실시간 동적 GPS측위와 음향측심기 결합에 의한 해저수심측량에 관한 연구

A Study on the Coast Topography using Real-Time Kinematics GPS and Echo Sounder

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요 지

실시간 동적 GPS 측위를 이용한 해저수심측량은 GPS 수신기가 이동중인 상태에서 신호단절 없이 연속적인 수심측정이 가능하며 등수심도와 등고선 제작에 정확한 위치를 결정할 수 있고, 음향측심기는 발사파와 수신파의 도달시간을 측정하여 수심을 관측할 수 있기 때문에 실시간으로 정확한 3차원 측량이 가능하다. 본 논문에서는 해안지역에 대한 지형 분석을 하기 위하여 기준점에 대한 정지관측을 실시하여 좌표변환계수를 산출하고, 이로부터 실시간 동적 GPS 측량과 음향측심기를 이용하여 해운대 해수욕장과 해안을 관측하였다. 1:1,200 축척의 수치지도에서 추출한 수치표고모델에서의 체적은 97953.9 m^3이며, 실시간 동적 GPS와 음향측심기를 이용하여 추출한 수치표고모델에서의 체적은 95994.9 m^3로 나타났다. 이는 수치지도에서의 체적과 측량결과의 체적이 단지 2.0%정도로 나타나 실시간 동적 GPS와 음향측심기의 결합에 의한 해저수심측량이 매우 성공적임을 알 수 있었다.

1. Introduction

Although GPS surveying with code measurement shows excellent performance in navigation or GIS data acquisition, the accuracy level is not in millimeters (mm) but in several meters (m). Therefore, the RTK GPS surveying using carrier phase should be used in the area requiring higher accuracy such as construction, dredging, ocean surveying, seismological observation, and the taking off and landing of aircrafts.

In dredging and sounding surveys, it is necessary to measure the height of the water surface above a known level. The traditional method of measuring the height of the water surface above the datum is to establish water level sensors at one or more fixed locations in the shore. These sensors record the water levels at pre-defined interval. Then, the water level at a given time at the vessel location is interpolated from these records. For bathymetic survey, a precise three- dimensional vector is measured from the RTK GPS antenna of the reference station to the remote RTK GPS antenna. The water level measurement with RTK GPS is a satellite-based positioning method which is capable of continuous positioning of moving platforms with relative accuracy of around ± 0.1 meters.

One of the goals of this research is the improvement of 3D-positioning accuracy in RTK GPS. To achieve this goal, both an accuracy analysis of baseline vector using OTF and an investigation of important factors affecting the ambiguity resolution were accomplished

Thereafter the real tests were conducted with RTK GPS at seaside, and with the combined RTK GPS and ES(Ehco Sounder) at the ocean floor to assess the feasibility of RTK GPS. The experimental results show that RTK GPS is very useful for the acquisition of GIS DB in the field of coastal engineering.

2. RTK GPS

As shown in Figure 1, the quality of RTK GPS strongly depends on the link of data transmission between the reference and the rover station. The reference receiver transmits the correction data to the rover, and then the rover calculates its position based on the received correction data. In details, the RTK GPS is performed as follows: the reference receiver computes the difference vectors between GPS observables at the reference station and its fixed known coordinates. Afterwards the correction values are transmitted to the rover receiver via a data link, and the rover receiver calculates its positions in real time comparing with its observables and the transmitted correction values because the rover's position have to be determined while the rover moves.

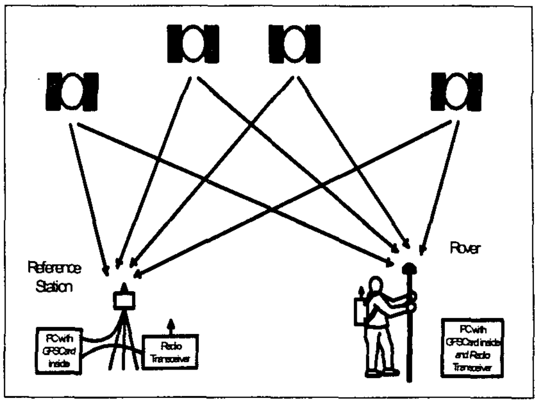

Fig. 1 Configuration of Real-Time Kinematic GPS

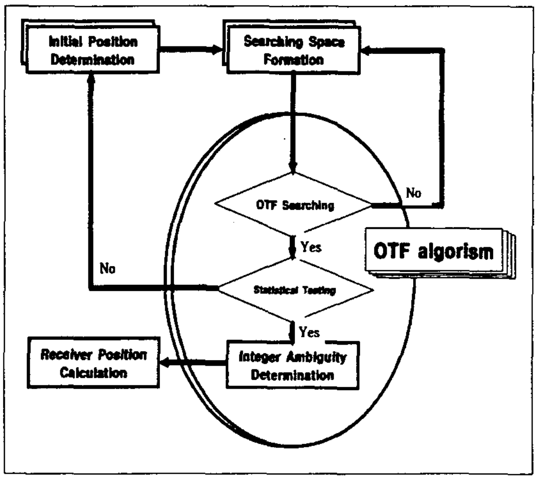

Fig. 2 Flow-chart of the OTF

3. Analysis of the GPS initialization for the ambiguity Resolution

To analyze the accuracy of ambiguity resolution using the OTF initialization method in RTK GPS survey, an observation network consist of 10 stations with baseline length ranging from 1 to 10 km. After fixing of one station at HAEUNDAE beach as a reference station to use RTK GPS, static surveying was performed by using Trimble 4000SSI receivers for one hours. In data processing, L1/L2 Iono-free and L1 fixed solutions by the linear combination of L1 and L2 are used as observables to reduce/eliminate the ionospheric effect. And Hopfield model is used for the tropospheric corrections. A variance ratio of 1.5 m was set as a threshold for the fixed solutions. Table 1 contains the results of baseline analysis and its precision, initialization time and the number of tracked satellites.

The experiment data of RTK GPS were analyzed with respect to initialization time ranging from 2 to 20 minutes and the number of observed satellites changing from 4 to 8. Theoretically, OTF does not require the initialization time, but the RMS of baseline length from the test showed that the initialization time is necessary to get a precise positions as shown in Figure 3.

In Figure 3, it was shown that more than 4 minutes of initialization is necessary to reach the accuracy better than 1cm. In this case, the RMS of baseline fixing is reduced to 0.0001(m/min) within 3km of baseline distance, and to 0.0002(m/min) with baseline length of 3 ~ 10km.

Table 1 Measurement values of each point to test networks

Point	Baseline length ±Stand. dev. (m)	Initialization time	Number of Satellites
CP 01	1277.532±0.001	2 min ~ 10 min	6
CP 02	3137.538±0.002	2 min ~ 15 min	5
CP 03	5217.162±0.002	2 min ~ 15 min	5
CP 04	7062.371±0.001	2 min ~ 20 min	5
CP 05	9802.481±0.001	2 min ~ 15 min	7

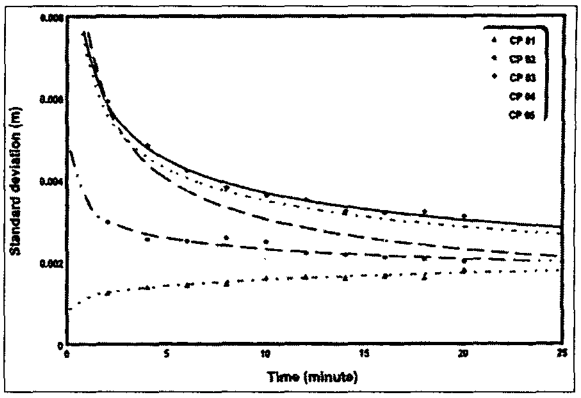

Fig. 3 Accuracy of measurements according to the initialization time

4. Topography analysis

4.1 Control point surveying

HAEUNDAE beach was selected as experimental area to reveal the possibility of RTK GPS to use for the coastal mapping. Since a rapid development in beach area near experimental site, it has been lost a lot of sand. Thus several thousands tons of sand are refilled for the beach nourishment. Therefore, a submarine topography of nearby beach as well as beach itself should be surveyed in order to (exactly) understand the movement of sand. Therefore, for the control point necessary for RTK GPS measurement, a precision of 1st order point assigned in the experimental area was used. And it was distributed widely as per control point, and the result surveyed for 4 hours by a static survey at these control points was used and analyzed.

To acquire the local coordinates seven-parameter transformation between WGS 84 and Korean Geodetic datum was applied. Table 3 is listed the transformed coordinates and WGS84 coordinates.

Table 2 7-parameters and standard deviation calculated from GPS

	ΔX(m)	ΔY(m)	ΔZ(m)
Parameter	120.603	-479.898	-669.225
1σ	6.953	6.145	5.448
	ω(deg)	φ(deg)	κ(deg)
Parameter	1.5309	-2.0836	-1.8762
1σ	0.1867	0.1941	0.2211

Table 3 WGS84 and transformed coordinates

Site	WGS 84		
	Latitude	Longitude	Ell. H
BASN	35-10-48.546	129-05-45.769	285.216
KIGO	35-09-58.205	129-09-03.690	177.421
HAE1	35-09-23.794	129-10-27.090	34.476
HAE2	35-09-27.515	129-10-18.480	33.768
HAE3	35-09-33.801	129-10-08.461	33.617
HAE4	35-09-31.816	129-09-35.064	33.278
HAE5	35-09-25.393	129-09-14.179	33.213
HAE6	35-09-18.779	129-09-16.742	36.496
HAE7	35-09-08.194	129-09-09.964	45.298
Site	Korea Datum		
	Latitude	Logitude	Ortho Height
BASN	35-10-37.430	129-05-43.516	254.850
KIGO	35-09-47.058	129-09-01.467	147.910
HAE1	35-09-12.631	129-10-24.878	4.748
HAE2	35-09-16.353	129-10-16.267	4.040
HAE3	35-09-22.642	129-10-06.247	3.889
HAE4	35-09-20.660	129-09-32.825	3.550
HAE5	35-09-14.238	129-09-11.953	3.485
HAE6	35-09-07.621	129-09-14.516	6.768
HAE7	35-08-57.035	129-09-07.734	15.570

4.2 The topography analysis of seaside

For the analysis of topography in the seaside HAEUNDAE beach are performed the RTK GPS survey. Back-hoe with tire was first used to analyze the characteristics of RTK GPS with the (moving) speed of vehicles, but because that is not fitted to the topography, backhoe with track shown in Figure 4 was used later and equipped with a 4000SSI dual frequency receiver. Figure 5 shows the moving trajectory of rover set mounted on backhoe.

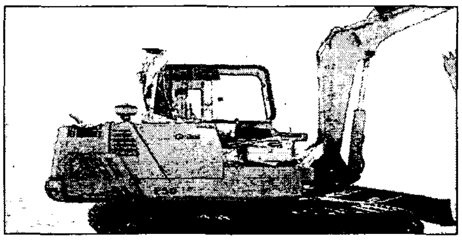

Fig. 4 Equipment setting for rover station

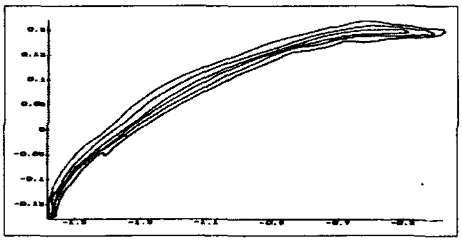

Fig. 5 Trajectory of RTK GPS rover receiver

4.3 The topographic analysis of the seafloor with RTK GPS and Echo sounder

Generally, DGPS (Differential GPS) is used for sounding the tide level surveying, but shows low accuracy for positioning. Therefore, this studies adopted RTK GPS surveying. Echo sounder for sounding is E-Sea sound 103 of MARIMATECH. The installation of a depth sounder is shown in Figure 6. The information such as the offset from GPS antenna to Echo sounder, GPS antenna to the water surface, the offset of a transfer device below the water surface are input as a source.

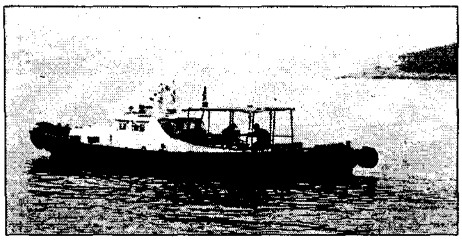

Fig. 6 Equipment setting for bathymetric survey

The software used for the saving, the analysis of sounding data acquired in real-time was HYDROPRO made by Trimble Navigation Ltd. It is to verify the moving path of ship in real-time, predetermined path and the marine chart of experimental area, and then performed the surveying.

5. Analysis and Discussion

The DTM of digital map drawn on a scale of 1:1,200 is introduced to estimate the accuracy of seaside topography. Figure 7 contains the DTM of seaside topography by digital map, and Figure 8 contains DTM of that by RTK GPS. The volume shown in Figure 7 is 97953.9 m^3, the volume in Figure 8 is 95994.9 m^3. Therefore, the analysis shows having about 2.0% of error in the volume difference between a numerical map and the surveyed data, and it is understood that the seaside topography surveyed by RTK GPS was successful.

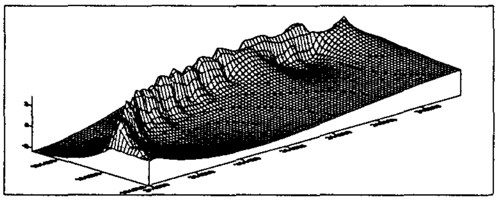

Fig. 7 DTM of generated from Digital map

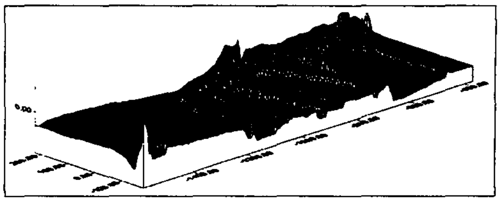

Fig. 8 DTM with RTK GPS and E/S

Since the boundary of measurement result is not identical, it is estimated that the comparison of volume and water depth is not correct. Therefore, it is found that the result shows almost similar, if a survey accuracy is compared with 3-Dimensional perspective drawing of two figures. Also, if a submarine topography measurement combined with RTK GPS and E/S is carried out every year, a moving quantity of earth and sand in the tested region can be assessed, and can be used effectively for reclamation of harbors, dredging, or measuring the change of drifted sand quantity in riverbed.

6. Concluding Remark

In order to carry out an exact analysis of topography for the seaside region, a control point was established by static survey, and coordinate transformation of the control point were executed. From these control points, it was surveyed using a construction machine by RTK GPS measurement. The topographic analysis of seaside and seafloor with RTK GPS and the combined RTK GPS and Echo sounder results are as follows:

The precision of 10km baseline with initialization time of over 4 minutes is better than 1cm in RTK GPS. It is expected that time table showing PDOP and RDOP under 4 influencing on the positioning accuracy is good for the observation plan.

The DTM of seaside topography by digital map of the volume is 97953.9 m^3. The DTM of that by RTK GPS and E/S of the volume is 95994.9 m^3. Therefore, the analysis shows having about 2.0% of error in the volume difference between a numerical map and the surveyed data, and it is understood that the seaside topography surveyed by RTK GPS was successful. Comparing the contour map and DTM obtained from the topographic analysis of seaside by RTK GPS and those from the topographic analysis of seafloor by the combined RTK GPS and Echo sounder; those by digital map and the seafloor's bathymetric map are well matched and also shows a comparable numbers in volume.

It will be very useful for the combined RTK GPS and Echo sounder to measure the reclamation and dredging of harbor or quicksand change of riverbed and apply to the database build-up of GIS effectively.

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