of this puzzle, and will continue to do so in the future. Technology innovation is now providing improved accuracy and performance for lower prices, making the collection of higher accuracy positions a more attractive option for all applications, with significant productivity benefits across entire organizations.

The Role of Accuracy

The quality of the geospatial data starting point has great bearing on what can be done with the data and where it can be applied. Management strategies that include an understanding of individual applications, together with selection of the appropriate geospatial technology, will achieve greater effectiveness and efficiency across all operations.

Spatial data quality is directly related to the type of measurement equipment being used and the application for which the data was initially collected. The complexity and difficulty of using survey and measurement instruments for high-accuracy collection is being replaced with easy-to-use devices and interfaces that collect better positional accuracy at reduced price points.

A sound beginning strategy for determining the many factors related to position collection recognizes the 'accuracy - use connection'. Accuracy and precision are very important when integrating survey data with other kinds of geospatial data because they often form the lowest or baseline tier upon which all other geospatial workflows and data will build upon. Lower quality data may be sufficient to verify a position or mark a completed task to a location, but not to update or change the position of the asset, especially when the initial position was derived from a high-accuracy source.

The operational use of geospatial data across a city, region or utility often accesses a seamless database whose records are expected to be of the highest quality available. The close management and stewardship of accuracy within this database is an ongoing challenge where accuracy can be too easily degraded by poor field data collection practices, inferior equipment, non-standardized practices, and lack of oversight. Technology increasingly addresses these points of failure by reducing complexity and automating accuracy assurance processes.

The degree of data accuracy relates to how different data types can be combined and used with each other. Achieving multi-functional capability with the same system for multiple applications requires high-accuracy data, thus the accuracy to quality relationship is critical to realize maximum value from the data collection effort.

Innovations to Achieve High-Accuracy

Field data collection has benefitted greatly from the Global Positioning System (GPS) constellation of navigational and location satellites operated by the United States government. The term GPS is quickly being supplanted with the term Global Navigation Satellite System (GNSS) as other nations have joined in setting up their own 'sat nav' systems. Other initiatives include Russia (GLONASS), Europe (GALILEO), China (BEIDOU or Compass) and Japan (QZSS).

All GNSS work by measuring the distance between the satellites and the receiver. They do this by timing when the signals leave the satellite and when they are received at the receiver. For instance, the coarse-acquisition (C/A) code sent on the GPS sends a bit every 0.98 microseconds, so a receiver is accurate to 0.01 microsecond, which equates to about 3 metres. This is the best possible accuracy of a standard unaided receiver.

Field data collection handheld manufacturers have responded to these new constellations by creating receivers that can receive signals from more than one constellation. Using two or more constellations results in increased availability of satellite signals, improving accuracy and reliability, particularly in difficult environments such as inner city environments and under heavy vegetation.

Exclusive reliance on orbiting satellites for position has its limitations, since atmospheric conditions and surroundings can degrade positional accuracy. Ground-based efforts to improve accuracy use differential correction by processing signal errors collected at a known position or base station, then applying these corrections to individual operational GNSS receivers. This approach requires two receivers, the collection and or processing of errors and the transfer of these to the field receiver. Accuracy may be improved to submeter accuracy in many cases.

Another ground-based approach to improve positional accuracy is the real-time kinematic (RTK) surveying approach. Trimble's Virtual Reference Station (VRS™) service is an example of an RTK network that models corrections and differences in signals between many fixed base stations. As field devices move throughout the field site, modeled corrections are continually transferred to these receivers.

Obstructions of satellite signals effectively cast a shadow over the GNSS receiver, either degrading the satellite signal strength or completely blocking the signal and stopping it from being tracked at all. Trimble has a introduced a new technology to mitigate the effects of satellite shadow. Trimble Floodlight™ satellite shadow reduction technology approaches the problem of loss of GNSS productivity by increasing the sensitivity of the receiver to better perform with weak signals using barometer-based altitude measurements to reduce degraded signals and to replace missing signals during temporary outages and increasing the number of satellites in view by adding GLONASS support.

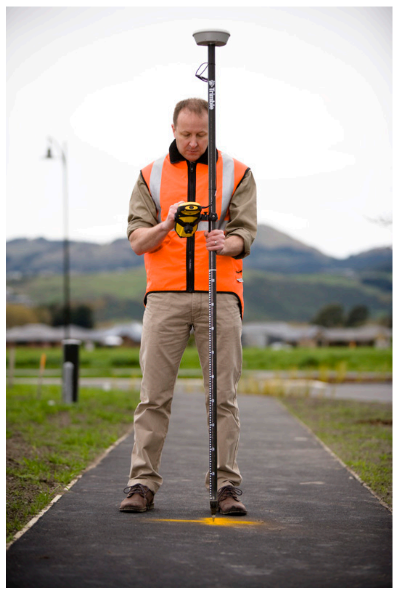
Many countries have created continually operating reference stations (CORS). These networks provide wide region correction data for use with high-accuracy GNSS field equipment.

Survey-grade, highly accurate receivers usually work by computing the phase of the radio frequency carrier emitted by the satellite. In these RTK systems, the distance between the base stations and the rovers is a function of the phase difference between the two antennas. As a result, the key issue in using differential corrections lies in being able to tell the difference between cycles of the carrier, or 'ambiguity resolution'. While all manufacturers are constrained by the physics of the situation to producing receivers that solve the same sort of problem in the same way, there are considerable differences in the software that is used for ambiguity resolution, which mean that some receivers work much better than others in a given situation.

Another consideration for optimal field work conditions is the use of mission planning software. Since navigation satellites are constantly moving in orbit, mission planning tools factor in the location of the satellites to determine the most suitable times for performing high-accuracy data collection in specific locations where the most satellites will be visible and trackable.

Accuracy Across Scales

Asset managers have an increasing number of position collection tools at their disposal. There is a continuum of technology, with associated increase in cost for more accurate tools with higher degrees of contextual information.



At the very low end, GPS receivers in mobile phones offer a data collection option with little accuracy and little means to collect any details other than position alone. On the high end, mobile LiDAR sensors collect a great deal of position information quickly with a high degree of accuracy. LiDAR collection provides near realism at high cost, with large volumes of data that have associated costs of data storage and the need to purchase software systems that can process the data.

Most asset managers' needs lie between these two extremes, with requirements varying depending on the scope and scale of work. Some will need to provide more accurate data for small areas while others seek to cover larger scale regions with better precision.

There are different price/performance ratios for different levels of accuracy as well as considerations for different scales of work. Many projects will require a hybrid approach that harness varying degrees of positional accuracy for their data collection applications. Increasingly, the use of a central repository for this information within a geographic information system (GIS) means that all the data collected will be used repeatedly by a great many users.

The handheld approach is the standard for field workers for its relatively low cost, high performance and adaptability. It can provide suitable navigation and positional accuracy needed while also supporting the extended geographic information system (GIS) needs.

The value of high-quality data increases when it's used for a variety of uses such as transportation, utilities, housing, construction, architecture and other infrastructure applications that apply their tools, craft and data atop this foundation. For example, an architect who wishes to present a high quality design needs high quality spatial data upon which to orient a new building, bridge or railway. Insurance professionals assessing risk factors for flood plains are interested not only in climate history, but 3D measurements of topography that help them to see and understand the relationship of buildings and other infrastructure in terms of flood potential.

In addition to accuracy, the data pedigree becomes important so that the multiple users of the data have the ability to see how the data was collected and can ascertain its fitness for their purpose. The ability to record metadata on the positions that are collected, including a photo for context and the device and techniques that were deployed to record the position, give a needed trust for the multiple use cases of the data.

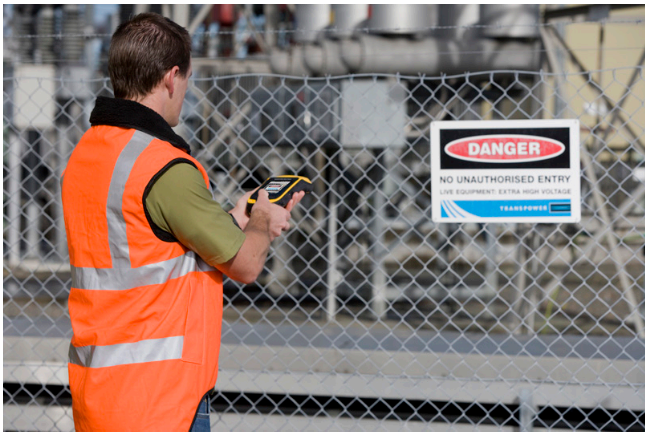
When you come back to make a decision on a position in five years time, it's important to have a sense of the quality of that position based on the details that you recorded at the point of collection. Elements of trust regarding data are particularly needed in a data sharing environment in a large organization with lots of assets and multiple departments accessing those assets, such as a large utility or a municipality. Another important use for metadata is the common need to merge datasets, particularly in our world of constant mergers and acquisitions, where data compatibility and usability is dependent on its integrity.

Data at the Point of Exploration

Mobile position platforms, such as handheld GNSS receivers, provide data and exploration tools to the point of contact and interaction. The handheld device is very relevant in a hybrid position collection world, and is even superior in some cases, because it provides attribute information in the hands of the professionals doing the work.

There remains a superiority of the human as a sensor for details that couldn't be collected in any other way. Mobile LiDAR is a forward-facing technology that can't see behind signs and obstructions. Aerial imagery has a greater degree of precision, but can't read the fine print of serial numbers and discern asset types at high resolution. The human sensor at the point of contact is ideal for this type of work, and the handheld GNSS receiver fills a much-needed gap in data collection. The addition of digital cameras within the collection devices, such as the 5 megapixel camera in Trimble's GeoExplorer® 6000 Series GNSS handheld, adds to the human sensor benefit by capturing close-up images as a visual reinforcement of data pedigree.

In light of the need for higher accuracy, handheld solutions are evolving to capture high-accuracy positions through a variety of different means. The new Trimble GeoExplorer 6000 series GeoXH™ handheld takes a next step for collecting and maintaining high-accuracy GNSS data in the field, with real-time decimeter (10 cm / 4 inch) to subfoot (< 30 cm) accuracy, and integrated Internet connectivity options that allow for two-way connections between the office and the field.



Part of the issue of outfitting field workers with the highest-accuracy device possible is one of productivity. When you're sending a work crew out, you want to be sure that they are collecting data wherever they are. GNSS yield and productivity in tough environments such as in urban canyons and under tree canopy are addressed through the latest advancements with access to multiple satellite constellations, and other approaches.

The added signals aid those workers in an urban setting, where it isn't as difficult to revisit a site, but where speed of collection is imperative due to safety and an expected pace of work. Workers in remote areas appreciate the added signals and speed to lock on a position, because it's not as easy to go back.

This new level of accuracy in a lower-cost and accessible device means that workflows are more streamlined without the need for a separate trip to the work site by a surveyor. Some surveying workflows are actually detrimental for reliable positions, because there is often a multi-day lag between when things are staked and worked on or when they can collect data from newly dug underground infrastructure. For instance, if the job is to dig a trench to get to buried utilities, the workers can find the trench with a highly accurate device, dig the trench, place and record the position of the necessary operation, and fill the trench back in without having to leave it open for some time until the surveyor can visit. The worker is thus empowered to deal with the full scope of work while still maintaining an accurate and trusted position that can be relied upon in the future.

With a focus on the efficiency of the workforce, you enable a whole new flexibility while also safeguarding the quality and accuracy of the position data about your assets. By placing high-accuracy into the hands of workers doing the work, there are no multi-day lags between position collection, and reliable high-accuracy position is tied much more closely with the work.

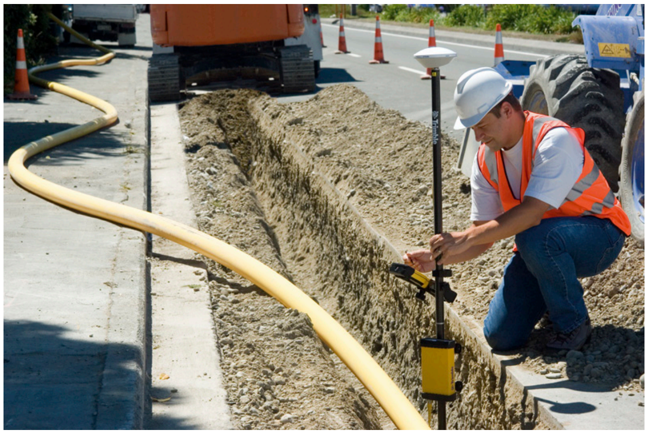
These latest-generation handheld GNSS receivers are at the nexus of all other collection means, as it provides a means to visualize data that has already been collected, to collect new data against established positions, and also to collect high-accuracy positions and attributes where no other position baseline has been set.

High-Accuracy Mandate

The U.S. Rail Safety Improvement Act of 2008 that passed shortly after the deadly commuter rail accident in Los Angeles mandates a whole new level of positional accuracy in order to improve rail transportation automation. The federal rail safety program for Positive Train Control (PTC) on the Class 1 freight rails in North America mandates that each train be tracked, and that no trains may travel on a track without its location being known.

There are significant technological hurdles for the railways to address before compliance with PTC becomes mandatory in 2015. The requirements of the system are to prevent an over-speed through automated engine controls, to avoid signal violations, to protect track crews, to prevent movement through a switch even if it is in the wrong position, and to know the location of every rail asset within 2.2 meters of horizontal accuracy and 0.8 meters vertical.

Achieving the location requirement is a difficult task given that the accuracy requirement is below today's mapping-grade GPS, and the PTC requirement specifies that the location of all assets must be maintained to 100% accuracy at all times. To meet these requirements, the four major Class 1 North American rail companies have banded together to specify guidelines for an interoperable system, and each is actively surveying all of their assets.



There are hurdles here due to an old hierarchical structure that has divided operations by asset class, with departments for signals, track, locomotives, etc. Each asset operation has been responsible for recording their own details, including the location of the asset, and the accuracy of those positions vary widely.

Surveying the entire tracks of each railroad to assay all assets is a considerable project, given the miles of track, and the by-and-large non-technically savvy crew. CSX, one of the major East coast operators, has devised a plan that involves a mobile handheld GPS data collection and a custom program that was created jointly by Trimble and Esri. The solution was built with both Esri ArcPad and Trimble GPS Pathfinder® Software Developer Kit, and contains rigid processing rules, relying on differential correction to achieve the necessary accuracy.

The railroads are using a breadth of different geospatial tools in order to meet this mandate. On the survey side are mobile solutions, such as described above, as well as LiDAR data collection via a high rail vehicle that travels all along their tracks and a helicopter that collects both aerial LiDAR and aerial imagery. LiDAR provides the detail and accuracy to verify field data collection, and is also a good enough accuracy for cataloging a large number of the assets. However, they're also ground verifying all assets, because there are some things that the sensors can't pick up, like the DOT number on a road crossing. Similarly, there are other details on signage that can't be read and recorded other than by field crews.

The hybrid approach is a necessity due to these and other limitations. The LiDAR collects precision at high speeds, but can be obscured, and won't give a 360-degree view. Driving the high rail on the track with video and imagery provides a means to record speed signs and mile posts and other ground attribution that you can't get from aerial. Field crews are also needed to verify position and cross check the items collected.

This aggressive mandate of Positive Train Control is speeding along many geospatial advancements due to the challenges that it poses. All the tools and technology to make such a system are available, yet the mandate pushes the boundaries in terms of both the scale and accuracy that are required, as well as the communication and coordination between multiple competing companies that must share their databases in real time in order to meet the safety requirement.

The handheld component of this project is at the center of all data integration, because field-verified information becomes the most trusted source, referencing and relying on the high precision of the automated solutions.

Return on High-Accuracy Investment

E.ON, a Germany-based energy company that is pursuing a global presence in both renewable and non-renewable power generation runs a 110kV high-voltage grid ranging from Schleswig-Holstein to Bavaria with both above and below-ground cables. The company also runs communication cables for the remote control of transformer stations. Over the years, the company has mapped their cable networks, but the procedure and communication has not been consistent when changes in the cable networks were made.

Lack of knowledge about changes has often led to cable disturbances, because the location of telecommunication cables were not recorded or communicated. It has also been difficult to fix these disturbances or cable movements without adequate location details to direct repair crews. The lack of information added cost and time to maintenance and also involved safety and risk management concerns.

During the last quarter of 2009, E.ON decided to pursue a handheld GNSS solution based upon the accessible price of Trimble GeoXH handhelds versus survey equipment or contract surveyors. The company purchased virtual reference stations (VRS) service in addition in order to reach sub-meter accuracy. The E.ON requirement is to locate cable lines within 30- 40 cm, the width of a shovel of a small excavator. The needed accuracy is provided through the handhelds and this service, avoiding the need to hire external surveying companies.

Using GeoXH handhelds, the field personnel can collect data for cables and cable re-allocations, coupling locations, subsurface splitters, junctions and other important infrastructure information. This technology enables the incremental improvement of existing documentation, for recording changes and improvements to the network, and for communicating infrastructure plans.

With these easy-to-use devices in the vehicle, workers can examine and collect the differences between the plan and the reality. When a disturbance in the line occurs, the changes to the lines are recorded, noted and saved after the repair work is completed.

Only one accurate map of the network is needed, and the ability to have correct coordinates on hand during regular work saves time and the expense of external contractors. Having high-accuracy information at hand also leads to improved safety and the risk of damages to cables during field work considerably reduced or prevented.

With improved geospatial information, it is now also possible to present the coordinates for work digitally, without the need for paper plans, communicating the locations of E.ON cable lines via email or Google Earth, saving time.

Future Potential

With advancements in high-accuracy in a portable form factor at a low cost, handhelds will continue to be central to data accuracy improvements. Pervasive access to spatial data provides information within the context of the work and without the need for added specialists. The portable device is easily accessible, allowing field workers front-line input into position quality as well as the data and workflows tied to their day-to-day work.

There's an efficiency with an integrated handheld device that has a camera, bar code scanner, and various custom applications. Trying to integrate position with photos and other attribute data in a non-integrated device has proven time consuming and difficult, particularly in the context of fieldwork or for automated collection scenarios such as mobile LiDAR where the van is rolling by at 95 kilometers per hour (60 miles per hour).

There is also the potential for the development of cloud services that integrate large volumes of actionable geospatial data over the Internet. The concept of a public land survey register (cadastre) at a country scale with all power, gas, telecommunication and utility lines and cables available to all suppliers is within reach. This would lead to a simplification and time-reduction when dealing with construction inquiries and projects, with the data available only to those that need access, and specific to the work at hand.

The use of GNSS field devices is a solid element in building out these kinds of 'digital infrastructure' that would connect wider groups of people together, result in greater collaboration and improve upon communication while reducing costs.

Technology is filling in the gaps in data accuracy without requiring highly specialized users to come do this type of work, while also empowering users that aren't experienced surveyors or map experts. The trend toward more automated high-accuracy data collection will continue on pace with improvements in systems to share and collaborate around work that has a strong spatial component.

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