VRS Systems for Improved Efficiencies in Port Operations

Mariners were one of the first public groups to adopt GPS in its early days Ã nearly twenty years ago. The next leap forward in the acceptance and widespread use of GPS was Differential GPS (DGPS). DGPS was driven by demand from the offshore marine survey industry, which wanted reliable, round-the-clock, sub-metre accuracy. Accuracy being infectious, the marine survey industry adopted the centimetre-accurate Real Time Kinematic (RTK) GPS surveying that land surveyors had pioneered.

The latest development in precision surveying accuracy and reliability is enhanced RTK using the Virtual Reference Station (VRS) system. This paper explains VRS application in the port environment.

Port Environment - The Issues

All shipping ports world-wide share one main objective: to ensure that ships move into and out of port safely and without delay. An efficient port, therefore, is one where tolerances for under-keel clearance are minimised without compromising safety. With the draft of ships increasing as post-Panamax ships capable of carrying 4,100 TEU containers come into service, it is now more crucial than ever that ports operate as efficiently as possible. Improving the efficiency of port operations involves several issues. These are discussed below. Port operators can optimise under-keel tolerance by dredging. However, operators considering dredging face a number of restrictions, including environmental concerns and costs. The environmental concerns of a community may demand minimal or no dredging; usually a compromise is reached whereby dredging must be targeted and controlled.

In order to reduce both the environmental impact and costs port operators must dredge accurately and the best way to achieve the accuracy they need is through a high-precision positioning system. The standard of safety in most ports across the world is high, and this high standard must be maintained even under the pressure of ever-increasing demands for fast turnaround times for vessels and passengers. The safe transit of vessels covers approach channels, turning basins and berths. Safe berth docking and piloting systems ensure that vessels and expensive infrastructure, such as wharves, are protected. Some ports cover a large area and have long approach channels (see Figure 1). For example, the Houston Ship Channel is 100 km (56 miles) long and carries seven hundred vessels a day. Large ports are particularly demanding of port operations and services. They require:

- Precise vertical data, to centimetre accuracy, over the port and port approaches
- Cost control; precise dredging is required as over-dredge is seldom paid for. This means precise positioning to centimetre level
- Controlled piloting and berthing so that minimal damage occurs to infrastructure and ships. Pilots require detailed knowledge of position, heading and closing velocities
- 24/7 system reliability
- The move to one-person survey and piloting parties using lightweight systems

Positioning Systems in Use Today

The majority of positioning systems in use for waterways today are satellite-based.

DGPS systems - Since the mid-1990s many of the worldâ€™s port approaches and treacherous waterways have been covered by DGPS using International Association of Lighthouse Authorities (IALA) radio beacons. These systems have greatly improved safety at sea as ship captains can now know with confidence and to meter accuracy their shipâ€™s position, as well as its speed over ground. For commercial shipping, DGPS is required for electronic charting systems. For port operations, DGPS is used for dredging and surveying, and for services such as asset tracking (for example, containers).

WAAS (EGNOS) Systems - In the USA and Europe, the continents are covered by a satellite-based augmentation service called WAAS (in the USA) or EGNOS (in Europe). These systems are currently under trial on waterways. They are not yet officially operational, nor are they optimised for coastal marine areas. In some coastal areas the required satellite is at a low elevation angle and the correction signal may be blocked by surrounding buildings, vegetation or vessels.

RTK GPS Systems - Real-Time Kine-matic (RTK) GPS systems are used extensively for both capital and maintenance works related to ports. Typically, an RTK system is installed by a single organisation such as a survey or construction company. The system consists of one reference station with a radio link operating at a 10-15 km range. This allows multiple roving applications, such as those in construction, hydrographic and land surveying. The horizontal error budget at the rover is typically 10 mm + 1 ppm. The error budget increases when the rover is further from the reference station and when there are atmospheric disturbances. The table below compares the accuracy of DGPS and RTK GPS.

The table shows that RTK GPS offers ship captains significantly more accuracy than DGPS. However, the next generation in RTK implementation, the Virtual Reference Station (VRS) system, surpasses even the quality control and accuracy of RTK, at the same time as lowering operating costs for its users.

What Is a VRS?

A Trimble VRS is an integrated system of GPS hardware, software and communications links that uses data from a network of fixed reference stations to model errors throughout a region. The model generates â€˜virtualâ€™ reference stations near a surveying location, which then relay a localised set of standard format correction messages to a roving receiver. All users in the region are provided with centimetre accuracy and improved performance and reliability.

How VRS Works
Fixed reference stations continually transmit GPS observation data to a Trimble VRS central server. The data is sent to the central server over a modem, frame relay, the Internet, or other communication link.
In the example in Figure 2, five reference stations, all spaced 50 km apart, are sending data to the central server. At the central server the network processor performs integrity checks on all GPS observations. The processor checks the data from each station, rejecting outlying data and correcting cycle slips.
Once the integrity of the data is checked, the central server computes ionospheric, tropospheric and ephemeris errors by analysing double-difference observations. The effects of these errors on any rover working within the network can be modelled, allowing systematic errors for RTK to be significantly reduced. The effects of the errors are shown in the easting, northing and elevation of collected points. Figure 3 shows the effects of errors on a point that is 32 km from the nearest reference station.
The central server receives the position of a rover working in the network and performs a geometric displacement to the given location. It interpolates and applies corrections for the ephemeris, tropospheric and ionospheric errors and generates a â€˜virtual reference stationâ€™ for that specific rover. It then produces a set of standard format correction messages as if they were coming from the virtual station and transmits these to the server. While a VRS is designed and installed for its centimetre-accuracy service, the correction signals can also be used by DGPS receivers for sub-meter accuracy. This is beneficial whenever a port does not have IALA DGPS coverage, and when lower-cost GPS receivers are used for positioning applications.

The Applications
RTK and a VRS can be used for numerous applications at port:

- Hydrographic surveying of the shipping channels, turning basins and berths
- Precise dredging and construction Ã piling and coastal protection. See Figure 4
- Use of survey equipment for both marine and land survey operations, such as land reclamation surveys
- Under-keel clearance. Figure 5 shows the main variables acting on under-keel clearance, which are a function of time and position
- Berth docking and piloting systems
- Precision tracking for position and speed to feed into the Vessel Tracking System (VTS)
- A positioning system infrastructure for automation and tracking of land-based goods handling facilities, such as container yard management

The Efficiencies and Conclusion
Employing RTK and a VRS at a port lowers the cost of surveying and positioning, increases productivity and improves the accuracy of 3D positioning. Because a VRS is an online survey infrastructure, it provides numerous cost and timesaving benefits. By saving users time, a VRS RTK system enables them to spend more time on profitable surveying activities:

- Users save time through not setting up or moving a physical reference station
- Because a physical receiver is not required, users are spared the expense of the purchase
- Port operators save on staffing costs. Fewer crew are required; some RTK systems can be operated by just one person
- Expensive dredging rework is eliminated as the VRS enables an accurate initial dredge

A VRS and RTK system is a precise and accurate system for vertical measurements over a large site. For this reason, it is the ideal positioning system for dredging and under-keel clearance. VRS accuracy is achieved through the following:

- In a VRS network common control is already established, so that errors are not propagated from inaccurate control points. All data is quality assured
- Because all users share the same infrastructure, the number of survey errors arising between users is minimised. The dredging contractor and client share the same, quality-controlled positioning network for operations
- The whole port can use one survey datum, which is continually monitored for reliability and accuracy
- Long-range RTK/VRS systems ensure that accuracy is not degraded by distance from the reference station
- Tide is measured at the shipâ€™s position, not at the tide gauge some distance away

RTK can measure heave and draft and serve as a tide gauge, making unnecessary separate hardware sensors. GPS can also replace the gyrocompass on construction barges and survey vessels. See Figure 6.
A VRS and RTK system also provides the following benefits for port operations:

- Ships can carry more tonnage and operate in a wider window around the tides
- Ships can travel more safely and at higher speeds
- Precise positioning data is available at the critical time for piloting, docking, survey and construction
- Positioning data is provided in all weather, day and night
- The system provides more precision for extended ranges over the port for survey and dredging (the precise vertical height is determined at the vesselâ€™s location)
- Other items of equipment, such as multiple tide gauges, are not required
- Dredging can be carried out with only minimal impact on the environment