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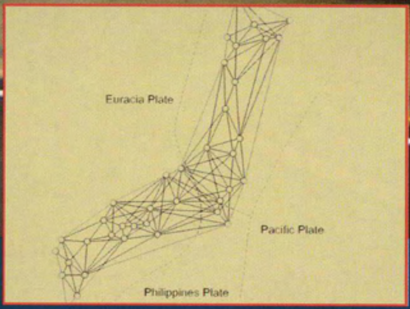
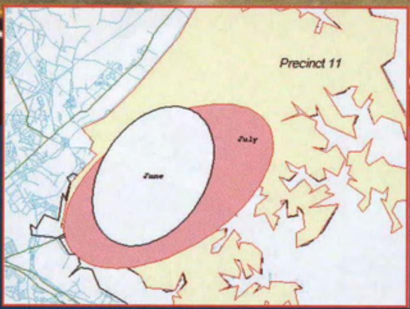
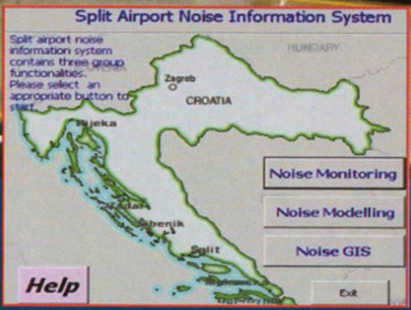


Earthquake Prediction Using GPS



GIS and Crime: CrimeStat II



GIS in Airport Noise Management

a GITC publication

Ultrahigh-precision GPS Positioning and Navigation

Gantry Crane Auto-steering

Machine control requires instantaneous positioning with accuracy better than a few centimetres and extremely high reliability. Conventional technologies such as induction-loops, transponders and Charge-Coupled Device (CCD) cameras have been successfully employed for gantry crane auto-steering systems. However, for reasons of reliability and economic efficiency these are being replaced by GPS-based technology such as RTK (Real-Time Kinematic). The authors describe a GPS RTK-based auto-steering system, which they helped to develop. The system consists of three major components: GPS hardware (dual-frequency receivers and antennas), RTK processors (industrial panel PCs and RTK software) and an IEEE 108.11b-compatible 2.4 GHz wireless local area network (WLAN).

By Dr Donghyun (Don) Kim and Dr Richard B. Langley, University of New Brunswick, Canada

The gantry crane auto-steering system aims at improving container-handling productivity and operational safety at a busy port container terminal (Figure 1). The main task of the system is to keep a Rubber-Tyre Gantry Crane (RTGC) on track and so prevent accidents like hitting containers and other cranes. The track is a line mark, or alternatively an electrical guide wire in the container yard. Identifying the line mark and calculating corresponding deviations in the front and rear axles of an RTGC are essential for keeping the crane on track.

Figure 1, A rubber-tyre gantry crane; width 23m, height 21m

Auto-steering System

The large size of an RTGC makes it difficult manually to control the crane. Furthermore, manual operation is rather risky because the crane moves over relatively long distances (typically 500 metres) whilst its path must be kept straight in quite narrow spaces. To steer the crane automatically a number of guidance sensors have been developed which enable the crane to run precisely along a straight line. The crane operator determines speed, and a computer or some other controller steers the crane. A Programmable Logic Controller (PLC) is usually central to an automated process control system. By continuously processing the signals from input devices, the PLC determines which actions the output devices need to execute. In an RTGC auto-steering system, calculated deviations of the front and rear wheels are fed into the PLC so that it can adjust the speed of the left and right wheels to keep the crane on track. Operators turn the wheels only to make ninety-degree changes and when the crane is stationary at special, low-friction turning pads.

Conventional Systems

Earlier RTGC auto-steering systems made use of:

- Guide wire (e.g., induction-loop) installed underground. A mental factors such as surface reflection and line mark condition. Common drawbacks of all conventional approaches are that:

- The sensors can detect only line marks within a limited effective range, say several decimetres. If the crane exceeds this range there is no automatic way to get the crane back on track
- They are based on physical line marks in the container yard and hence are highly dependent on environmental factors

tions from track of the front wheels and the other monitors the rear wheels (Figure 3). Both orientation and location of the crane can thus be precisely computed. The GPS component also includes one RTK processor unit for the base station and one for each crane. The base unit of the WLAN is installed at the base station, while each crane has an individual station adapter. To improve the performance of WLAN communication, additional access points may be installed in the container yard if necessary.

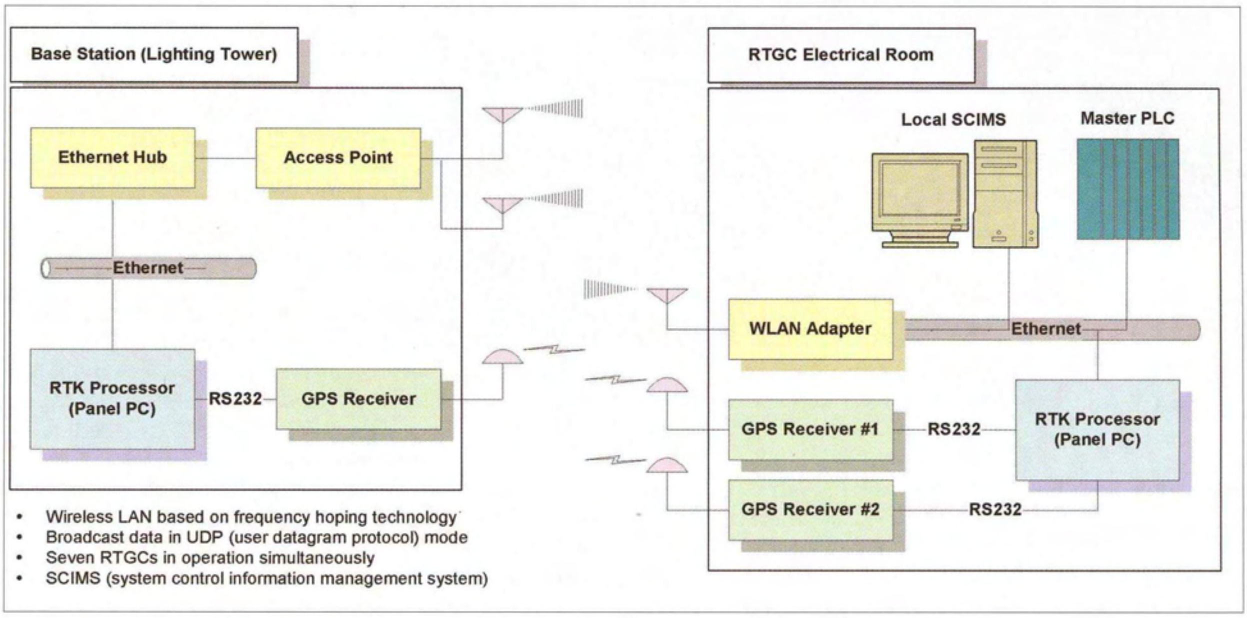


Figure 2, Block diagram of the RTGC auto-steering system based on GPS RTK technology

sensor mounted on the crane determined the location of the wire. This system is not much influenced by dirt, concrete, ice, snow and so on

- Transponders installed in regularly spaced holes (e.g. 5 metres) along the track. When the crane passes over a transponder the crane antenna receives its code. The location of the transponder relative to the antenna is measured using an inductance coil
- Newer systems use CCD cameras mounted on the crane. These observe painted lines on the ground. Using digital image processing technology, the line mark is identified and deviations computed

Guide wires and transponders have to be carefully installed to avoid the influence of metal within and very near the track. Furthermore, installation under the ground is laborious and damage may occur when the ground moves. Replacement requires much time-consuming work. CCD camera systems are highly dependent on environ-

The basic shortcoming – the use of physical marks – can be avoided by using an electronic map with virtual guide lines and a GPS receiver to precisely locate the RTGC on the map. The control system can then compare the GPS position of the crane with the virtual lines and steer the crane accordingly.

GPS RTK-based System

The GPS RTK-based auto-steering system we helped to develop consists of three major components (Figure 2):

- GPS hardware (dual-frequency receivers and antennas)
- RTK processors (industrial panel PCs and RTK software)
- IEEE 108.11b compatible 2.4 GHz (Wi-Fi) wireless local area network (WLAN) base unit (Ethernet hub and access point) and station adapters

One GPS unit is positioned at the base station and two on each crane; one monitors the devia-

Performance Parameters

The most significant challenge is that a fully operational and safe RTGC auto-steering system requires GPS RTK software with high levels of accuracy, integrity, continuity, availability and computational efficiency. The horizontal accuracy should be 1.5 centimetres at a 95 per cent confidence level. This enables the integration of GPS with the auto-steering control system and is almost the highest real-time accuracy level currently attainable from GPS. For the system to be safe, the GPS RTK software must include a self-diagnosis routine able to detect failures when the positioning accuracy degrades. For this, two parameters should be rigorously considered:

- Integrity, specifying the risk associated with equipment latency or design failure

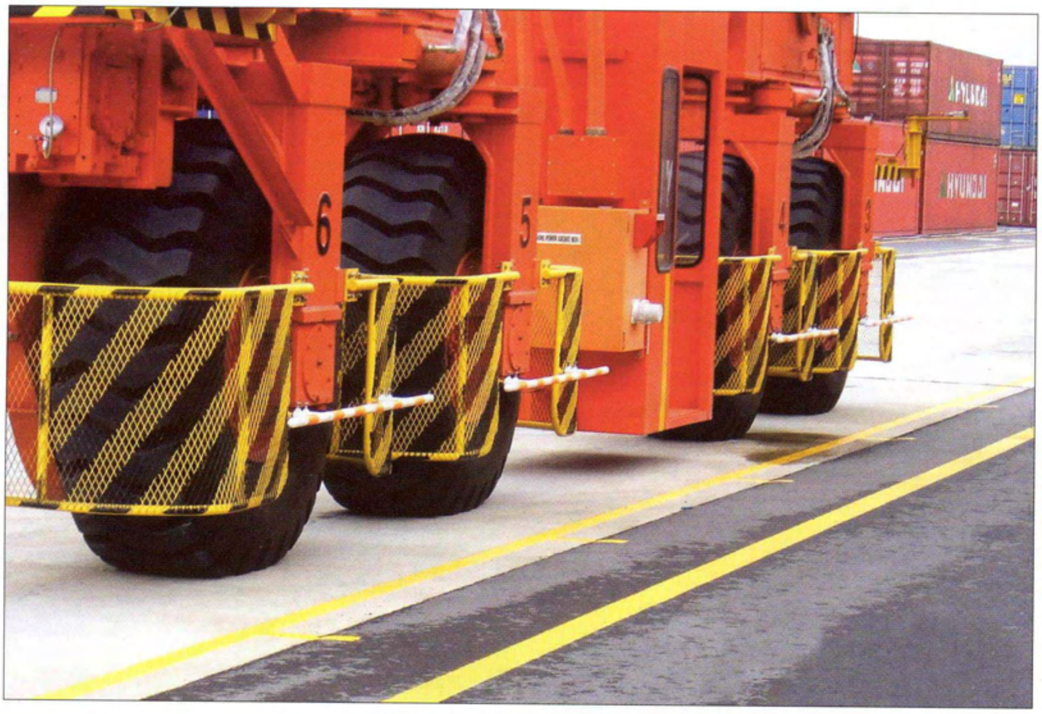


Figure 3, An RTGC's front and rear wheels moving along a concrete lane (corresponding to a virtual strip about 70 centimetres in width and 500 metres in length)

- Continuity, specifying the risk associated with unscheduled function interruptions

In general, the availability parameter depends on the visible GPS constellation. This parameter affects GPS data processing software design because a minimum number of satellites commonly observed by both base and remote receivers should be available all day. Since the system works in real-time and, furthermore, must be capable of measuring the off-track deviation of an RTGC with an update interval of less than 150 milliseconds, data processing speed needs to be fast enough to handle observations obtained at a data rate of 10Hz. In this case, the latency of data communication and the computational efficiency of GPS data processing software are crucial. It is important to keep the system latency as short as possible to minimise auto-steering response time. A longer response time results in larger wheel deviations.

Ultrahigh-performance GPS RTK

To enable an RTGC to operate in automatic mode, the University of New Brunswick (UNB) has developed ultrahigh-performance GPS RTK software for gantry crane auto-steering. The UNB RTK system currently determines the position of the crane every one tenth of a second, which is commensurate with the dual-frequency data rate. The accuracy is better than 2 centimetres with extremely high reliability. The kernel of the system involves the UNB OMEGA (Optimal Method for Estimating GPS Ambiguities) ambiguity search engine and quality control algorithms. Two subsidiary tools – an optimal inter-frequency carrier-phase linear combination of the L1 and L2 measurements and receiver system noise estimation routine – support the system, to attain ultrahigh performance GPS positioning and navigation.

Test Run

After setting up the hardware and software, the PLC and GPS RTK software were tuned on-site to determine system parameter values. System tuning allowed the PLC to control the speed of each wheel to keep the crane on a track. Moving the crane at different speeds, the behaviour of the system was monitored. An example showing dynamics induced by typical crane operations, for example auto-steering and container lifting, is illustrated in Figure 4. The sinusoidal pattern of wheel deviation is typical in auto-steering mode. Deviations of the GPS antennas on the crane (and, correspondingly, those of the front and rear wheels of an RTGC) from the virtual lines were computed in real-time and fed into the PLC, enabling it to adjust the speed of the front and rear wheels.

Acknowledgements

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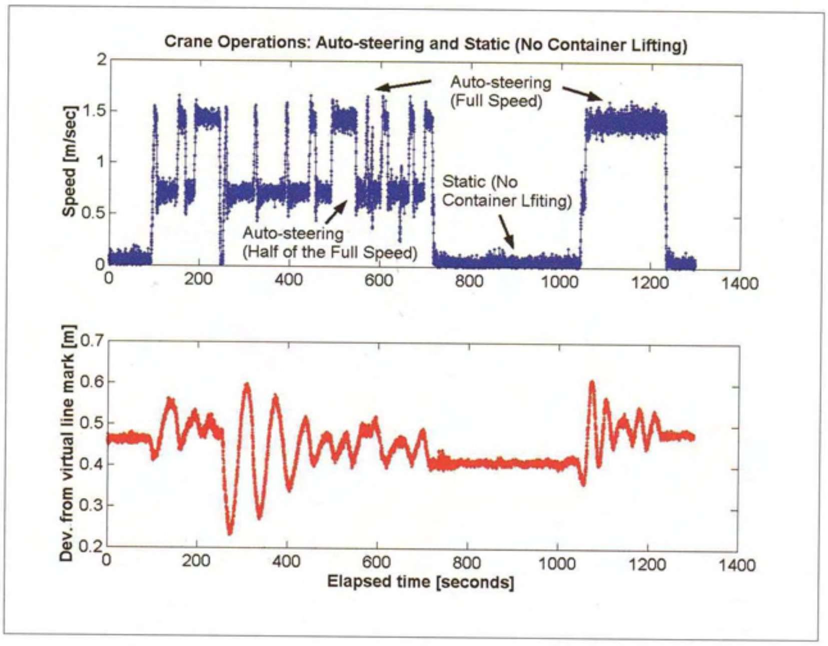

Figure 4, Crane dynamics during an auto-steering test run; top shows speed, bottom shows deviation

1999-2001. Other research was carried out under contract in 2002. The support of Seoho Electric Co. is acknowledged.

Further Reading

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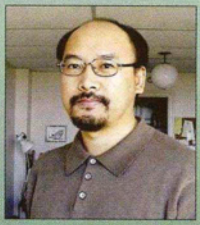
- Kim, D., R. B. Langley, J. Kim and S. Kim (2003). 'A gantry crane auto-steering system based on GPS RTK technology'. The European Navigation Conference, GNSS 2003, Graz, Austria, 22-25 April, at press.◆

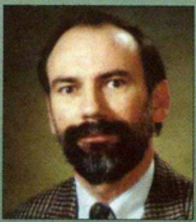
Biography of the Authors

Both authors are with the University of New Brunswick (UNB).

Dr Donghyun Kim, research associate in the Department of Geodesy and Geomatics Engineering of UNB, developed the UNB RTK software for a gantry crane auto-steering system. He has a BSc, MS and PhD in geomatics from Seoul National University. Involved in GPS research since 1991, his current research interest includes ultrahigh-performance RTK positioning.



Dr Donghyun Kim



Prof. Richard Langley

Prof. Richard Langley has been teaching and conducting research at UNB since 1981. He has a BSc in applied physics from the University of Waterloo and a PhD in experimental space science from York University, Toronto. He is a co-author of the Guide to GPS Positioning and columnist and contributing editor on the magazine GPS World. Current research interests include the study of atmospheric effects on wide-area augmentation systems, adaptation of techniques for space-borne GPS and the development of GPS-based systems for machine control and deformation monitoring

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