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Geometric Corrections of Inaccessible Area Imagery by Employing a Correlative Method

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ABSTRACT

The geometriccorrection of a satellite imagery is performed by making a systematic correction with satellite ephemerides and attitude angles followed by employing the Ground Control Points (GCPs) or Digital Elevation Models (DEMs). In a remote area or an inaccessible area, however, GCPs are unavailable to be surveyed and thus they can be obtained only by reading maps, which are not accurate in reality. In this study, we performed the systematic correction process to the inaccessible area and the precise geometric correction process to the adjacent accessible area by using GCPs. Then we analyzed the correlation between the two geo-referenced Korea Multipurpose Satellite (KOMPSAT-1 EOC) images. A new geometrical correction for the inaccessible area imagery is achieved by applying the correlation to the inaccessibleimagery. By employing this new method, the accuracy of the inaccessible area imagery is significantly improved absolutely and relatively.

Keywords : Precise Geometric Correction, Systematic Correction, KOMPSAT-1, Electro-Optical Camera, Ground Control Points, Inaccessible Area.

1. Introduction

It is necessary to correct geometric errors of the remotely sensed data containing geometric distortions caused by scan skew, mirror-scan velocity, panoramic distortion, platform velocity, earth rotating, perspective geometry and variations in the attitude and altitude [1]. Those geometric errors can be corrected with different levels of the process. The first level is called a systematic correction with satellite ephemerides and attitude data. The second is precise geometric correction using a sufficient number of GCPs to improve absolute position accuracy. The third is the use of a DEM to correct parallax error due to the local terrain elevation [2].

It is not easy to survey GCPs or to produce DEM with GPS measurement or Total Station

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instruments in the inaccessible area. GCPs can be only obtained by reading maps. Inaccessible area images corrected by using systematic correction process have a small relative position error but have a large absolute position error [3]. For this reason, the inaccessible area imagery is requires a suitable geometric correction method for applications in Remote Sensing and GIS technology.

This paper presents a combined geometrical correction method that KOMPSAT-1 EOC images of the inaccessible area are corrected with the systematic correction process and then are revised with GCPs obtained from the adjacent accessible area nearby to improve absolute position accuracy.

2. Systematic Correction

For this study, we selected a 230km long and 17km wide area on Korea peninsula, which is covered by 18 KOMPSAT-1 EOC images. The case study area is shown in Fig.1 We assumed that the north of 200km long area is inaccessible and the remainder of 30km long area is accessible. Though the GCPs can be obtained only in the accessible area, satellite ephemerides and attitude data provided with the image can be available for geometric correction in the whole area.

3. The Precise Geometric Correction for Accessible Area

All KOMPSAT-1 EOC images were corrected through the systematic correction process. To improve absolute position accuracy, those georeferenced KOMPSAT-1 EOC images need to be corrected more precisely by using well-distributed GCPs, which can be surveyed in the accessible area.

To verify a new geometric correction method, we have selected and surveyed all GCPs in the case study area. Nineteen GCPs in the accessible area and seventy-eight points in the inaccessible area were obtained by Fast-Static GPS survey. The PCI, a

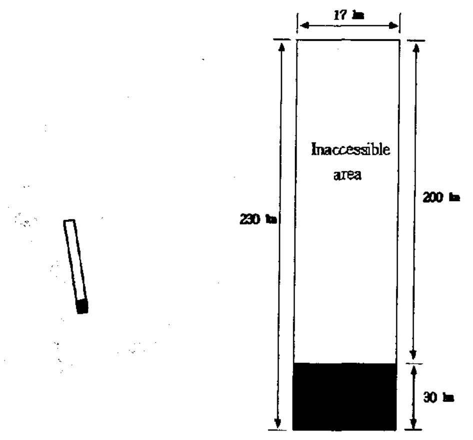


Fig.1 Case study area (left) shown inaccessible and accessible area scale (right)

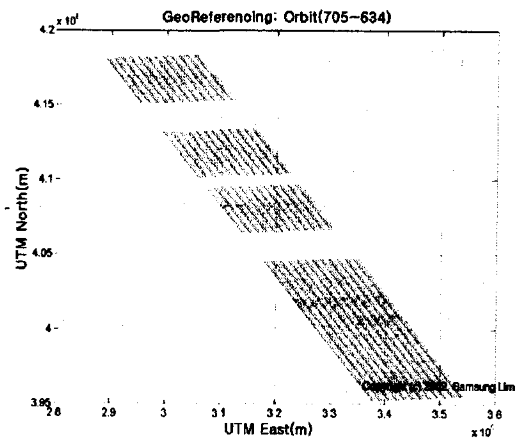


Fig.2 UTM coordinates of all KOMPSAT images corrected with systematic correction process

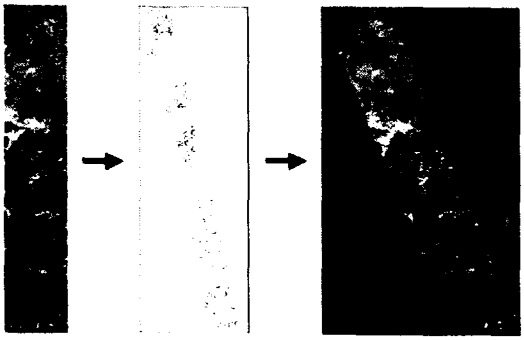


Fig.3 Precise Geometric Correction using the GCPs

popular image processing software, is used for image rectification. As one KOMPSAT-1 EOC image covers relatively small area of the peninsula, the first-order affine transformation is sufficient to rectify the imagery.

The nearest neighbor, one of the resampling methods, was selected for brightness value (BV) interpolation [1]. Fig.3 presents all KOMPSAT-1 EOC images were corrected using GCPs. Note that above 18 georeferenced images are just for verifying our new geometrical correction method.

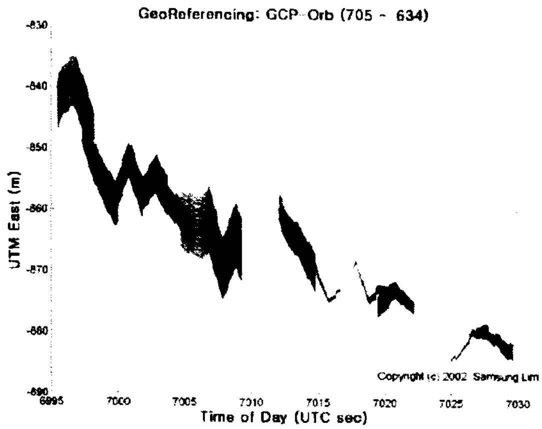
4. Correlation Between Images

It is meaningful to analyze correlation between images corrected by using the systematic correction and the precise geometric correction by using GCPs. In other words, the correlation suggests absolute position error of systematic correction images and can be expressed by

$$\Delta UTM = UTM(P.C) - UTM(S.C) \tag{1}$$

where is $UTM(P.C)$ coordinates of KOMPSAT images corrected by using GCPs and is $UTM(S.C)$ coordinates of KOMPSAT-1 EOC images corrected by using systematic correction. The ΔUTM means difference between $UTM(P.C)$ and $UTM(S.C)$ on the same pixel.

Fig.4 and 5 show ΔUTM East and ΔUTM North of all georeferenced KOMPSAT-1 EOC images with respect to UTC time. A variation of ΔUTM East declines more rapidly than ΔUTM North. It means that the systematic distortions such as earth rotation, perspective, platform velocity, panoramic distortion etc. are corrected with satellite ephemerides and attitude data but nonsystematic distortions



ig.4 ΔUTM East

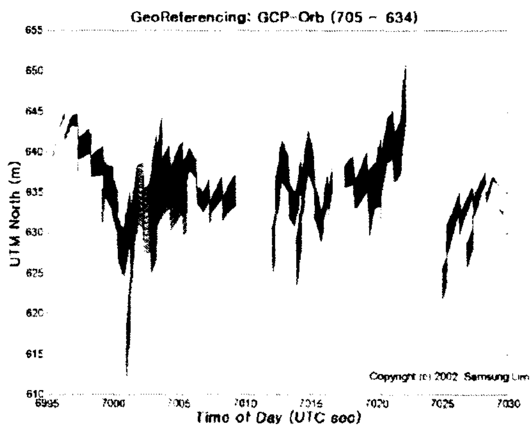


Fig.5 ΔUTM North

caused by sensor system attitude or altitude remains after performing systematic correction [1].

The UTM coordinates of physical features recorded on the KOMPSAT-1 EOC images corrected by using the precise geometric correction reflect almost real position on the plane rectangular coordinate system. Therefore, the prime cause of the declined tendency of ΔUTM is influenced by $UTM(S.C)$ which is function of ephemerides and sensor system attitude angles.

Fig.6 shows effect of platform attitude errors on the region of earth being imaged[5]. Fig.7 and 8 show roll and pitch angles of the sensor platform when KOMPSAT -1 EOC was exposed. The bottom of sinusoidal curve is gradually being increased in Fig.7. We assumed that main factor of the ΔUTM declination was the deviation of roll angle.

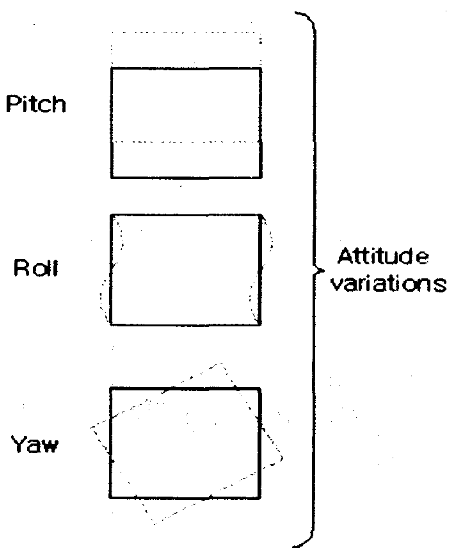


Fig.6 Effect of platform attitude errors on the region of earth being imaged, those errors occur slowly compared with image acquisition

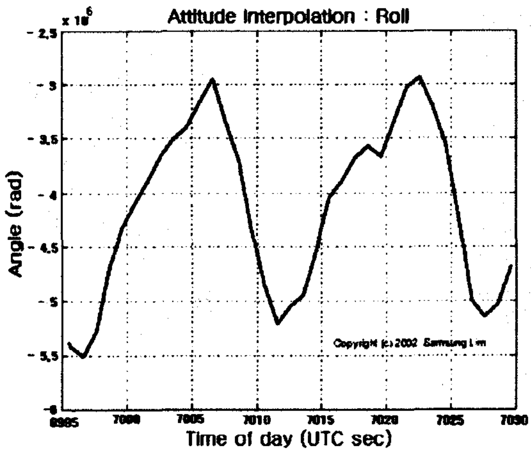


Fig.7 A variation of roll angle

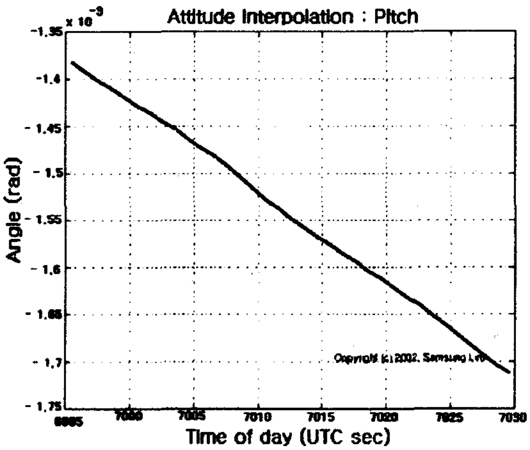


Fig.8 A variation of pitch angle

5. Adjustment of the Attitude Data

It was assumed that KOMPSAT-1 EOC sensor system axis was not maintained normal to Earth's surface and the other parallel to the along-track direction of KOMPSAT-1 EOC flight [6]. Therefore, we had adjusted roll and pitch angles included in the images by using Equations (2) and (3) to remove attitude deviation. It is regarded that the effect of yaw angle might be neglected.

$$AdjustedRoll = -\sin\alpha \times \Delta t + \cos\alpha \times Old\_Roll \quad (2)$$

$$AdjustedPitch = -\sin\theta \times \Delta t + \cos\theta \times Old\_Pitch \quad (3)$$

where α is rotating angle for roll correction, the angle θ is for pitch correction as well as the scaling angle of α for offset of small bias occurred to north direction, Δt is the elapsed time since the initial time of the first scan, Old_Roll and Old_Pitch are original attitude angles before adjustment, AdjustedRoll and AdjustedPitch are new attitude angles after adjustment. Note that α, θ and Δt are computed by attitude Euler angles of accessible area images.

All images were newly corrected by using ephemerides and attitude data adjusted.

$$adj\Delta UTM = UTM(P.C) - adjUTM(A.S.C) \quad (4)$$

where is $adjUTM(A.S.C)$ is UTM coordinates of KOMPSAT-1 EOC images corrected by using ephemerides and attitude data adjusted. The $adjUTM$ means difference

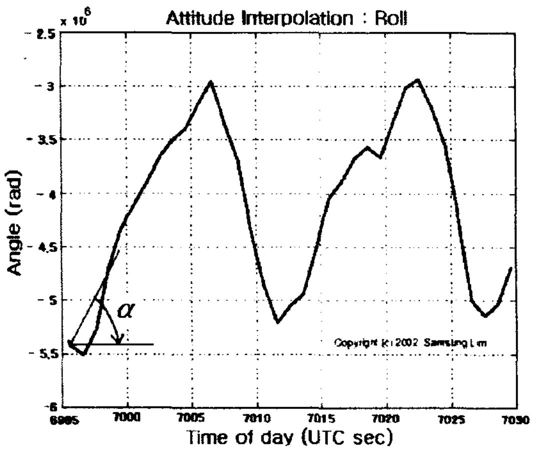


Fig. 9 Adjustment of roll angle data of all images

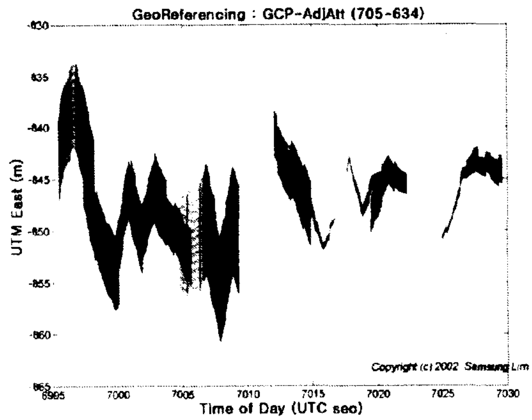


Fig.10after adjustment of roll angles

of UTM coordinates between $UTM(P.C)$ and $adjUTM(A.S.C)$ on the same pixel.

Fig.10 shows the declination of $adj\Delta East$ become small, compared with Fig.4. This graph shows the geo-location errors caused by the deviation of roll and pitch data is reduced remarkably.

6. A New Geometric Correction Method

An improved systematic correction was performed in the whole area images after the adjustment of attitude data (roll, pitch). The difference between the improved systematic correction UTM coordinates and the precise geometric correction UTM coordinates of the accessible area images has a significant statistical meaning. We can identify that the difference was almost regular in the accessible and inaccessible areas.

Therefore, on the assumption that a precise geometric correction process or image rectification by using GCPs was performed precisely, we can add the average value of $adjUTM$ in the accessible area to UTM coordinates of the inaccessible area

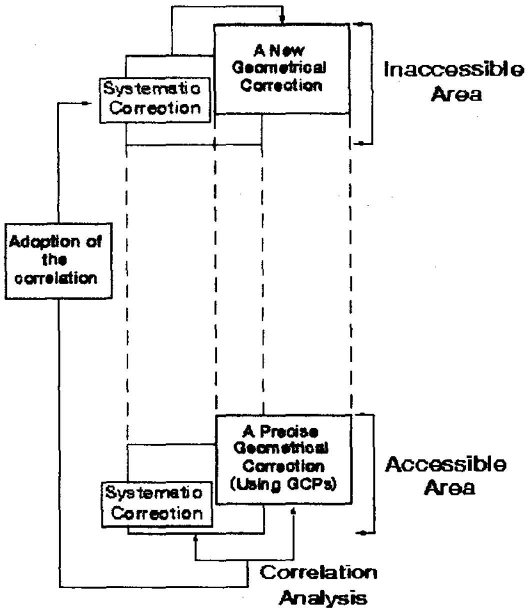


Fig.11 A new geometrical correction method

KOMSAT-1 EOC images that is georeferenced with the improved systematic correction by using ephemerides and adjusted attitude Euler angles.

$$NewUTM = UTM(I.S.C) + adj\Delta UTM(average) \quad (5)$$

where $adj\Delta UTM(average)$ is an average of absolute position error in the accessible area, $UTM(I.C.S)$ is UTM coordinates of the inaccessible area image corrected by using improved systematic correction method, the ***NewUTM*** means UTM coordinates of the inaccessible area image corrected by using a newly developed correction method. Note that a new correction method is effective on the same along-track direction. Fig.11 shows a new geometric correction method for inaccessible area imagery.

7. Results

To verify absolute position accuracy of the inaccessible area KOMPSAT-1 EOC images corrected by a new geometric correction method, we compared UTMcoordinates of images corrected by using the new correction method with UTM coordinates of images corrected by using GCPs. The latter were assumed that they could be obtained through GPS survey or Total Station instruments

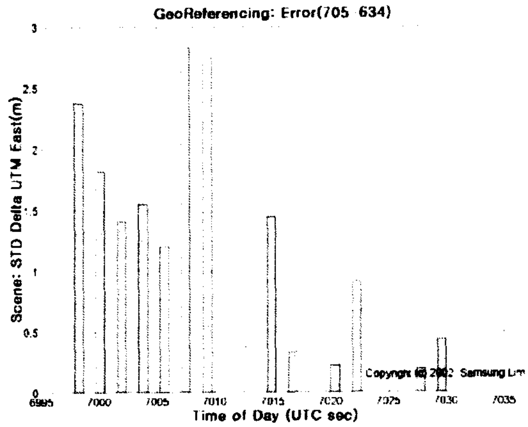


Fig.12 Standard deviation of absolute position errors of UTM East

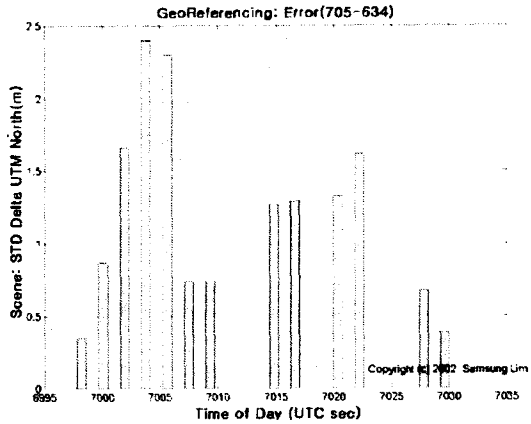


Fig.13 Standard deviation of absolute position errors of UTM North

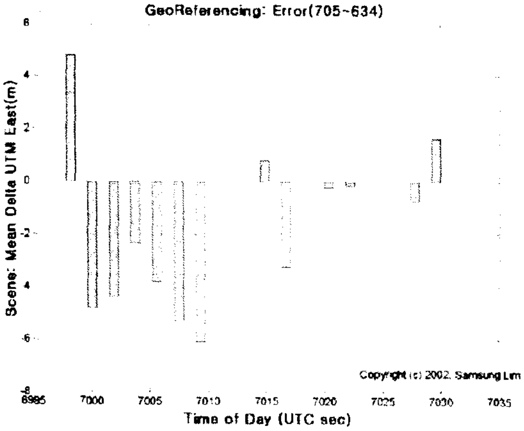


Fig.14 Average of absolute position errors of UTM East

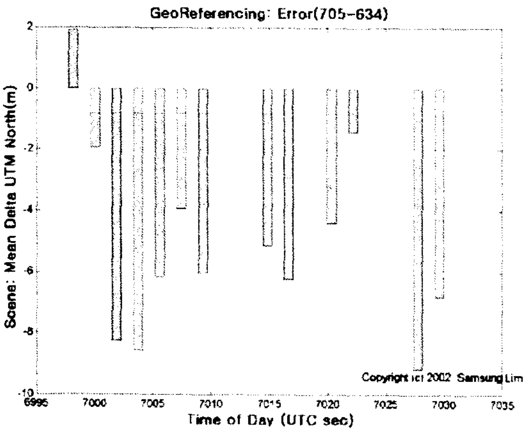


Fig.15 Average of absolute position errors of UTM North

directly in the inaccessible area.

Fig. 12 and 13 show the standard deviation of absolute position errors of UTM coordinates ranged less than 3.0m of each inaccessible area images corrected by the new method.

Fig. 14 and 15 show the average of absolute position errors ranged less than 10m in the inaccessible area image.

8. Conclusions

This paper showed a new geometrical correction method for inaccessible area imagery. First, we monitored ephemerides and attitude data and then adjusted the bias of attitude data. The study area images were corrected by using systematic correction method. To improve the absolute position accuracy of inaccessible area images georeferenced in UTMcoordinates, we computed average of absolute position errors between the two images corrected by each method in the accessible area. Then we added the value to UTMcoordinates of each pixel of the KOMPSAT-1 EOC images corrected by the systematic correction. As a result, we could obtain high accuracy KOMPSAT-1 EOC images corrected geometrically.

Acknowledgments

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