DEM GENERATION FOR SPOT-3 STRIPS USING ORBIT MODELING TECHNIQUE

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ABSTRACT: The purpose of this paper is to extract DEMs from Spot-3 strips using orbit modeling technique. Spot-3 stereo strip images along 420km in distance were used for experiments. The orbit modeling technique has been suggested to establish accurate geometric models for a whole strip taken on the same orbit using only a small number of GCPs on the top area of the strip. This method enables extraction of orientation parameters of the scene along the strip that is needed to generate DEMs. Consequently, we were able to extract DEMs over the areas without accurate GCPs obtained by GPS surveying per each scene. Assessment of accuracy was carried out using USGS DTED. DEMs generated from the orbit modelling technique suggested showed satisfactory performance when quantitative analysis of accuracy assessment was carried out.

KEY WORDS: sensor model, orbit modeling, DEM, accuracy assessment, image strips

1. INTRODUCTION

Research for extraction of a Digital Elevation Model (DEM) and acquisition of accurate geolocation has been performed for many years. Results of such research can be used for orthoimage generation, three-dimensional Geographic Information System (GIS) construction and so on.

Recently, as the supply of diverse satellite images increases, extraction of DEMs using satellite images is becoming more important. To get productive results such as DEMs from satellite images, a suitable sensor model for image should be developed before anything.

Sensor model refers to the establishment of geometric relationship between image coordinate system and their corresponding ground coordinate system. Notably, the model based modified collinearity equations (Gugan and Dowman, 1988; Orun and Natarajan, 1994), Direct Linear Transformation (Gupta and Hartley, 1977) and Rational Function Model (Dial and Grodecki, 2003; Tao and Hu, 2001) have been proposed as sensor modeling technique for satellite images. On the other hands, a new modeling technique, that uses satellite orbit and attitude angles as model coefficient, was proposed to model satellite orbital segments as a whole from a few control points (Kim and Dowman, 2006; Kim et al, 2007).

A study of DEM generation algorithm also was performed by many researchers and generally accurate GCPs of each stereo pairs are needed to achieve DEMs from satellite images.

In this paper, through orbit modeling technique based on orbit-attitude sensor model, the feasibility of DEMs generation of a whole strip with a particular Ground Control Points (GCPs) configuration will be investigated using Spot-3 stereo strips. The orbit modeling technique suggested will be used to establish accurate geometric models of a whole strip taken on same orbit using only a small number of GCPs on the top area of the strip. First of all, we will find the best sensor model for geometric modeling of entire image strip on the same orbit. And then we will attempt to extract orientation parameters of the scene along the strip that is needed to generate DEMs. And we generate DEMs over the area without true GCPs obtained by GPS surveying for the scene under processing.

For assessment of results, DEMs generated from orbit modelling technique suggested will be compared with the corresponding area presented in Digital Terrian Elevation Data (DTED) and also accuracy analysis using DTED will be performed for quantitative analysis.

2. DEM GENERATION FROM ORBIT MODELING

2.1 The procedure of DEM generation from orbit modeling

In this section, we will explain how to generate DEMs without GCPs from orbital modelling technique suggested. For experiment, Spot-3 stereo strip images were used and we obtained GCPs on the strip by GPS surveying. Table 1 shows characteristics of stereo strips used in this research.

Table 1. Characteristics of image strips used.

ID	Left strip	Right strip
Satellite	Spot-3	Spot-3
Date of Acquisition	4 April 1995	28 Jan 1995
Tilt Angle	+19.8°	-23.4°
Strip length	420 km	420 km
Resolution	10 m	10 m

We first attempted to establish sensor model of entire strip images which cover 420km using only a small number of true GCPs on the top scene, the area marked with a circle in Figure 1. We then extracted exterior orientation parameters of each scene.

In this paper, the orbit attitude model (Kim et al, 2007) was applied as sensor model method for extraction of orientation parameters because the orbit attitude model showed better results in terms of the accuracy of estimating exterior orientation parameters over the position rotation model (Kim and Dowman, 2006).

The orbit-attitude model were evaluated by seven different kinds of the combination of unknown parameters such as position bias, drift, accelerations and attitude biases (Kim, 2006). Among them, the best type of model with optimum parameters combination was applied for modeling of entire image strip on the same orbit here. We then extracted orientation parameters for each stereo pair to generate DEMs and consequently, DEMs over the scene without GCPs could be generated. Figure 1 shows the procedure of DEM generation from orbital modelling technique suggested.

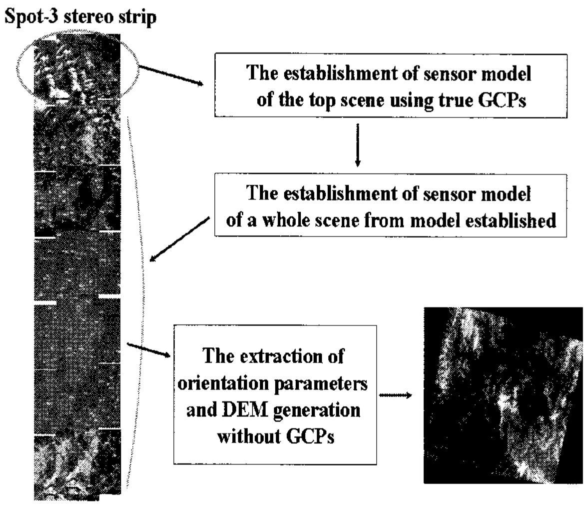

Figure 1. DEM generation from orbit modelling

Through this procedure we were able to establish accurate geometric modeling of a whole strip and generated DEMs of each stereo pair successfully. Results of DEMs generated will be presented in the next part.

2.2 Results of DEMs generated

In this section, results of DEMs generated from orbit modeling suggested in this research is presented. The orientation parameters of entire image strips were extracted from the method suggested and we were able to generate DEMs of the all scenes without true GCPs per scene. As for stereo image matching for DEM generation, we used the matching method using image pyramid (Daniela et al, 2004) and base on epipolarity and scene geometry developed in house (Lee et al, 2003). All of the procedure of DEM genereation was performed fully automatically and successfully.

To check whether DEMs were generated successfully from the method proposed or not, we compared results of DEMs with DTED. Figure 2, 3 and 4 show both result of

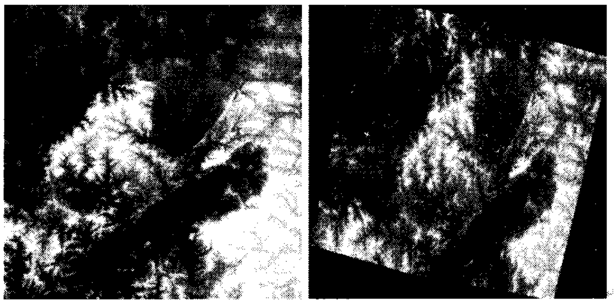

Figure 2. Comparison of result of DEM with DTED (Left: DTED, Right: DEM of Cheon-ahn area)

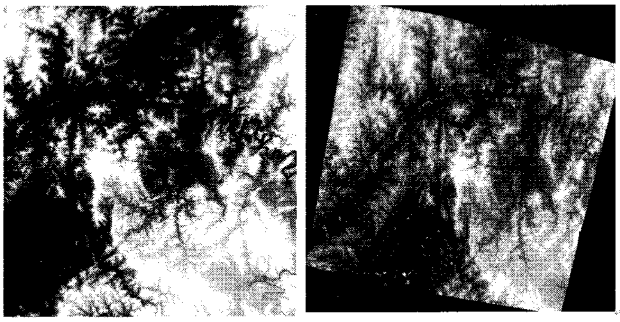

Figure 3. Comparison of result of DEM with DTED (Left: DTED, Right: DEM of Dae-jeon area)

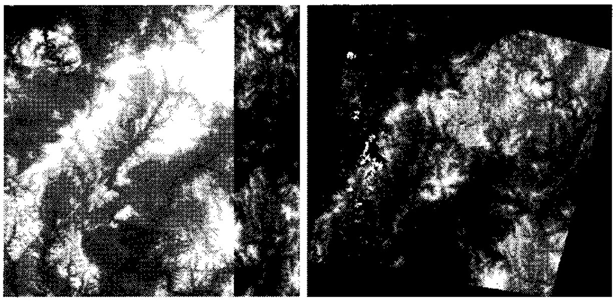

Figure 4. Comparison of result of DEM with DTED (Left: DTED, Right: DEM of Kwang-ju area)

DEM(right) and the corresponding area described in DTED(left) for comparison. Figure 2 shows DEM of Cheon-ahn area situated at a distance of about 100km from Choon-chun where GCPs are available and Figure 3 and 4 show each DEM of Dae-jeon and Kwang-ju area situated further south. We could confirm that image matching was done well and the corresponding area which can be visible in DTED was described well in the DEMs generated.

Therefore it was proved that the orbit modeling technique suggested can make extraction of DEMs without true GCPs. This can be a significant contribution if there are many difficulties, such as expense and time, to get accurate GCPs for DEM generation. In addition, there is worth in terms of the feasibility of DEMs generation of inaccessible area where the field measurement is impossible.

The experiment results show that DEMs generated have a good quality. In the next section, accuracy assessment using the reference DEM will be accomplished so that we analyze how much quantitatively reliable DEMs were generated from the method proposed.

3. ACCURACY ASSESSMENT

Qualitative analysis of DEMs generated was already done by the naked eye through comparison with the surface presented in DTED. In this part, quantitative analysis will be discussed additionally to support a valid conclusion. For accuracy analysis of the DEMs generated, assessment was carried out using USGS DTED. We calculated errors of DEMs, provided that heights of DTED are true values. The strips used were comprised of seven scenes and we carried out assessment for all DEMs except Choon-chun, the top scene. And assessment for DEM of Yang-pyung, the second scene from the top, was excluded because image quality of Yang-pyung stereo pairs was very poor due to cloud. Therefore assessment for DEMs extracted from third to seventh scene of the strip was carried out and table 2 shows results of accuracy assessment using DTED.

Table 2. Results of accuracy assessment

ID	MAE (unit : m)	RMSE (unit : m)
Cheon-ahn	18.56 m	32.58 m
Dae-jeon	19.51 m	26.66 m
Jeon-ju	17.04 m	26.51 m
Kwang-ju	21.56 m	30.25 m
Nha-ju	14.00 m	18.39 m

Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) were calculated as standard of accuracy, and we could confirm that about 15~20m as MAE and 25~30m as RMSE were calculated as a whole.

For comparison, we used all height grids of DEMs through bilinear interpolation. Since we compared all of the matching points even including water, occlusion area, shadow and so on, blunder points were included for comparison. Likewise, errors associated with mismatches were included. Also inaccuracy of DTED itself might be included within the errors figures.

Taking the above statements into account, and considering that the resolution of DTED was 30m, it could be concluded that all DEMs generated without GCPs show acceptable accuracy.

In additional experiments, we could confirm that accuracy of DEMs generated from true GCPs also was almost similar. Table 3 shows the accuracy of DEMs generated from true GCPs.

Table 3. the accuracy of DEMs generated from true GCPs

ID	MAE (unit : m)	RMSE (unit : m)
Dae-jeon	16.57 m	27.88 m
Kwang-ju	18.77 m	26.12 m

This facts support again that the orbit modeling technique suggested was stable and reliable.

We believe the magnitude of errors in the DEMs generated will be reduced with high resolution satellite images such as IKONOS, Quickbird, Kompsat-2. In our earlier investigation, DEMs generated from high resolution satellite images showed an accuracy of 10m MAE and RMSE within 15m when the orbit-attitude model and stereo image matching based on epipolarity and scene geometry were applied using true GCPs (Jeong et al, 2008). Therefore, we could expect that more accurate DEMs can be extracted if we apply orbit modeling technique proposed to high resolution satellite image strips.

Considering the above explanation, the results of accuracy assessment support that DEMs generated from the orbit modeling has satisfactory performance.

4. CONCLUSION

In this research, we performed the generation of accurate DEMs without GCPs using the orbit modeling technique. For this, we first established precise sensor modeling of the top scene using a small number of GCPs. We then found out the orbit-attitude model with optimum parameter combination which could establish a sensor model of a whole strip well. Through the procedure of orbit modeling technique suggested, orientation parameters for each stereo pair were extracted successfully and we were able to generate DEMs of all images without GCPs.

For assessment of results, both qualitative analysis and quantitative analysis were performed. DEMs generated not only appeared similar to the DEM generated using accurate GCPs but also showed satisfactory performance even in quantitative analysis.

These experiment results support that accurate geometric modeling and DEM generation without accurate GCPs is possible using the orbit modeling technique, which is the major contribution of this research.

In the near future, we will test other satellite image strips. Orbit modeling technique suggested should also be applied successfully for high resolution satellite images such as SPOT-5, IKONOS and Kompsat-2.

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