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# Quality Test and Control of Kinematic DGPS Survey Results

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ABSTRACT

Depending upon geographical features and surrounding errors in the survey field, inaccurate positioning is inevitable in a kinematic DGPS survey. Therefore, a data inaccuracy detection algorithm and an interpolation algorithm are essential to meet the requirement of a digital map. In this study, GPS characteristics are taken into account to develop the data inaccuracy detection algorithm. Then, the data interpolation algothim is obtained, based on the feature type of the survey. A digital map for 20km of a rural highway is produced by the kinematic DGPS survey and the features of interests are lines associated with the road. Since the vertical variation of GPS data is relatively higher, the trimmed mean of vertical variation is used as criteria of the inaccuracy detection. Four cases of 0.5%, 1%, 2.5% and 5% trimmings have been experimented. Criteria of four cases are 69cm, 65cm, 61cm and 42cm, respectively. For the feature of a curved line, cubic spline interpolation is used to correct the inaccurate data. When the feature is more or less a straight line, the interpolation has been done by a linear polynomial. Differences between the actual distance and the interpolated distance are few centimeters in RMS.

***Keywords*** : GPS, Differential GPS, Quality Control, Kinematic Survey, Trimmed Mean

## 1. Introduction

The Ministry of Construction and Transportation of South Korea developed the Highway Management System (HMS) to maintain the national highway network effectively and efficiently. For this purpose, the government also developed the National Highway Management Information System (NAHMIS) to manage as-build drawings of the highways. Drawings of NAHMIS are obtained from the raster images at the time of road construction and given in AutoCAD format. Coordinates of NAHMIS drawings are in Transverse Mercator (TM). For NAHMIS, the map of a highway consists of 500m long tile-like drawings. Therefore, we expect some discrepancy between two consecutive drawings when they are joined together. One of the main purposes of this study is to improve the accuracy of the joined NAHMIS drawings.

A kinematic DGPS survey for 20 km of a highway has been conducted for the

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assessment of NAHMIS map accuracy. The area of the survey has lots of hills and mountains as usual in South Korea. Since such geographical conditions are not optimal for the real-time kinematic DGPS survey, we postprocessed the data. Postprocessed kinematic DGPS surveying with dual frequency receivers is available to a centimeter level precision. Such a high precision DGPS surveying enables us to produce a relatively accurate GIS coverage map[1]. However, depending upon geographical features and surrounding errors in the survey field, inaccurate positioning is inevitable in a kinematic DGPS survey. Therefore, a data inaccuracy detection algorithm and an interpolation algorithm are essential to achieve the requirement of a digital map[3]. In this study, the fact that the vertical error is relatively higher than the horizontal error in GPS data is taken into account to develop the data inaccuracy detection algorithm. Then, the data interpolation algorithm is obtained, based upon the surveying feature type.

The overall procedure of this research is as follows in brief. 1) Static DGPS survey for control points is conducted because the NAHMIS coordinate is the TM and thus we need transformation parameters. 2) Kinematic DGPS survey for the feature of interests is conducted. 3) Find and store inaccurate data with the criteria of inaccuracy detection algorithm. 4) Interpolate the inaccurate data by linear and spline method, depending on the type of the feature. 5) Join the NAHMIS map and make a correction using DGPS survey data. 6) Analyze the NAHMIS map accuracy and make it available for HMS.

## 2. Coordinate Transformation

For the accuracy assessment of the NAHMIS drawings, it is required to transform the WGS84 coordinates into the TM coordinates. Therefore, seven transformation parameters between the WGS84 datum and the Bessel datum should be obtained. For this purpose, we selected two distant fixed control points and six supporting control points in the survey area as shown in Figure 1. Each fixed control points are surveyed at least for two hours and other six points are surveyed at least for thirty minutes. The greatest distance among the control points is about 30km.

The static survey of the base station for kinematic DGPS results to 2.5cm of horizontal error and 5cm vertical. Six supporting control points are less accurate than the base station because those points are observed for less period of time. Table 1 shows the overall accuracy of the control points. Although it is accurate enough to be used for computing the transformation parameters, CP 6 has the worst accuracy among six. For that reason, CP 6 is omitted. With five control points, we

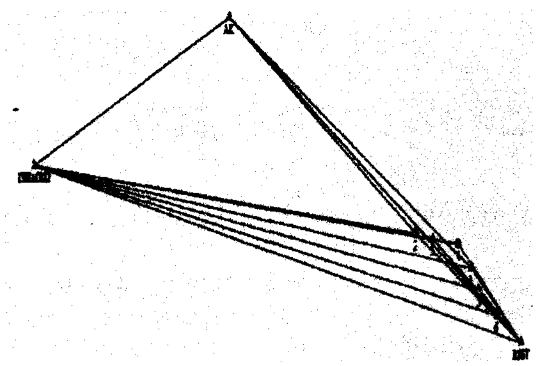

**Figure.1 Control Points for 7 transformation parameters**

**Table 1. Coordinates of control points**

| Control Points | | Coordinates (TM, meter) | 1.0σ (meter) |
|---|---|---|---|
| Inha University | X | 438772.0212 | Fixed |
| | Y | 169279.2351 | Fixed |
| | Z | 35.4970 | Fixed |
| Air Korea | X | 449140.1284 | Fixed |
| | Y | 194407.9802 | Fixed |
| | Z | 15.6574 | Fixed |
| Base Station | X | 426250.4452 | 0.024541 |
| | Y | 232131.5106 | 0.017509 |
| | Z | 99.0481 | 0.049171 |
| CP 1 | X | 431422.0354 | 0.056656 |
| | Y | 225653.0845 | 0.043655 |
| | Z | 67.1010 | 0.112513 |
| CP 2 | X | 433854.7551 | 0.031373 |
| | Y | 218580.4257 | 0.021746 |
| | Z | 80.6347 | 0.080009 |
| CP 3 | X | 433538.0865 | 0.057533 |
| | Y | 220803.2077 | 0.039979 |
| | Z | 70.2880 | 0.138955 |
| CP 4 | X | 433160.0964 | 0.062756 |
| | Y | 224046.4768 | 0.048384 |
| | Z | 59.5171 | 0.144067 |
| CP 5 | X | 428155.4206 | 0.066151 |
| | Y | 228938.1122 | 0.047623 |
| | Z | 69.0703 | 0.110090 |

**Table 2. Seven parameters for transformation**

| Parameter | Value |
|---|---|
| Translation X (meter) | -328.412 |
| Translation Y (meter) | 833.935 |
| Translation Z (meter) | 119.524 |
| Rotation X (second) | -20.153506 |
| Rotation Y (second) | -9.769107 |
| Rotation Z (second) | 1.053073 |
| Scale Factor | 0.999996757 |

obtained the seven transformation parameters as given in Table 2.

## 3. Data Inaccuracy Detection

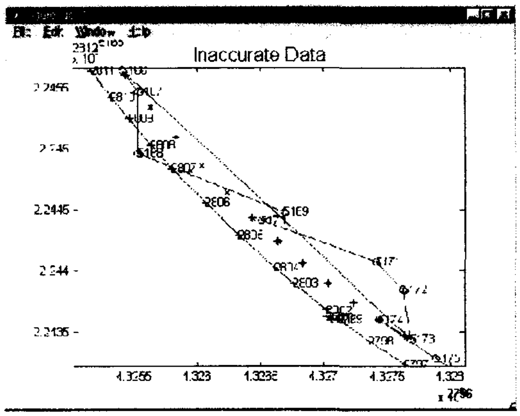


**Figure 2. Inaccurate data of kinematic DGPS survey**

The vertical error of GPS survey is relatively higher than the horizontal error because of the GPS characteristics. The survey area of this study contains many obstacles for kinematic DGPS, for instance, tall roadside trees, overpass bridges, mountains beside the road, tunnels and so on. As a result, the kinematic DGPS survey has inaccurate data that should be re-surveyed.

A typical pattern of inaccurate data of the survey is shown in Figure 2. Since the vertical variation is relatively higher, data inaccuracy detection is much easier when this fact is utilized. In this study, we present the inaccurate data detection algorithm as follows. 1) Get maximum and minimum heights of the overall data and use these values as the limit of detection. 2) Use the trimmed mean of vertical variation as criteria of the inaccuracy detection. Four cases of 0.5%, 1%, 2.5% and 5% trimmings have been experimented. Criteria of four cases are 69cm, 65cm, 61cm and 42cm, respectively. We selected the last case as our criteria for the final detection. 3) Get the horizontal distance of two consecutive points as criteria. Since the survey of the road is a line type and the survey is conducted in a way of evenly spacing, the horizontal accuracy is a good criterion of inaccuracy detection.

Figures 3 and 4 illustrate the vertical variation and the horizontal distance distribution of surveyed data, respectively. These two figures show clearly that there exist some inaccurate data vertically and horizontally. Table 3 gives the criteria to detect the inaccurate data.

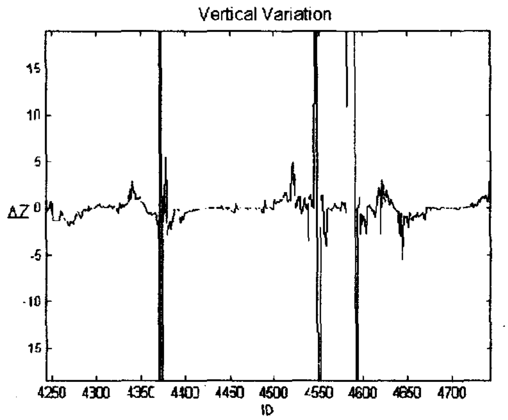


**Figure 3. Vertical variation of survey data**

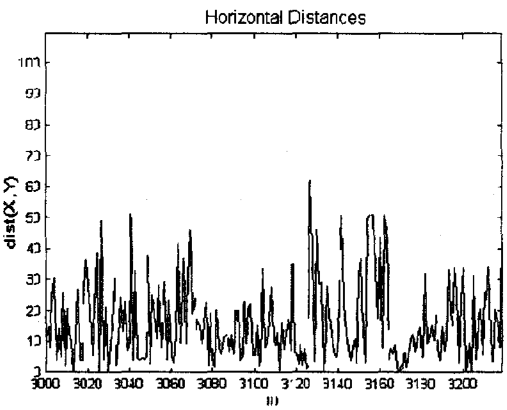


**Figure 4. Horizontal distance distribution**

**Table 3. Criteria of inaccuracy detection**

| | Line A |
|---|---|
| Total points | 1564 |
| Mean(Z) | 43.01 m |
| Mean (Diff (Z)) | 0.75 m |
| TrimMean (Diff (Z, 0.5%)) | 0.6881 m |
| TrimMean (Diff (Z, 1%)) | 0.6532 m |
| TrimMean (Diff (Z, 2.5%)) | 0.6102 m |
| TrimMean (Diff (Z, 5%)) | 0.4180 m |
| Limit (Distance (X, Y)) | 23.027 m |

Once the detection has been done automatically, then the inaccurate data can be interpolated in the following way. 1) Use the detection algorithm to find and store inaccurate data. 2) Use GIS software such as ArcView to check out some necessary section to be corrected. 3) Refer to surveyor's consideration about geographical conditions of the survey area. 4) Select the method how to interpolate, depending on the type of the road. For the feature of a curved line, cubic spline curve is used to interpolate the inaccurate data. If the feature is more or less a straight line, the interpolation has been done by a linear polynomial.

## 4. NAHMIS Map Accuracy

A NAHMIS drawing is a 500m long tile-like map as shown in Figure 5. It contains features associated with the road such as traffic signal posts, electric poles, overpass bridges etc. Figure 6 shows the kinematic DGPS survey of the same bridge shown on Figure 5. The DGPS data has been processed with the inaccuracy detection and interpolation algorithm. Figure 7 illustrates that the overlapped NAHMIS drawing with the DGPS data matches well enough.

**Figure 5. Typical NAHMIS drawing**

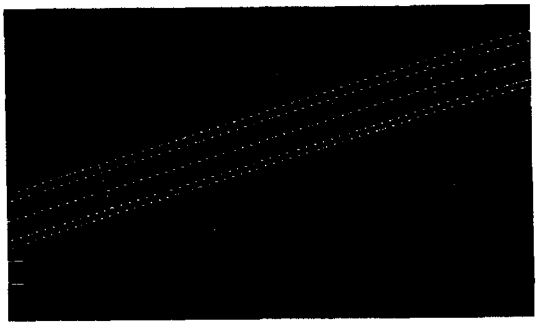

**Figure 6. DGPS survey of the bridge and road lines**

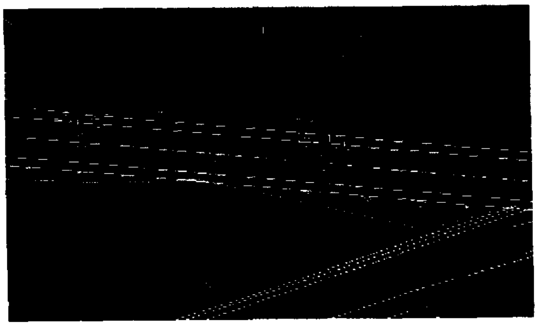

**Figure 7. NAHMIS drawing overlapped with DGPS data**

Table 4 shows the random sampling errors of NAHMIS drawing compared to kinematic DGPS survey. Ten points are randomly selected and the RMS is proven to be 1.17 meters. This value represents 1.17mm for 1:1000 scale map and 0.23mm for 1:5000 scale map. Note that the error includes the distortion from the coordinate transformation and the map projection as well.

**Table 4. Analysis of the random sampling errors**

| ID | Horizontal Error(m) |
|---|---|
| 0 | 1.1059 |
| 1 | 0.7460 |
| 2 | 0.7837 |
| 3 | 0.5036 |
| 4 | 0.8597 |
| 5 | 1.2031 |
| 6 | 1.4661 |
| 7 | 1.4879 |
| 8 | 1.4592 |
| 9 | 1.5384 |
| RMS | 1.1702 |

As the result of this study, we obtained the GIS coverage map for 20km range of a rural highway. The coverage map is obtained by combining kinematic DGPS survey result and the existing NAHMIS drawings. This is very useful for HMS and NAHMIS because the tile-based NAHMIS drawings are joined together. Relatively inaccurate data has been corrected without hassle of re-survey, which is definitely effective and efficient.

## 5. Conclusions

In this study, a trimmed mean and a first order differencing technique are used to develop an algorithm for data inaccuracy detection. A cubic spline curve and a linear polynomial are used to interpolate the inaccurate data. Processing detection and interpolation, based on this algorithm, resolves the accuracy problem associated with the kinematic DGPS surveying. This method is proven to be useful for HMS and NAHMIS.

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