Inverted RTK system and its applications in Japan

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Abstract

The Real Time Kinematic (RTK) technique is the most productive and accurate GPS positioning method today, as it can be determinate position within few centimeters instantly. This method is widely used for applications such as surveying, structure monitoring and machine guidance etc. In order to perform RTK processing for large scale systems (i.e. precise vehicle monitoring with many rovers), many expensive RTK receivers and same number of bi-directional communication units have to be installed to collect observation data communicate with the reference site and monitor its RTK solutions. Moreover, if applications require remote control or apply sensing instruments, we have to install computers at each rover. To limit expense and complexity of system management with a large number of rovers, we have developed server based RTK processing platform to share RTK function for all rovers. The system can be process many GPS stations with a single personal computer. we have also developed a specialized dual frequency GPS receiver unit without on-board RTK processing capability to reduce receiver cost in order to demonstrate the advantage of our server based RTK platform. This paper describes the concept of our server based RTK platform and specialized GPS receiver unit with existing applications in Japan.

Keywords: RTK, Real Time Kinematic, Inverted, Reverse, Server, Client, Monitoring, Survey, Machine Guidance

1. Introduction

Many different GPS positioning methods were developed for precise positioning for dynamic applications for a variety of applications. The most popular method is Differential technique (DGPS). There are many applications that using this method such as navigation, resource management and mapping. It can be use simple receiver where the correction messages are broadcasted by beacon etc., but accuracy is around 1 meter when using ordinary GPS receiver.

RTK technique is most accurate real time positioning method today, it can determine positions within a few centimeters instantly. Thus this method is used for many applications such as survey, structure monitoring and machine guidance etc., In order to perform the RTK processing, it is necessary to setup a GPS receiver at the reference point with known precise coordinates, and transmit its observations data to mobile GPS receiver (so called rover). Moreover, the RTK calculation is usually performed at the rover site receiver by using transmitted observation data observed at reference point.

In the case of integration for large-scale monitoring system, many rovers need to know their positions accurately Many expensive RTK receivers and same number of communication units are needed. Moreover remote control or remote sensing instruments require installation of additional computers at each rover.

We have developed a client-server based RTK platform to avoid increasing expense and complexity of system management for systems with many rovers. We have released inverted RTK software named “SurvStation” that shares RTK function for all rovers, it can process many of GPS receivers data with single personal computer.

Moreover we have also released specialized dual frequency GPS receiver unit named “NetSurv” without RTK processing firmware to reduce receiver cost in order to demonstrate the advantages of our concept “Network GPS Survey”. Of course, we can use other dual frequency receivers if it is required.

This paper describes the concept of our client-server RTK platform and specialized GPS receiver unit, and explains some current applications of our system in Japan.

2. Client-Server based RTK platform

2.1 Software description

There are several inverted RTK systems are available but our system has fully integrated hardware and software for efficient operation and complete control from the server site.

SurvStation has four major components as shown as Table 1.

Table 1. Components of SurvStation.

Administrator	Administrator is a control module to manage GPS receivers and its characteristics (Reference or Rover), receiver and antenna type, reference coordinates, and data format. Administrator accepts user demand by command that is executed from provided API to change and modify configurations, processing and message exchanges between server processes and rovers.
Data Hub	Data Hub is conductor between server and rovers to communicate observation data (translate, compress, uncompress, buffering), exchange results, messages, and control commands. Data Hub is perform under TCP-IP conditions

Process	Process is RTK core module through use of "on-the-fly" (OTF) ambiguity resolution algorithms. This is Independent tasks that user can be execute and design baseline combination by API via Administrator.
Application	Application is user-interfacing module to accept and respond API command to manage system, control and manage NetSurvs, and make data stream to trace positions of rovers to user process by packet based inter communication.

The most important function in SurvStation is the portion of RTK analysis. We have integrated real time GPS data processing engine "RTNet" that jointly developed with GPS Solutions Inc. (Boulder, CO, USA). RTNet has several options to process GPS measurements for purpose of applications.

The main characteristics of the RTNet summarized as shown as Table 2.

Table 2. Characteristics of RTNet.

Designed for processing of GPS networks with the highest possible accuracy. Besides the careful modeling of all effects that may influence the GPS measurements an important feature of the RTNet model is the correct handling of the measurement dependencies.
Works with the full variance-covariance matrices and not only with their baseline-related parts.
Primarily designed for real-time applications (however, post-processing is possible, too). In order to achieve high numerical stability of the estimation process a square-root filter is used instead of a simple Kalman filter.
Estimate a large number of parameter types. In addition to the ambiguities and station coordinates the list of parameter types includes the receiver and satellite clock corrections, parameters that characterize the ionospheric and tropospheric biases etc.
Process data in network mode or in PPP mode in real-time or post processing.
RTK on-the-fly ambiguity resolution capability for dynamic applications.
In addition to its original main purpose (precise network deformation monitoring) RTNet is capable to estimate DGPS corrections and generate virtual reference station (VRS) data and area correction parameters (FKP) corrections for the network region.

SurvStation uses RTNet in RTK mode for dynamic application such as vehicle monitoring, but it can also be used in deformation monitoring mode for low-dynamic applications such as landslide and structure monitoring.

2.2 Hardware description

NetSurv is a specialized dual frequency GPS receiver unit that operates in the environment of SurvStation. There are three major models NetSurv1000, NetSurv2000 and NetSurv3000, that are produced for several applications.

NetSurv1000 is designed to demonstrate the concept. This unit consists of a WindowsCE based small computer, a dual frequency GPS board and programmable interfaces. We have installed this series unit to several precise vehicle-monitoring applications like a container yard control. (Figure 1).

Figure 1. NetSurv1000 and NetSurv1000L receivers.

NetSurv2000 is designed for mobile uses such as Field Surveyors. This receiver consists of an iTron-based microprocessor, dual frequency GPS board, serial port, and internal modem to connect to a mobile phone. Moreover, compact flash memory slot has installed to capture GPS observation data to perform post process static and kinematic survey. (Figure 2).

Figure 2. NetSurv2000 receiver and antenna.

NetSurv3000 is a brand new receiver for the Field Surveyor. There are three models according to work survey styles as Network RTK, Post process static and kinematic survey and ordinary RTK with a wireless communication unit. Also it can use most of network communication card to communicate SurvStation server system. (Figure 3)

Figure 3. NetSurv3000 receiver, antenna and controller.

3. Applications

3.1 Tsunami detection buoy system

The GPS Tsunami detection buoy System consists of an offshore buoy and an onshore station. The GPS antenna is equipped at the top of the buoy floating on the sea. The observed 2Hz GPS raw measurement data at the buoy is transmitted to the station using a radio system. The station also has a GPS instrument as a reference and SurvStation compute the precise position of the buoy and forwards it to the web server for real-time monitoring of the change of sea-surface via VPN（Virtual Private Network）technology. Therefore, anyone can watch the sea surface in real time through the web page.

Long term experiment of Tsunami detection buoy system was conducted by Earthquake Research Institute in University of Tokyo and Hitachi Zosen Corporation to have applied about two years to proven the accuracy and the stability in operation, and its successfully ended.

Brief system schematic and actual buoy in ocean are shown as Figure 4.

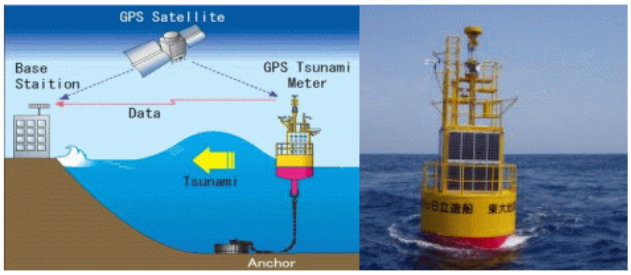

Figure 4. Systems schematic and actual buoy in the ocean.

The following Figure 5. is a result at the experiment on ocean was shown. Influence of the Tsunami by the Peru earthquake was detected clearly and the results were in agreement with the tide gauge on shore.

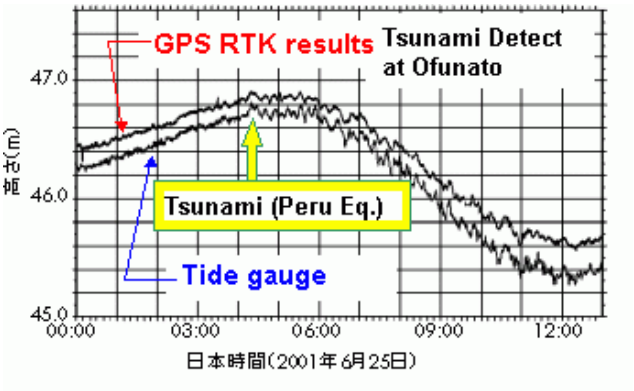

Figure 5. Result of Tsunami detection buoy.

3.2 Container yard management system

We have integrated precise location monitoring of large-size transfer cranes, container carriers, large-size reach stackers and special large-size forklift trucks using SurvStation and NetSurv into container yard management system. This system enables users to grasp the present locations of containers on carrying in real time, to improve the efficiencies of directing carriers and the inventory management of container yards and the cargo handling scheduling.

The following Figure 6. shows the container yard where SurvStation and NetSurv are installed, Figure 7. provides an overview of SurvStation and NetSurv integrated into the total management system.

Figure 6. Container yard.

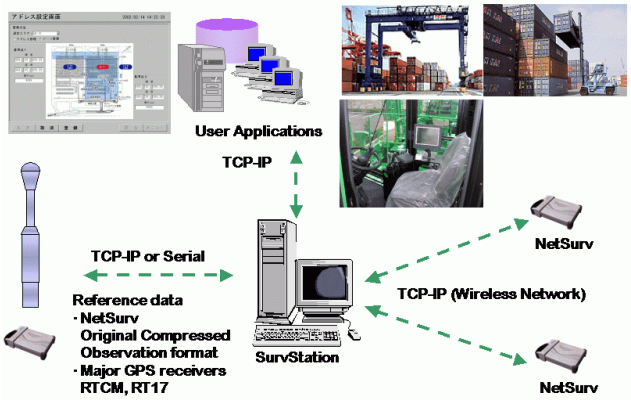

Figure 7. Overview of SurvStation and NetSurv integrated into container yard management system.

3.3 Navigation aiding system for Dry-docking of vessel

Dry docking of vessel requires sensitive control of tugboats by the dock master. We have developed a dock master aiding system that navigates vessels safety and efficiently to dry dock. (Figure 8)

Figure 8. Dry docking of vessel.

Two (2) GPS receivers are set along the center line of the vessel (Figure 9). The positions are processed precisely, and merged to be displayed on the PDA screen of the dock master. It is a positional management support system that can display the distance and direction relative to the target, and manage the dry docking. Figure 10 shows PDA screen to navigate vessel to desired position.

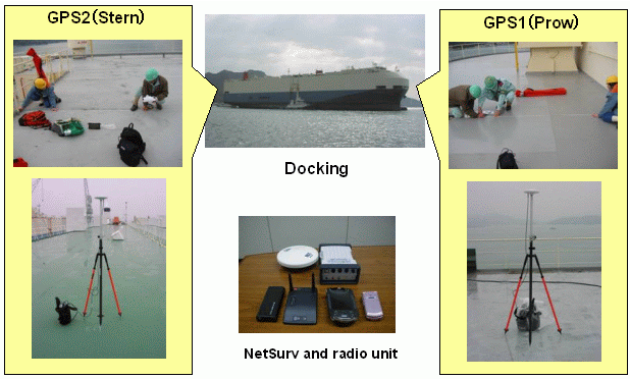

Figure 9. GPS setting on the vessel.

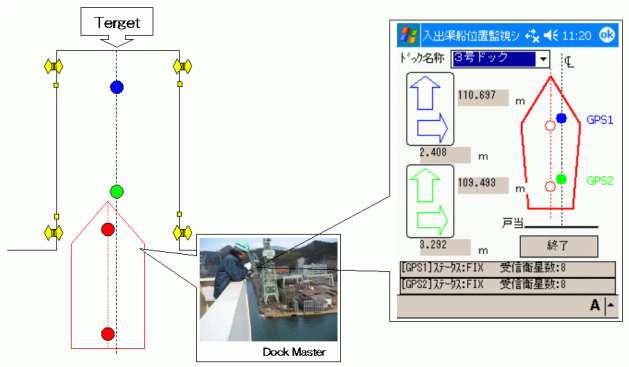

Figure 10. Navigation screen.

3.4 ASP based RTK processing service for surveyor

This is our biggest and most challenging application using client-server RTK platform to produce high performance RTK survey solutions in all over Japan using the 1300 stations nation wide GPS network operated by the Geographical Survey Institute of Japan.

To reduce GPS receiver cost to perform RTK survey, we can provide NetSurv receiver units, but they should be used with SurvStation to process RTK, It is not realistic in the case of small number of rover such as survey, they will not buy server package because expense become larger than just buy ordinary RTK receiver. In order to carry out efficient RTK with a small number of rovers or even a single rover (i.e. far a small surveying company), we developed the server system that shares the RTK processing function of SurvStation and serves it with reference data that provided by Nippon GPS Data Service Corporation. Users can also be apply their NetSurv as a reference observation site if required. Figure 11 is an overview of eSurv ASP system diagram.

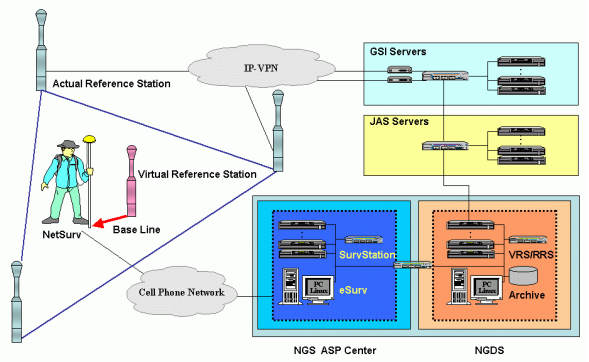

Figure 11. eSurv ASP system diagram.

By using one NetSurv receiver unit and eSurv ASP service, highly precise RTK processing is realized all over Japan. Typical survey styles using NetSurv receiver as shown in Figure 12 and eSurv server machines as shown in Figure 13.

Figure 12. Typical Survey scenery with NetSurv.

Figure 13. eSurv server machines in ASP center..

Most important and valuable things are we can service improved RTK solution anytime, this mean that ordinary RTK receiver should upgrade their firmware to improve solutions without any change to receivers, also we can realize secure data management to network operation organization because client-server RTK does not need to send reference data to outside.

3. Conclusion

We have developed client-server RTK platform to realize cost effective RTK solutions for application that needed many rovers, With the release this platform, the systems offers advantages not available elsewhere. We are now working to realize more attractive things with server-client scheme.

Acknowledgement

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