STORM DAMAGE

INTEGRATION
Wildfire risk analyzed & managed in real time

STANDARDS
Promoting CAD/GIS data interoperability

DEAD RECKONING
Estimating a position when GPS isn’t available
Dead reckoning has been used by aviators, marine vessels and surveyors as a navigation solution for centuries. This process of estimating a position by advancing a known position using course, speed, time and distance to be traveled can be a valuable tool when GPS is an issue. But, alone it is prone to error. As the saying goes “You’re dead, if you don’t reckon right”.

Enter technology. Terrestrial Mobile LiDAR Scanning (TMLS) where advancements in GPS satellite navigation and inertial navigation systems provide accurate positioning it is still on the basis of the surveyor’s dead reckoning. Dead reckoning implies estimation and inaccuracy; however the concept is a sound process when coupled with well control TMLS technology.

Dead reckoning, using the roll, pitch and yaw data from the IMU (inertial measurement unit), aids traditional GPS navigation via intelligent algorithms based on a vehicle’s distance and directional changes during GPS signal interruption. When there is no GPS, the system relies on the IMU and DMI (distance measuring instrument) for short periods of time.

TMLS in challenging environments like inside a tunnel or an urban canyon where GPS reception is lost, or even worse—environments where GNSS signals are intermittent like overhead forestry canopies can be very challenging. Some of the issues include:

- Resulting trajectory lines can be compromised adding to the post processing time
- GPS antennas require intervisibility with GPS satellites
- Reflected GPS signals can create multi-path effects
“When you are talking PDOP (Positional Dilution of Precision) the only thing worse than no GPS is ‘hit and miss’ GPS,” said Michael Frecks, PLS and President/CEO of Terrametrix. “Of course, PDOP is improving with the introduction of more satellites and through the use of GLONASS but the key to GPS carry-through, like the old surveyor days of dead reckoning is within the closely coupled GPS and IMU.”

Dr. Graham Hunter, President of 3D Laser Mapping and the developer of the StreetMapper 360 technology said, “What is interesting about TLMS technology is that accuracy can be higher in tunnels with no GPS than in urban areas with intermittent GNSS.”

GNSS multipath can cause large errors that are difficult to solve but significant reduction in accuracy arises when there is no GNSS signal when passing under a bridge or past a tall building. “In 2008, on a project in downtown Los Angeles we had very long periods of intermittent GPS signal and tremendous GNSS multipath due to the urban canyon environment,” explained Frecks. “This led to significant errors in the post processed trajectory line and hence the final scan data accuracy.” Direct Inertial Aiding (DIA) technology has been developed to improve the accuracy in these conditions.

DIA works by configuring the IMU to send real-time positional information to the GNSS receiver. This is dead reckoning in real-time, where the accuracy over a short distance is high but there is a lot of drift in the long term. Without this information, every time the GNSS receiver has a signal interruption, the receiver loses track of its location (as we are in a moving vehicle). When the signals return (for example, after we come out from under a bridge), it takes typically 6 to 10 seconds for the GNSS receiver to calculate its current location. With DIA, the receiver knows...
its approximate current location and the solution to calculate its current location from GNSS signals is simpler so it takes about 1 second. This means that we gain 5 to 9 seconds of good quality GNSS positional data for every signal outage and this adds up to be a significant improvement for a typical urban survey.

In a tunnel survey, there are no GNSS signals for long periods, up to 15 minutes for example. In this situation, dead reckoning with the IMU data is used for a long period time and there will be significant drift in the data. “The smart stuff is that the characteristics of this drift are well defined and the errors can be modeled. With the right processing workflow and some control points, this can allow highly accurate results”, said Dr. Hunter.

Terrametrix uses the precision on board navigation of the StreetMapper technology which includes a Global Navigation Satellite System (GNSS) receiver, a fiber optic gyro-based Inertial Measurement Unit (IMU) and the latest Direct Inertial Aiding (DIA) to assist in areas of poor or non-existent GPS reception. StreetMapper 360 and StreetMapper Portable are the only systems on the market to offer highly accurate navigation, in areas of poor or non-existent GNSS.

The StreetMapper technology was used in two areas of concern for the South East Pennsylvania Transit Authority (SEPTA): a four tube 8,800’ tunnel and a portion of the Airport Line under canopy from I-95 underpasses to the airport rail terminal. The purpose was to supplement areas where the airborne acquisition, performed by Robinson Arial Surveys, Inc, located in Hackettstown, NJ was not able to obtain coverage and to supplement traditional survey which proved too dangerous and timely along the 100 mile corridor route.

KS Engineering out of Philadelphia, PA set control which was established by conventional and GPS survey methods and placed on the state plane coordinate system. Track coordination of limited and restricted access required that scan data had to be acquired during the limited Night Owl schedule (1 am to 5 am) during a maximum of ten days. The use of existing infrastructure to mobilize the StreetMapper system also prevented possible conflict with Philadelphia International Airport. Terrametrix completed the acquisition in four days because of the speed of acquisition. Due to train schedules we were only allowed track time on one tube of the tunnel per night. The collection took less than one hour per night.

All told the “dead reckoning” solution provided by the DIA IMU and GPS within the StreetMapper’s high performance navigation system carried the data through almost 14 minutes in a GPS blackout environment. The final results after adjustment to control were an RMS error of 0.04’

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“Having an accurate system like StreetMapper coupled with the surveying knowledge of how to approach the project in a critical environment like tunnels and streetscapes is a powerful combination,” said Frecks a land...
surveyor for 35 years. Frecks is known for pushing the envelope with scanning applications from static to mobile. “You don’t know what this technology can do until you push it beyond its limits. The work flow processes created exceptional results on this project.”

The StreetMapper processing work flow had been simulated and tested in a real environment for over a year. Completion of 3 miles of tunnel data showed the power of the StreetMapper system.

“The tunnel tests have shown that StreetMapper can achieve better than 35cm positional error in a 2000m tunnel that takes about 2 minutes to drive. For a 500m tunnel, this shows that in these cases a positional error of better than 6 cm can be expected and this is all without control points which will further improve the accuracy” according to Dr. Graham Hunter, the developer of the StreetMapper system.

The continued work in updated processes of tunnel scanning was seen with the successful completion of the SEPTA project containing 4 tracks and catenary wires. The project was part of a Positive Train Control (PTC) project and included a clash detection requirement as well.

The American Railway Engineering and Maintenance-of-Way Association describes Positive Train Control (PCT) as having four primary characteristics: train separation or collision avoidance, line speed enforcement, temporary speed restrictions, rail worker wayside safety.

Prior to the installation of PTC the Southeastern Pennsylvania Transportation Authority (SEPTA) required a baseline survey of its commuter rail system to:

- Establish baselines for mainline and regional lines
- Evaluate SEPTA records and establish baseline equalities
- Determine ruling grades, track charts and geometry car data
- Map mile and half mile markers

The benefits of using mobile mapping systems, such as StreetMapper, for transportation projects are numerous. Speed and safety of data acquisition are high on the list as is the sheer volume of data that is captured in a single pass. A highly accurate virtual reconstruction of the environment can be created allowing for documentation of all visible features and elimination of field revisits. Whether by highway or by rail terrestrial mobile LiDAR scanning (TMLS) was the clear cut choice by SEPTA for their limited GPS high traffic areas.

Cyn René Whitfield is a nationally published journalist who has been involved in marketing for land surveying and 3D laser scanning documentation for the past 28 years. She is currently the Business Development Coordinator for Terrametrix LLC (www.terrametrix3d.com), Omaha, Neb., and can be reached at cwhitfield@terrametrix3d.com.