AN EXPERIMENTAL RESULTS ON THE REFINEMENT OF DEMS USING ITERATIVELY GENERATED ORTHO-IMAGE FROM SPOT STEREOPAIRS

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ABSTRACT

DEM generated by correlation matching may contain various sources of matching errors due to the geometric condition and radiometric differences between the stereopairs. These errors may cause incorrect DEM. They also results in not only degrading DEM accuracy, but also requiring correction during the post-processing of editing the mismatched parts. Iterative orthoimage refinement (IOR) technique has been investigated mainly on the aerial photography to improve the DEM generation and correction procedures. In this study, we developed and implemented IOR concept for SPOT imagery. To do this, left and right orthoimages are generated using DEM and digital differential rectification from the stereopairs. Iterative orthoimage matching was applied to calculate parallax which was used to correct elevation error. Experiments are conducted to demonstrate the applicability of IOR for SPOT imagery. Three kinds of DEM have been tested. The experimental results show that IOR can be effectively utilized for refining the SPOT derived DEM to improve the procedure for DEM generation and to lessen the editing workload.

1 INTRODUCTION

Automatic DEM generation method has been widely implemented on the current digital photogrammetric workstation systems. Comparing with the manual process, the digital approach has much benefits in producing DEM through the digital correlation matching techniques. However, correlation method may contain many sources of matching errors if the image has undetectable features, repeated micro structures, linear edges, and so on. Also these errors may arise when the stereo images have different geometric and radiometric conditions. They results in not only degrading DEM accuracy, but also requiring correction during the post-processing of editing the mismatched parts.

Since editing process of DEM is generally conducted by the operator with the computer or analytical plotter, it could be labor-intensive job. So, an automatic error correction technique has been strongly desired to reduce the editing workload in the digital photogrammetric workstation systems. Many studies relevant to DEM correction have been mainly conducted to the aerial photography. In order to correct DEM effectively and quickly, Schenk(1989) proposed the DEM generation using iteratively rectified images. Norvelle(1996) used Iterative Orthophoto Refinement(IOR) approach to correct the elevation. Lobonc(1996) provided the theoretical background for elevation correction computation and demonstrated the practical aspect of IOR using GDE DPW 750 for aerial photos. Since SPOT imagery have different characteristics from aerial photos, some other approaches may be needed to accomplish DEM correction. Especially, when a user wants to generate dense DEM(about 2 pixel post interval) using SPOT-P image, it is difficult to effectively eliminate the blunders created during the correlation matching process.

In this study, we modified the aerial IOR concept and applied it to the SPOT imagery. To do this, left and right orthoimages are generated from the stereopairs using DEM by digital differential rectification. Iterative orthoimage matching is applied to calculate parallax which was used to correct elevation. Experiments are conducted on the test site(part of SPOT GRS 305-277) to demonstrate the feasibility of IOR for the refinement of SPOT-derived DEM through iteration.

2 IOR PROCESS

2.1 IOR Concept

IOR concept is based on the assumption that two(left and right) orthoimages generated from the same source of DEM should be identical. Two orthoimages can be produced using the same DEM and the corresponding exterior orientation parameters from the stereopairs. If the exterior orientation parameters are correctly estimated, elevation errors of DEM may cause the geometric mismatches between the two orthoimages. The mismatches can be estimated from the parallax through the matching of orthoimages.

To perform IOR, stereo images, exterior orientation parameters and DEM are required. Orthiomages are generated firstly by applying DEM to each stereo image, then the conjugate points in stereo orthoimage were found by stereo matching technique. The correction of elevation is computed by parallax between the two orthoimages. This process is repeated until the parallax is smaller than the predetermined threshold. Figure 1 shows the procedure of DEM refinement used in this study.

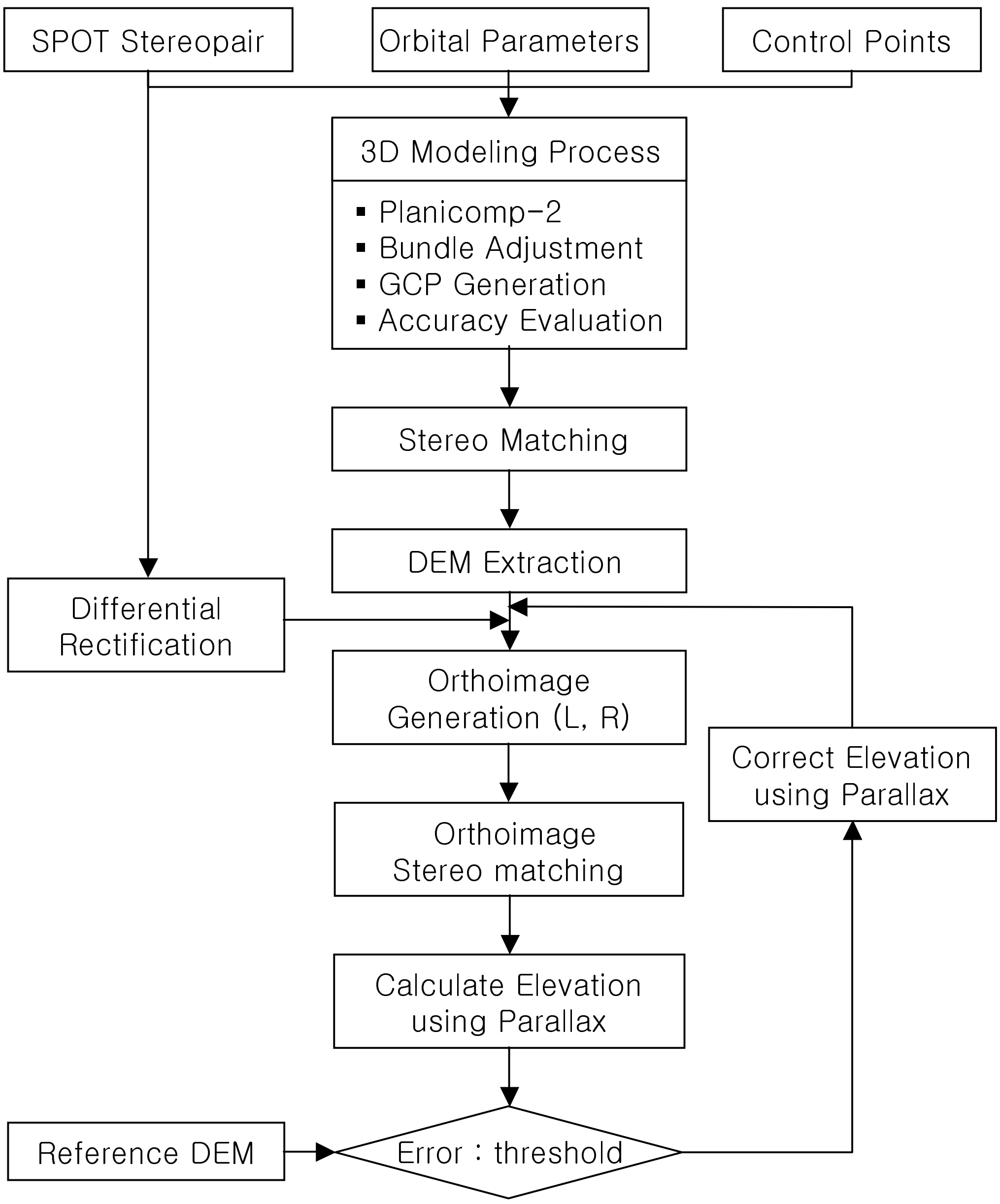


Figure 1. Iterative DEM refinement procedure used in the study

2.2 Orthoimage Generation

To generate the orthoimage by differential rectification, reference image and 3D modeling results(exterior orientation parameters) and the DEM are used. Differential rectification can be done by the direct or indirect method dependent on the direction of coordinate transformation. In this study, the indirect approach is used to make orthoimage shown in Figure 2.

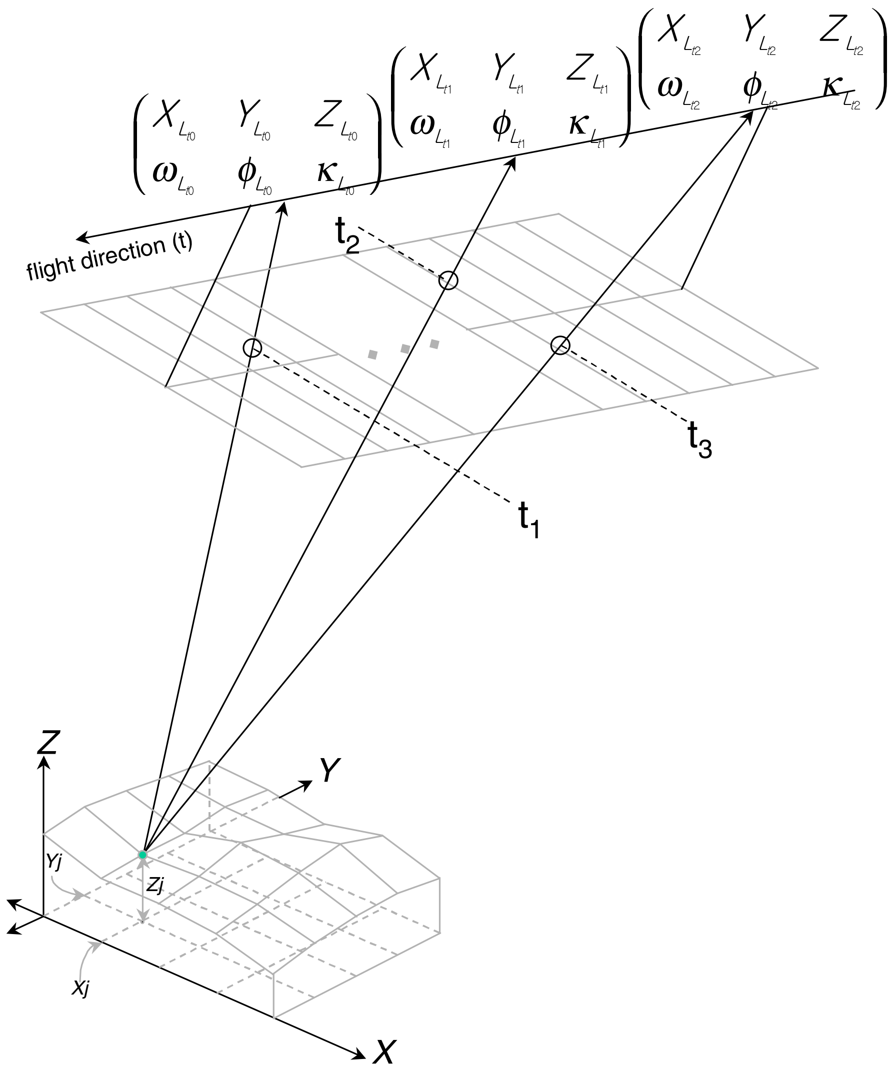


Figure 2. Indirect coordinate transformation concept

2.3 Elevation Correction

The relationship between the matching error of the orthoimage and the error in DEM is shown in Figure 3. The parallax is converted into height correction and used to estimate a new elevation. There are x and y parallaxes. However, if y parallax is negligible, we can estimate the elevation from only the x parallax shown in equation (1).

$$d_{H}' = d_{X} \times (H / B) \tag{1}$$

where,
$d_X = X_R - X_L$
$d_{H'}$ = estimated elevation to be corrected
H/B = baseline to height ratio

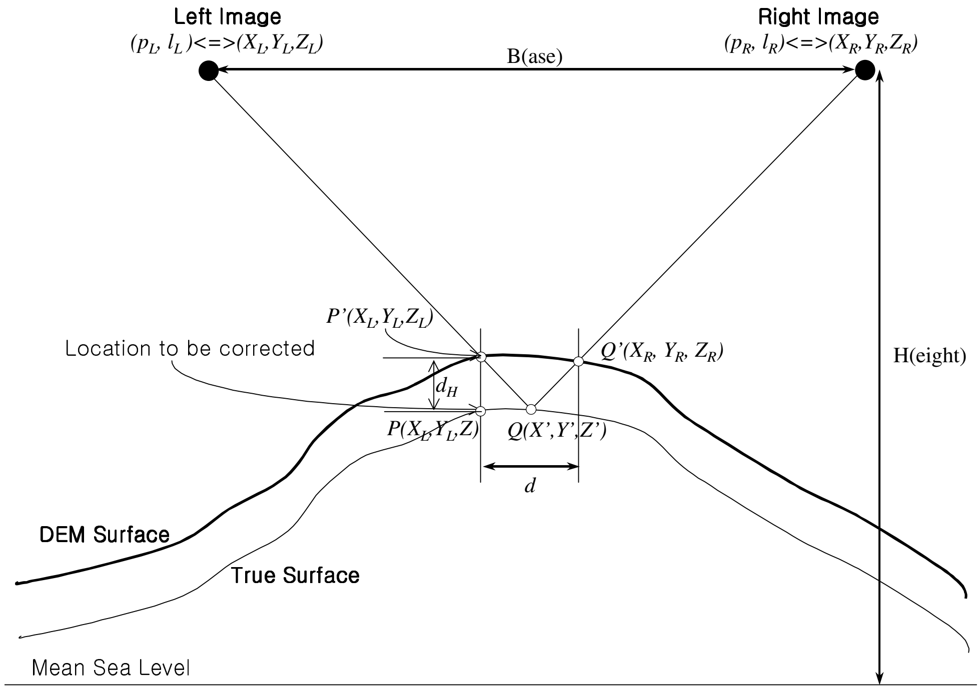


Figure 3. Relationship Between DEM and Orthoimage

Therefore new estimated ground coordinates are follows;

$$(X_L, Y_L, Z_L + d_{H'}) = (X_L, Y_L, Z_L + d_X \times (H / B)) \quad (2)$$

We iteratively update the elevation until the parallax is smaller than the predetermined threshold.

3 STUDY AREA AND DATA USED

Study area is 10km×10km in the ground. The ground coverage of SPOT GRS 305-277 is shown in Figure 4. The detail description of the SPOT images used in the study are given in Table 1. Three kinds of DEMs were generated to conduct experiments, i.e., DEM_1 from the DTED Level 1, DEM_2 from the left and vertical image pairs of SPOT, and DEM_3 from the left and right pairs of SPOT.

DEM_1 is used to investigate whether coarse DEM can be refined into fine DEM through IOR method. DEM_2 and DEM_3 are used to figure out whether IOR can be applied to the same area which has different geometric and radiometric characteristics due to different acquisition date.

A reference DEM was created by the analytical plotter using 1:30,000 aerial photography with 12.5m post interval.

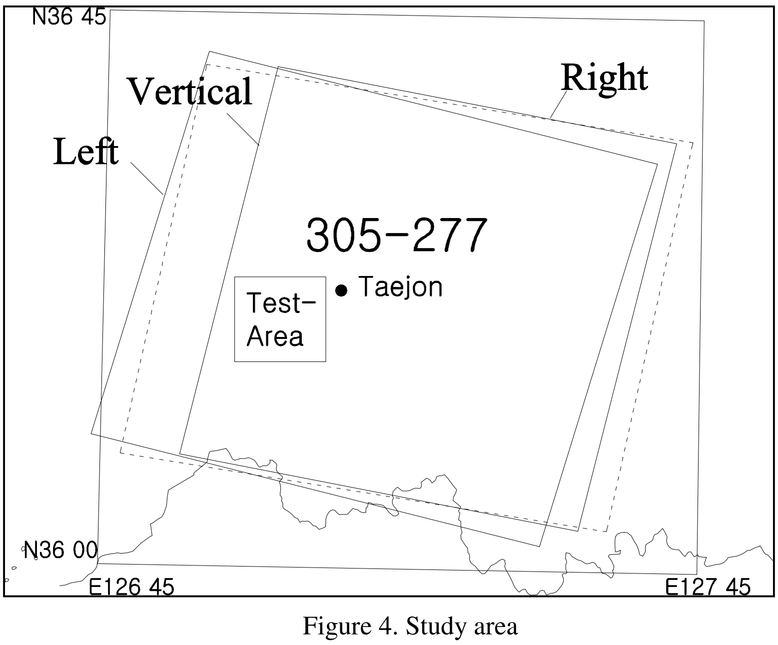


Figure 4. Study area

	Left Image	Near Vertical	Right Image
Center latitude	36°22' 03"	36°22' 03"	36°22' 03"
Center longitude	127°11' 51"	127°17' 45"	127°15' 57"
Incidence angle	L22.7°	R08.6°	R26.9°
Acquisition date	1995. 4. 4	1995. 4. 5	1995. 1. 28
Image type	PAN/1A	PAN/1A	PAN/1A

Table 1. Characteristics of SPOT images used in the study

4 EXPERIMENTS

The positional accuracy of (refined) DEM is analyzed by covariance analysis using with reference DEM and also RMSE on each DEM post is calculated. The parameters for covariance analysis and orthoimage matching are given in Table 2. Three sets of stereo orthoimage are produced based on the DEM_1, DEM_2 and DEM_3. For each set the x parallax is extracted to correct the each DEM. Results of applying iterative refinements are shown in Figure 5, 6 and 7. We can easily see the distinct refinement. The refinement of each iteration process is also depicted in Figure 8, 9, and 10.

	covariance analysis	orthoimage matching
mask window size	41 × 41	15 × 15
search width	5	6
search height	5	3
threshold correlation value	0.8	0.9
Interval	20/13	-

Table 2. Parameters for covariance analysis and orthoimage matching

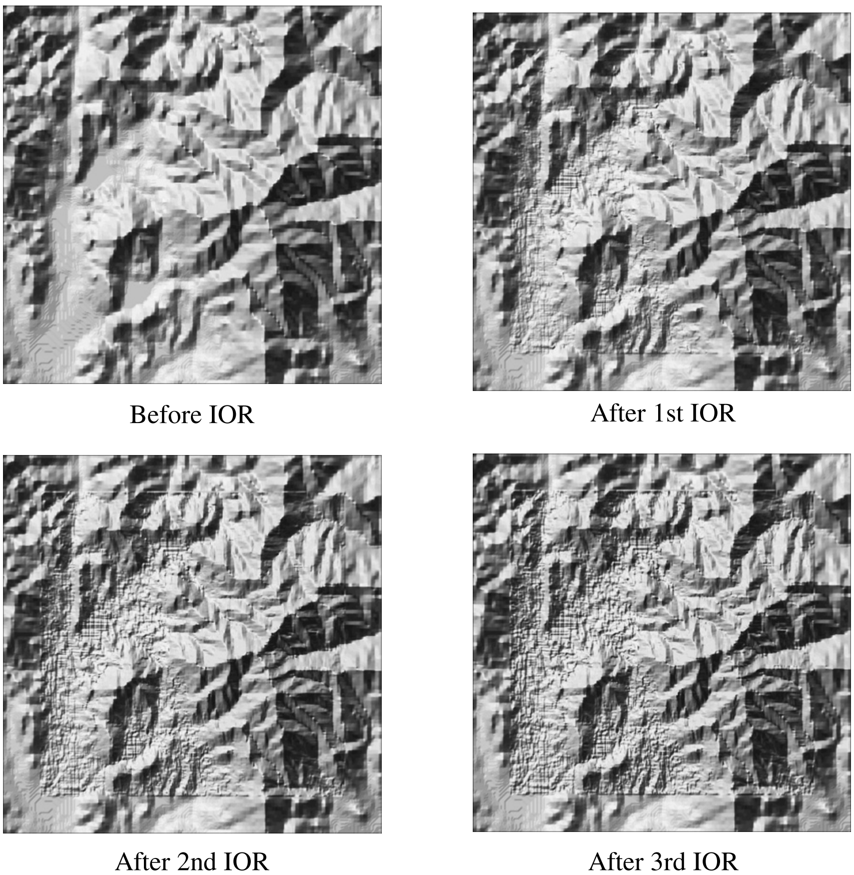
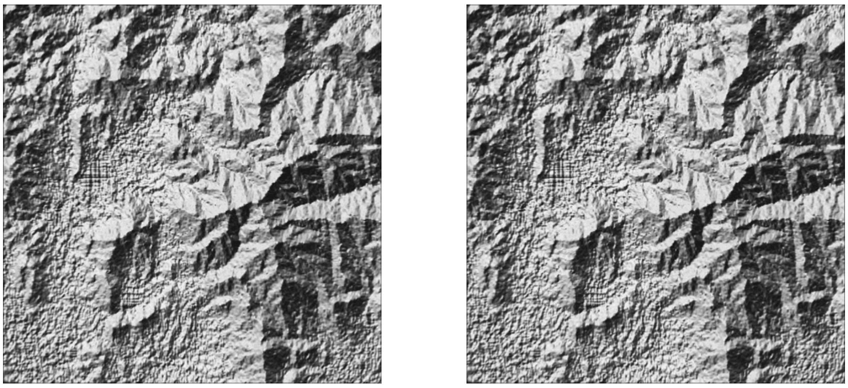
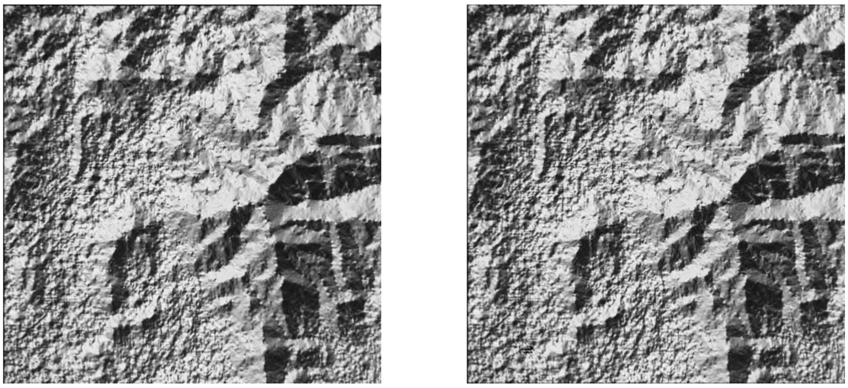


Figure 5. The resultant DEM for each iteration(DEM_1)



Before IOR After 1st IOR

Figure 6. The resultant DEM for each iteration(DEM_2)



Before IOR After 1st IOR

Figure 7. The resultant DEM for each iteration(DEM_3)

As shown in Figure 8, 9 ,and 10, both horizontal and vertical accuracies are generally improved by IOR process. For DEM_1, even though the standard deviations of easting and northing are decreased, their means are changed slightly. On the other hand, height error goes down in mean and is changed little in standard deviation. Consequently, these changes due to IOR iterations result in improving positional accuracy of DEM_1, horizontally and vertically.

The trends can be investigated by checking the pattern of parallaxes. Most parallaxes larger than 1 pixel are reduced into smaller than 1 pixel. Considering the 3D modeling error about 10m, the resultant accuracy after IOR is considered to be nearly approaching the modeling accuracy.

DEM_2 generated with SPOT L-V pairs showed the positional accuracy with CEP(Circular Error Probable of 90%) 20.8m and LEP(Linear Error Probable of 90%) 13.6m. DEM_2 has very good positional accuracy, therefore, the test was focused on the possibility of refinement of small detail parts. Significant effects were not found by IOR if the original quality of DEM is sufficiently good.

On the other hand, DEM_3 from SPOT L-R pairs showed worse positional accuracy than DEM_2, having CEP 32.35m and LEP 17.4m. This poor accuracy is basically caused by bad geometric condition and radiometric inconsistency between the stereopairs. The experimental results on DEM_3 shown in Figure 10 showed that IOR approach could be applied to the stereoimages with bad matching conditions.

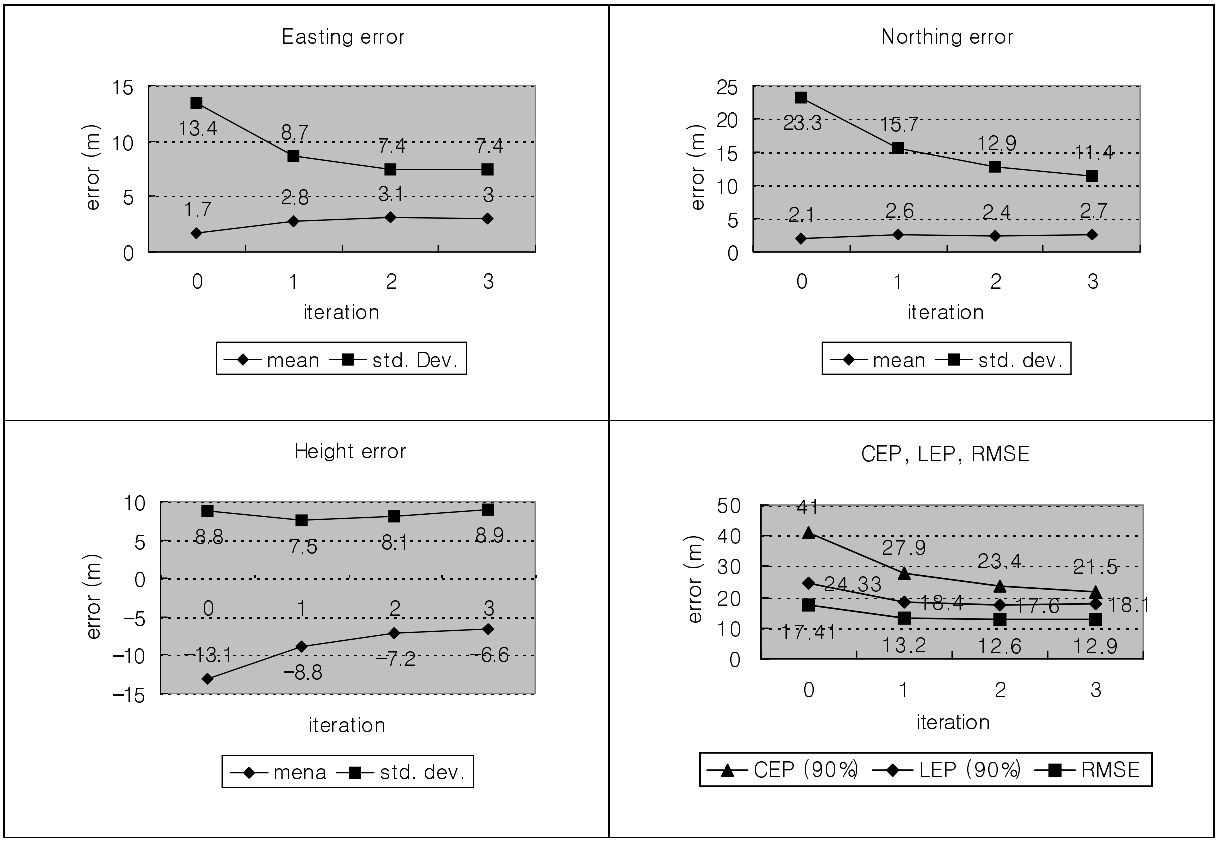


Figure 8. Refined results for each IOR iteration (DEM_1)

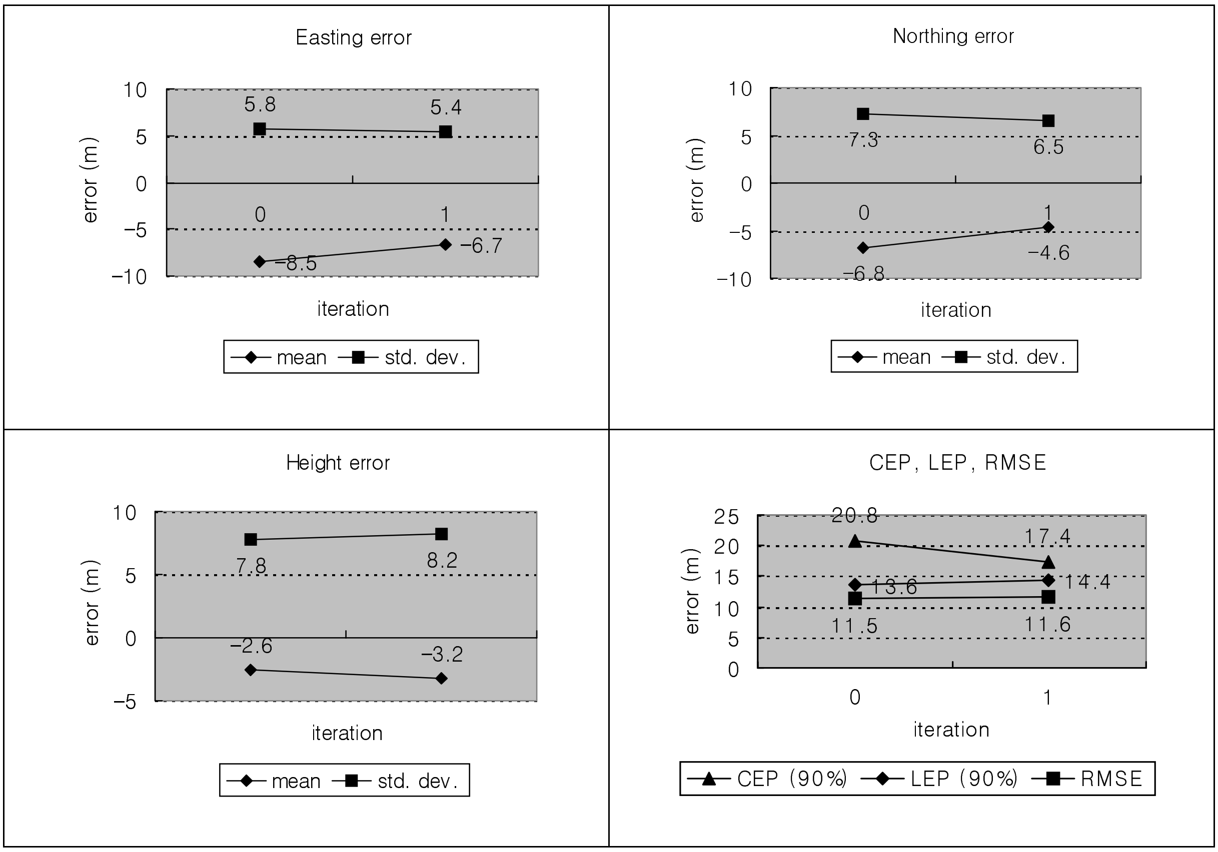


Figure 9. Refined results for each IOR iteration (DEM_2)

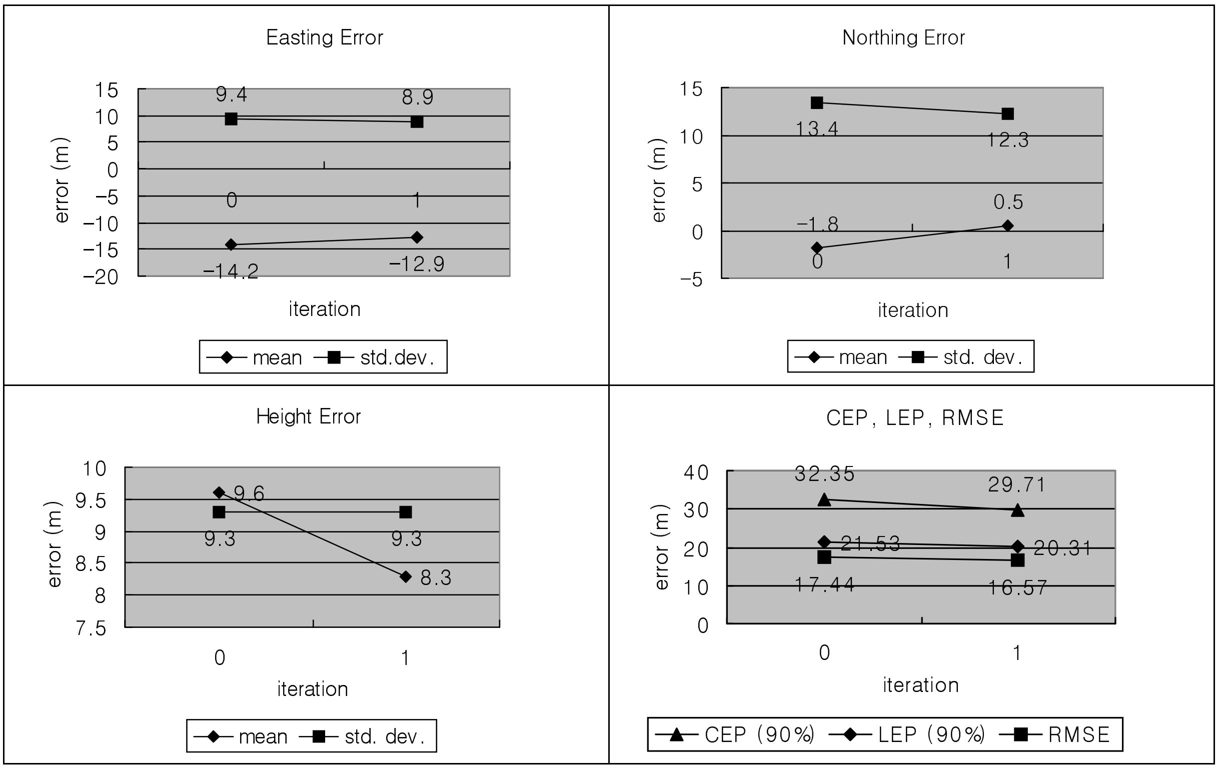


Figure 10. Refined results for each IOR iteration (DEM_3)

5 CONCLUSIONS

1) The accuracy and precision of SPOT derived DEM can be improved by applying IOR process. The possibility of improvement was demonstrated by implementing IOR for SPOT-DEM and DTED-DEM.

2) IOR has a little effects on the improvement of the DEM quality, if the quality of original DEM is sufficiently good. Actually, there are no significant changes in DEM quality by IOR for the DEM_2 which generated from the left and vertical images of SPOT GRS 305-277.

3) If the stereoimages are acquired in long time separation, various errors may be included when image matching is performed. In this case, IOR can be effectively used to improve the resultant DEM quality. Therefore IOR can be used as a tool for correction and/or refinement of DEM which is generated automatically by digital photogrammetric process.

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