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지상 제어점 결정을 위한 스캐닝된 지도의 이용 가능성 연구

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On Feasibility of Using Scanned Maps for Ground Control Point Marking

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Abstract

This paper presents a GCP marking technique using scanned maps. Twelve maps with a scale of 1:250,000 were scanned and stored as raster images. The distortion factors of scanned maps were modelled by polynomials. The coefficients of the polynomials were determined by a least square fit.

This technique does not require a bulky and expensive digitizing table so that it is suitable for a low-cost pre-processing system. The GCP marking using this technique showed a sufficient accuracy for KITSAT 1, 2 narrow camera images.

keywords : scanned map, ground control point, geometric correction.

요 약

이 논문에서는 스캐닝된 지도를 이용하여 지상 제어점(GCP)을 결정하는 기술을 소개하려

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한다. 이를 위해 1:250,000축척 지도 12장을 디지탈 스캐너로 읽어들여 비트맵 영상 형식으로 저장하였다. 읽혀진 지도의 기하학적 왜곡 패턴은 다항식의 모델로 성립되었고 그 다항식의 계수는 최소 자승법으로 결정되었다.

이 방법은 부피가 크고 값비싼 digitizing table을 사용하지 않으므로 저가 전처리 시스템 개발에 아주 유용하다. 이 방법으로 결정된 GCP는 우리별 1, 2호 소역 영상의 기하학적 보정에 충분한 정확도를 보여주었다.

1. Introduction

Accurate geometric correction of remotely sensed images is crucial to many applications which require accurate positional information of targets-of-interest in images. Systematic correction of raw images implies geometric errors due to many unknown parameters during the image acquisition such as positional and attitude errors of a satellite (Shin, 1993). High precision geometric correction can only be achieved by using Ground Control Points(GCP) (Moreno and Melia, 1993). A GCP is a point on the surface of the Earth where both image coordinates and map coordinates can be identified.

At present, GCPs are determined mostly by using paper maps on a digitizing table. A digitizing table is very costly and hence it is not suitable for a low-cost pre-processing system. In addition, paper distortion prevents GCPs from being determined accurately. Although a paper map is attached firmly to a digitizing table, paper distortions occur whenever a GCP is marked on the paper. Reference points (generally four corner points) on a paper map have to be marked whenever a map is put on a digitizing table. Moreover, an operator has to move between a digitizing table and a computer screen in order to determine GCPs on a map and in an image.

The GCP marking technique using scanned maps improve the aforementioned disadvantages. Firstly, a costly digitizing table is not required. Once the distortion factors of a scanned map are determined, there is no unpredictable map distortion since a scanned map image is displayed on a computer screen. More accurate GCP positions can therefore be determined. In addition, an operator stays in front of a computer screen marking GCPs in a remotely-sensed image as well as on a scanned map image. A scanned map displayed on screen can be enlarged to any scale so that more accurate GCPs can be determined by an operator.

This paper describes the GCP marking technique using scanned maps on an operational level. This technique has been developed as a part of the project named "KIMS" (KITSAT Image Mosaic System) (Shin, 1996a). KIMS is a pre-processing and mosaic software package for KITSAT 1, 2 images. It has been developed by the remote sensing system development team of the Satellite Technology Research Center, KAIST. It is a user-friendly menu-driven software which performs radiometric correction, geometric correction and mosaicking of geometrically corrected images. The GCP marking capability is a key part of the geometric correction algorithm.

Section 2 describes the preparation of scanned maps. The GCP marking method in KIMS is described briefly in Section 3. In Section 4, the accuracy of the determined GCPs is presented and Section 5 concludes the paper.

2. Map preparation

2.1. Map scanning

KITSAT-1 and KITSAT-2 each has two cameras on board (Lee *et al.*, 1996). Their characteristics

Table 1. The characteristics of the cameras mounted on KITSAT-1 and KITSAT-2.

	KITSAT-1 narrow angle	KITSAT-1 wide angle	KITSAT-2 narrow angle	KITSAT-2 wide angle
resolution	400 m	4 km	200 m	2 km
coverage	230km × 230km	2300km × 2300km	115km × 115km	1150km × 1150km
spectrum	black/white	black/white	black/white	color

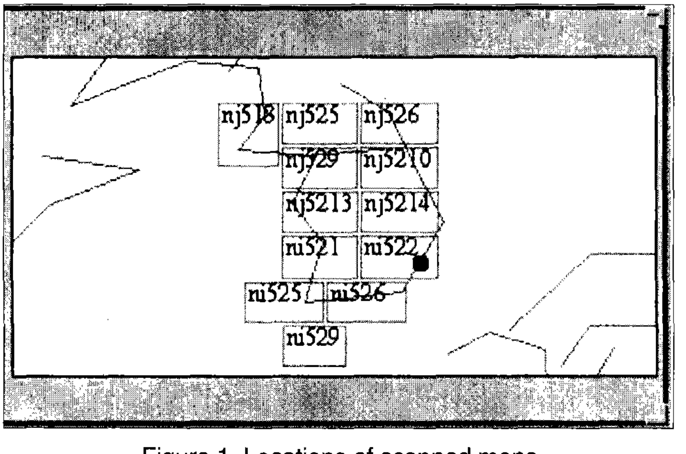

Figure 1. Locations of scanned maps

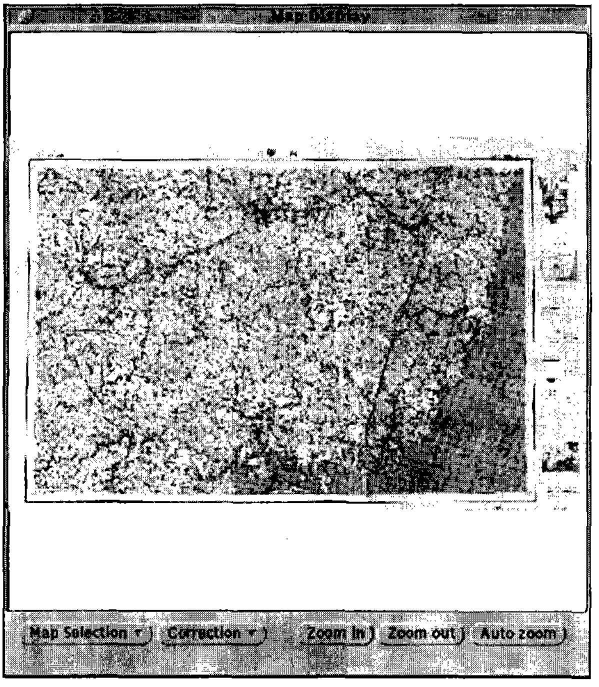

Figure 2. A scanned map displayed on screen.

are summarized in Table 1.

Twelve maps with the scale of 1:250,000 were scanned to raster images taking into consideration the resolutions of the KITSAT 1, 2 narrow images. They cover the South Korean Penninsula including Cheju island. They were projected by using the Transverse Mercator (TM) method. Figure 1 shows the geographical location of the twelve maps.

The maps were scanned by an Intergraph Eagle 3600 scanner with a resolution of 150dpi which resulted in approximately 4650×3000 pixels for each map (14Mbytes per map). This resolution corresponds to 42.3 m in ground scale ($1/150 \times 0.0254 \times 250000$). Figure 2 shows a scanned map (Masan area) displayed on a computer screen.

2.2. Distortion factor determination

Once the maps were scanned, the distortion factor had to be determined because the maps could have been rotated or folded while being scanned. First of all, a TM to lat/long (latitude/longitude) conversion function and vice versa were implemented. The direct transformation from lat/long to TM coordinates is (SERI, 1995):

$$X_{TM} = \frac{1}{2} Rk_0 \ln \left[\frac{(1+B)}{(1-B)} \right] \quad \text{(1)}$$

$$Y_{TM} = Rk_0 \left[\tan^{-1} \left(\frac{\tan \varphi}{\cos(\lambda - \lambda_0)} \right) - \varphi_0 \right]$$

where (X_{TM}, Y_{TM}) are TM coordinates, (φ, λ) are lat/long, $B = \cos\varphi\sin(\lambda-\lambda_0)$, k_0 is a scale along a central meridian, λ_0, and φ_0 is a central parallel. In the above equation, the Earth was modeled as a sphere and R is the radius of the Earth. The geometric errors caused by the spherical Earth model which is an approximation of the more accurate but more complicated Earth model, spheroid, were very small and were considered as part of the distortion factor. The inverse transformation would then be:

$$\varphi = \sin^{-1} \left[\frac{\sin D}{\cosh \left(\frac{X_{TM}}{Rk_0} \right)} \right], \quad \lambda = \lambda_0 + \tan^{-1} \left[\frac{\sinh \left(\frac{x}{Rk_0} \right)}{\cos D} \right] \quad \text{(2)}$$

where $D = Y_{TM}/(Rk_0) + \varphi_0$.

The distortion factor of each scanned map was determined by the first order polynomials, i.e. affine transformation, which take into account the distortions caused by the shift, the stretch/shrink and the rotation of the map scanning:

$$\begin{bmatrix} X_{TM} \\ Y_{TM} \end{bmatrix} = A \begin{bmatrix} X_m \\ Y_m \end{bmatrix} + B = \begin{bmatrix} a_1 & a_2 \\ b_1 & b_2 \end{bmatrix} \begin{bmatrix} X_m \\ Y_m \end{bmatrix} + \begin{bmatrix} a_0 \\ b_0 \end{bmatrix} \quad \text{(3)}$$

where (X_m, Y_m) are the coordinates on a scanned map image and (X_{TM}, Y_{TM}) are TM coordinates. The coefficients of the polynomials were determined by using the four corner points of a map as tie points. The TM coordinates of the corner points were obtained from the lat/long of the points using Equation (1). The image coordinates of the corner points were determined by pointing-and-clicking a mouse button on a computer monitor interactively. The scanned map image can be enlarged for easy and accurate determination of the corner point positions. The controllable zoom level of the scanned map display is one of the advantages over the usage of a magnifying lens on a paper map. Figure 3 shows an enlarged corner point of a scanned map on the screen.

The coefficients of the polynomials were then determined from the coordinates of four tie

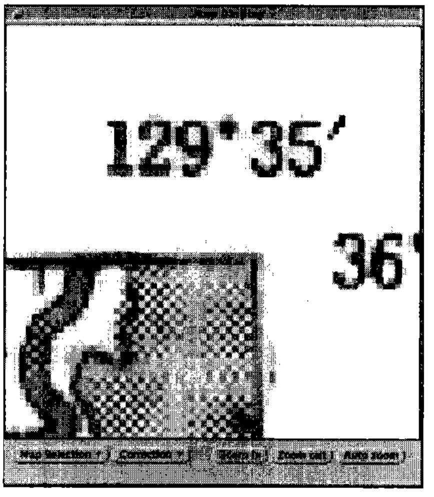

Figure 3. An enlarged corner point of a scanned map.

points. A least-square method was applied.

3. GCP determination

This section briefly describes the GCP marking technique in KIMS (Shin, 1996b). First, a map is selected for a given KITSAT image. A map can be selected automatically so that the selected map contains the sub-satellite point of the image taken. Figure 1 shows the sub-satellite point (a small and dark square) near Pohang and the map containing the point can be selected automatically. However, the sub-satellite point cannot be guaranteed to be within the image frame due to the inaccuracy of the position and attitude of the satellite. A map is also selected manually by indentifying the given image and selecting a suitable map frame in the canvas shown in Figure 1. The selected map is then displayed as shown in Figure 2.

The image and the selected map can be enlarged to any scale in order to assist the operator in marking GCPs with sub-pixel level precision. The zoom-in technique is so simple that the operator may press a mouse button on the upper-left corner of an area of interest and drag the pointer to the bottom-right corner to set a rectangular area in the image or the map. The area is then enlarged to fit the frame. To help the operator identify the corresponding point in the image and the map, KIMS has an auto-zoom function which enables the displayed map to be enlarged to match the ground resolution of the previously enlarged image.

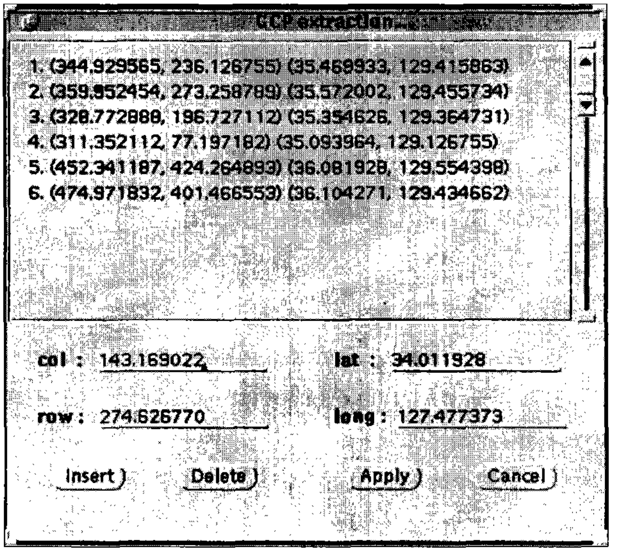

Figure 4. Pup-up window for GCP marking.

The GCP is then marked by pointing to a position in the enlarged image and the corresponding position in the enlarged map. Figure 4 shows a pop-up window in KIMS for the GCP marking. When a point in the image is selected, its column and row are displayed in the window at a sub-pixel level. The lat/long of the selected point on the map is shown in the window as well. Incorrect GCPs can also be deleted by selecting them in the text area in the window and pressing the "delete" button shown in Figure 4. Marked GCPs are displayed on the image and the map by yellow crosses.

4. Residual errors of scanned and transformed maps

As described in Section 2.2, four corner points of a scanned map were marked in order to determine the distortion factor of a map. After obtaining the coefficients of the distortion polynomials, the residual error was calculated as follows. Let (φ_i, λ_i) be the lat/long of a corner point, i = 1, 2, 3, 4. The TM coordinates (X_{TM}, Y_{TM}) were then calculated using Equation (1). The image map coordinates (X_{mi}, Y_{mi}) was obtained from Equation (3) in which the coefficient matrices A and B had already been determined according to the least square method as described in Section 2.2. In this calculations, the number of observations was 8 (4 (x, y) corner points), the number of unknowns was 6 (A, B matrix elements) and therefore the degree of freedom was 8-6 = 2. The RMS error between the calculated image map coordinates (X_{mi}, Y_{mi}) and the corner point positions determined by an operator from an enlarged map, (X_{mi}, Y_{mi}) was then:

$$E = \sqrt{\frac{\sum_{i=1}^{4} ((X_{mi} - x_{mi})^2 + (Y_{mi} - y_{mi})^2)}{4}} \qquad (4)$$

The calculated error was rescaled to the ground resolution taking into account the resolution of KITSAT narrow camera images. The ground-range errors from the GCP marking are shown in Table 2 for each digitized map.

As shown in Table 2, most of the maps provided GCP uncertainties much smaller than the map resolution 42.3 m (Section 2.1) and even smaller than the image resolution (200 m and 400 m). The results of the map 11 and 12 were caused by wobbling of the paper maps during the scanning process. This effect is shown in Figure 5, in which the upper-right corner of the map 12 shows an

Table 2. Residual map errors.

Map	1	2	3	4	5	6	7	8	9	10	11	12
Error(m)	1.901	10.433	12.854	5.665	3.669	0.951	4.784	12.317	0.626	3.542	38.445	52.686

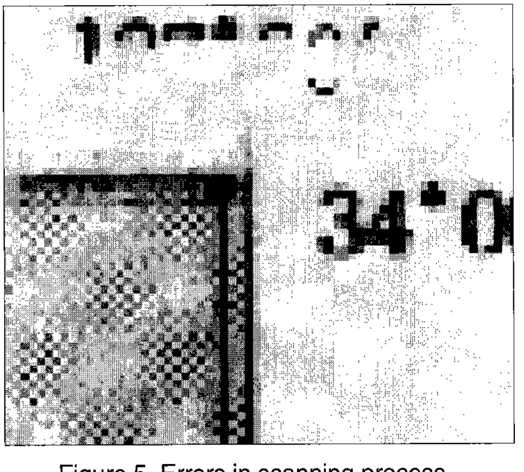

Figure 5. Errors in scanning process.

ambiguity with two vertical lines. The longitude of the corner point was not scanned properly either. In spite of the poor scanning results, the accuracy of 50 m is still at sub-pixel level compared with the resolution of the images.

5. Conclusion and Future plan

This paper presented a GCP marking technique using scanned maps. This technique did not require a bulky and expensive digitizing table so that it was suitable for a low-cost pre-processing system. The GCP marking using this technique showed sufficient accuracy for KITSAT 1, 2 narrow camera images.

A pre-processing system for KITSAT-3 images is currently in development. KITSAT 3 is planned to be launched in mid-1997 and it carries an advanced imaging system, a linear CCD scanner with a spatial resolution of 15 m. In order to use the GCP marking technique presented in this paper for the KITSAT-3 image pre-processing system, 1:50,000 maps are being scanned. Due to the large amount of data, the scanned map will be stored on CCT tapes (e.g. Exabytes). Map files corresponding to the KITSAT-3 images to be geometrically corrected will be restored from tapes.

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