Do you know where your containers really are? Savcor reveals all

Kari Rintanen, Technology Manager, Savcor One Oy, Vantaa, Finland

The problem of 'lost' containers

Searching for containers during vessel load is costly. Quay cranes typically average 20-30 moves/hour, while theoretical their efficiency could be even 30 per cent higher. The difference is the result of cranes having to wait for containers. Containers need to be loaded in a vessel in a certain order according to the load plan, thus waiting for one container may halt the loading operation of the whole crane. And finally, if the container is not retrieved in a reasonable time, the container may have to be left behind.

How are containers 'lost'? The most obvious reason is that the container is misplaced when taking it to yard storage area. Without a GPS system, the driver may place the container in a wrong row or bay, hit the 'OK' key, and the TOS system will receive incorrect information. When someone then wants to retrieve the container from the location where it should be according to the TOS, the container is not found.

Snowball effect and 'floating' boxes

If that was just an isolated problem of a single container, it would not affect average performance too much. But the first error easily creates more errors and causes a 'snowball' effect: when someone wants to bring another container to the container slot that is already secretly occupied, he/she needs to place the container in another location. If this deviation from plan is not reported (i.e. they just hit the 'OK' key as always), one misplaced container leads to other misplaced containers.

Another source of misplaced containers is shuffle moves. It is often required to 'dig' out containers because they are located under other containers. During this process the top containers have to be moved. Many TOS systems do not give instructions for shuffle moves and if GPS is not used, the driver needs to key in the new locations manually. This is a slow and error-prone process if there are many containers to be moved. There is a strong temptation not to report shuffle moves at all: it is not at all unusual to see 'floating' containers on TOS screens!

How do you keep yard inventory correct?

There are two simple rules to avoid inventory errors:

Rule 1: Report all container operations automatically

The key principle to ensure that all container moves are reported to the TOS correctly is to make reporting automatic each time the twist-locks of the container handling machine are operated. Savcor ContPos system will continuously monitor the operation of twist-locks, and also, when there are no job instructions for the

Figure 1. Automatic container position detection system (PDS) not only avoids TOS inventory errors, but also gives the advantage that the driver is not interrupted during the work cycle to operate a keyboard. The straddle driver can thus 'keep the left hand on the steering wheel and the right hand on the spreader controls.'

driver, determine the container slot when twist-locks are opened or closed and report the slot name to your TOS system.

The other great advantage of automatic reporting is that the driver is not interrupted during the work cycle to operate a keyboard. A straddle driver can thus 'keep the left hand on the steering wheel and the right hand on the spreader controls.' (Figure 1).

Report also unplanned moves

The TOS planning principles vary, with some systems giving great freedom to the driver to decide where to put containers, compared to the more disciplined systems that accurately plan even the shuffle moves. Both methods have their advantages, but in either case, it is important that the actual place position of the container is reported, even if it is not the planned position. Since keying in container slot codes is slow and error-prone, the only way to ensure error-free operation is to make the process automatic.

Driver guidance – 'traffic light' indicator

The advanced TOS systems plan the container storage locations carefully, anticipating future moves of the containers. It is thus important to guide the driver to correctly execute this plan. The Savcor ContPos system includes simple audio-visual indicators for the driver to verify the correct container position, even before the driver places down the container. In the simplest form this guidance is a 'traffic light' indicator where the light goes to green when the driver arrives to the right container slot. And if the driver decides, on purpose, to deviate from the TOS instruction, the actual drop position is reported to the TOS by ContPos.

Rule 2: Equip all vehicles with GPS

The problem in the past, especially with RTG-based container handling systems, has been that even though the RTGs were equipped with GPS, the smaller machines operating the same stacks did not have GPS. This has been historically due to the difficulty of positioning smaller machines (e.g. reach stackers) with traditional GPS. As a result, even if the RTGs maintained an accurate record of all container moves, the 'wild' reach stackers may have done secret moves and the TOS inventory was thus corrupted.

This problem is now history. With the new developments in GPS and gyro technology, Savcor RAAS GPS, have made it possible to implement a reliable container positioning system for reach stackers, mast lift trucks and other smaller vehicles (see Figure 3).

The need for improved GPS: Savcor RAAS

Straddle carriers, reach stackers and other small container handling machines are problematic for GPS because in port environments they often lose visibility with satellites.

GPS recovery time is important

Even a short signal break with satellites is critical, since standard GPS-receivers with sub-meter/RTK accuracy require a long time after the signal break until they reach again their specified accuracy (e.g. RTK GPS 2–5 minutes). The fundamental problem of straddle carriers, for example, is that during each work cycle, the carrier will pass under the crane, and the GPS-receiver will lose its satellite signals. A reach stacker, on the other hand, suffers from frequent GPS-signal shadows because the GPS antenna is often lower than the containers. As a result, in straddle carrier and reach stacker operations, GPS receivers with long initialisation times can not be used.

GPS 'accuracy' is its typical performance, not the worst case scenario

Analysing GPS performance based on vendor specifications is often difficult. The accuracies specified are only statistical mean values (CEP, σ or RMS), which are not worst case figures. Since the GPS-errors are normally distributed random variables, no GPS-vendor specifies a maximum error for their receivers. To give an example, a GPS-receiver of one metre 'accuracy' (CEP) will produce only 50 per cent of the measurements inside a disk of a radius of one metre, and in reality five per cent of the measurements have an error of more than two metres!

Figure 2 shows a typical scatter diagram of 'sub-meter' DGPS measurement in open sky conditions. Roughly two per cent of the measurements scatter outside of the right container slot and

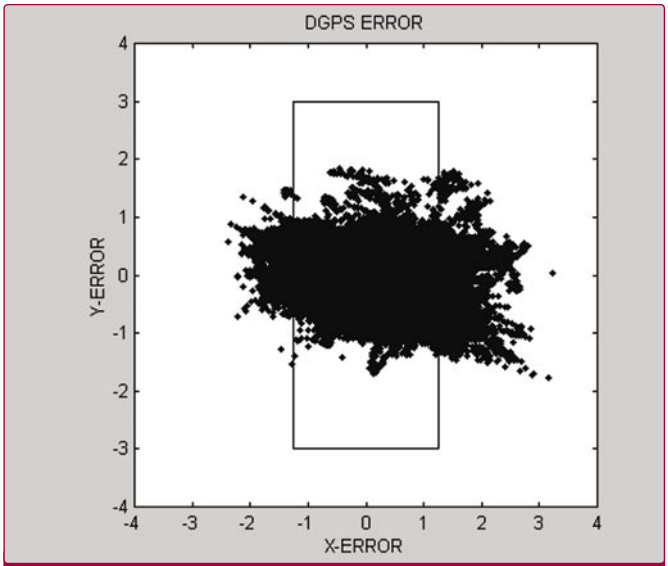

Figure 2. The performance of a standard sub-meter DGPS receiver in open sky conditions (recorded data over 24 hours). GPS-antenna has been placed in the middle of container slot. It can be seen that the measurements scatter outside of the container slot and the performance is thus not satisfactory for container positioning. Sub-meter specification only indicates that the average error is less than one metre. Data recorded 2 May 2006, 100 seconds of carrier phase smoothing used.

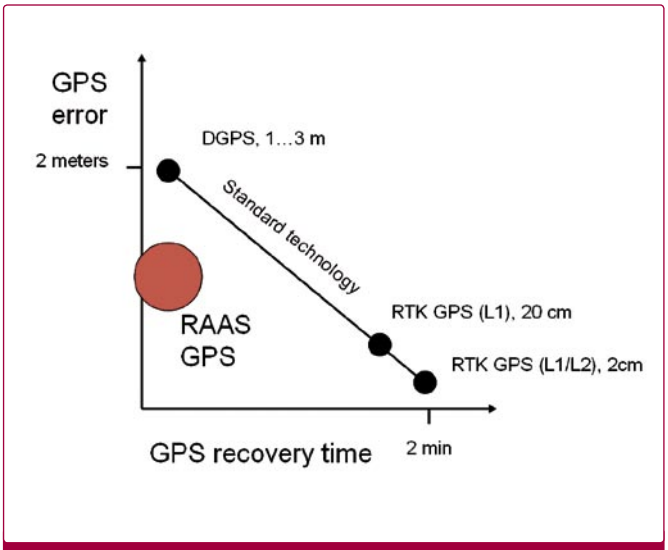

Figure 3. When analysing GPS receiver performance, it is important to consider two aspects at the same time: the accuracy and the speed (recovery time) of measurement. Some receivers do have excellent accuracy (RTK, +/- 2 cm), but need two to five minutes initialisation time to recover after a signal break, (e.g. when passing under the Quay Crane). A standard DGPS receiver, on the other hand, is fast but lacks the needed accuracy (see Figure 2). RAAS GPS algorithm has been developed to provide the right combination of speed and accuracy for container positioning applications.

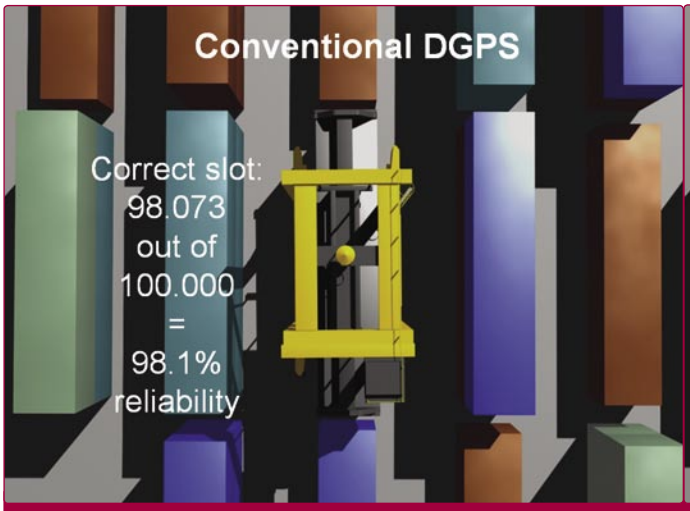

Figure 4a. Standard sub-meter DGPS receiver makes 2-5 per cent container slot identification errors in typical straddle carrier container port operation, depending on satellite visibility. Test data of 100,000 measurements has been collected during 24 hours in open sky conditions (i.e. all satellites visible). Two per cent of the measurements are closer to the left and right containers than the correct middle container (1.5 metre gap between container rows).

Figure 4b.The exact same test data processed by RAAS GPS algorithm. RAAS will process the raw data obtained from the satellites directly and combines this with yard lay-out information. There are no container slot identification errors in 100,000 measurement samples (i.e. better than 99.99 per cent reliability). The reliability of container slot identification has thus improved by a factor of 100 when compared to conventional DGPS.

will cause container slot identification error. In practical port conditions where the satellite signals are blocked and reflected (multi-path), two per cent to five per cent errors would be generated.

Why don't we use cm-accurate GPS (RTK)?

Real Time Kinematic (RTK) GPS is a special technology giving measurement accuracies around two centimetres. This technology uses dual-frequency GPS measurements and solves the integer number of full carrier wave cycles between the GPS antenna and satellites.

The accuracy provided by this technology would be more than enough for container positioning, but the initialisation time needed to solve the unknown integer parameters is too long, two to five minutes. For example, each time a straddle carrier passes under the quay crane, the GPS position is lost/disturbed and a new initialisation sequence is started. GPS position is thus not recovered when a container is placed down.

Accuracy versus speed

When analysing GPS-receivers, it is important to consider two aspects at the same time: the accuracy of the computed position and the time needed to compute that position (recovery time) (Figure 3). There are receivers that do have very good accuracy (RTK), but they are too slow to recover. There are also fast receivers (DGPS), but they seem to lack the needed accuracy/reliability (Figure 2). This problem was the starting point for Savcor to develop more specific GPS-algorithms for container positioning.

Savcor RAAS GPS solution

A GPS receiver collects data from each individual GPS-satellite every millisecond. There are normally 6-12 satellites visible, so the amount of data is massive. The major fault of standard GPS-systems is that all this data is reduced into a few parameters (latitude, longitude, height) and given to end-users in the form of a standard GPS-position message. The end-user then tries to match this reduced data to the containers. Most of the relevant data is lost in the process. Savcor RAAS avoids this data loss by using all satellites signals directly to identify each container slot, combining in total 100-2,000 pieces of data from GPS satellites. The reliability of each satellite signal is carefully analysed based on the knowledge of the satellite positions, conflicts between the satellites, and possible multi-path situations.

Reliability improved by 100

The field tests show that this technology will improve the container slot identification reliability by a factor of 100 when compared to sub-meter DGPS. Sub-meter DGPS can only provide a container slot accuracy of roughly 98 per cent (PDOP < 4, no multipath). RAAS GPS can maintain a reliability of better than 99.99 per cent in the same conditions (Figure 4a and 4b). The highly improved reliability is possible because RAAS GPS is using the satellites raw signals directly and combines yard layout information in GPS-calculation.

ABOUT THE AUTHOR

Mr Kari Rintanen is the Technology Manager of Savcor One, a company specialising in GPS-based positioning for container ports. He received his M.Sc (Tech.) degree in control engineering and Lic. Sc (Tech.) degree in automation from the Helsinki University of Technology. Before moving into the industry, he did several years' research work for Technical Research Centre of Finland, participating in various research projects funded by European Union and work machine industry (ESPRIT, Brite-Euram). His primary research topics were vehicle automation, outdoor navigation technologies, GPS and inertial sensors. Kari Rintanen is inventor of several patents related to GPS and inertial navigation.

Before joining Savcor One as the Technology Manager in 2000, he worked for several years as a Research Manager for Kalmar Industries, developing container handling vehicle automation such as for straddle carriers and RTGs, and also as a Research Manager for Nokia Telecommunications, developing new wide-band radio communication technologies.

ABOUT THE COMPANY

Savcor One has a mission to improve the efficiency of container terminals material handling processes by utilising real-time position information and wireless communications technology.

Savcor One is committed to help container terminal operators to improve the efficiency and quality of their operations – day in, day out. An efficient and high quality operation means happy customers, which in the long run are the ones that can keep a terminal profitable.

Savcor One's business is to ensure that the container yard inventory is 100 per cent accurate; eliminate lost containers and the high direct and consequential cost they cause; minimise empty driving, working together with TOS; maximise TOS performance by monitoring what really takes place in the yard; and improve CHE efficiency by bringing speed and precision to their operation.

The first DGPS/multi-sensor/RF systems were installed in late 1990s, and today more than 30 container terminals around the world utilise the technology developed by Savcor One.

ENQUIRIES

Savcor One
Mestarintie 17
FIN-01730 Vantaa
Finland

Tel: +358-9-2902 110
Fax: +358-9-2902 1130
Website: www.savcor.com