ESTIMATION OF SATELLITE PITCH ATTITUDE FROM ASTER IMAGE DATA

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1. INTRODUCTION

Accurate digital elevation model (DEM) is required in the field of hazard prediction. In producing DEM by aerial photogrammetry, we should remove the influence of aircraft or satellite vibration, especially pitch vibration. The Advanced Spaceborne Thermal Emission and Reflection radiometer (ASTER) is the optical sensor that is installed on Terra satellite and used for producing DEM (ASTER GDEM [1]). To keep accuracy of DEM, the pitch component of the satellite attitude is strictly controlled. However, since sampling period of star-tracker on board the Terra spacecraft is 1.024s, it is believed that there is displacement on ASTER image by satellite vibration with a higher frequency than satellite attitude information [2]. In this study, we analyze ASTER images to verify the influence of the pitch vibration and correct the images themselves.

Our strategy includes three steps. First, we compute displacement by SIFT (scale invariant feature transform) and template matching. Second, we remove the altitude-related disparity from the displacement. Finally, we analyze frequency of the displacement to reconstruct pitch vibration.

2. MATCHING METHOD

Feature based matching such as SIFT has been found useful for image registration in remote sensing [3]. The advantage of SIFT is low computational cost and suitability for multimodality images. However, combined method with area based matching such as MI (mutual information) is often used for keeping registration accuracy [4]. In these methods, for example, they use MI matching before SIFT matching to reduce search area and candidate points, and after SIFT matching to remove outliers. In this study, we use area based matching after SIFT matching to remove outliers.

3. REMOVAL OF PARALLAX

ASTER/SWIR has six line sensors which are spaced at regular intervals (1.33mm) in the along-track direction, so photo opportunity is different from each other. This time lag (360ms) makes line of sight (LOS) vectors in taking pictures of the same target area varied. Because the spatial resolution of ASTER/SWIR is 30m and time for scanning a line is 4.398ms, we can detect the pitch vibration faster than sampling period of star-tracker. Since all of the six line sensors take pictures through an optical system, there are fixed differences of LOS vectors between adjacent sensors. These produce disparities depending only upon height among pitch vibration. Since these differences are constant, we can cancel the disparities like bellow. ($g(t)$:displacement between adjacent sensors, $f(t)$:attitude variation, τ:time lag of taking pictures between adjacent sensors, h:height)

$$g(t) = f(t) - f(t - \tau) + disparity(h) \tag{1a}$$

$$g(t + \tau) = f(t + \tau) - f(t) + disparity(h) \tag{1b}$$

Setting $g(t)$:displacement between band7 and band8, $g(t+\tau)$:displacement between band7 and band8, we compute the subtraction.

$$g(t+\tau) - g(t) = f(t+\tau) - 2f(t) + f(t-\tau) \tag{2}$$

This left part is observable, and value to be obtained is attitude variation $f(t)$. Expression bellow is the Fourier transform of the upper expression, which is computed by multiplying $F(\omega)$ by constant term.

$$\mathcal{F}[g(t+\tau) - g(t)] = (exp(-j\omega t) - 2 + exp(j\omega t))F(\omega) \tag{3}$$

We can obtain $F(\omega)$ by division and $f(t)$ by inverse Fourier transform, additionally.

4. EXPERIMENTAL RESULTS AND CONCLUSION

Fig.1, in which intensity parallels the disparity in along-track direction, shows the satellite attitude jitter. Fig.2 shows the vibration spectrum indicating that there are two major components, one is 0.53 arcsec amplitude at 1.5Hz and the other is 0.26 arcsec amplitude at about 1.0Hz. The former is about 0.06pixel on the ground surface, and causes error of 0.125m on DEM.

In this study, we present the formulation for detecting pitch vibration using satellite images and correcting images using the vibration spectrum. This methodology is applicable for future satellites and optical sensors because a number of those adopt the same alignment as ASTER. This technique is useful for future small satellite of remote sensing mission that requires more lightweight attitude sensor and more sophisticated camera calibration method.

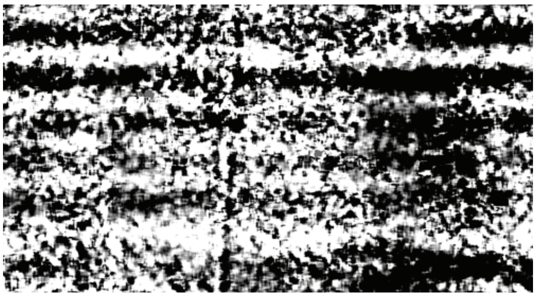

Fig. 1. Image to visualize pitch vibration

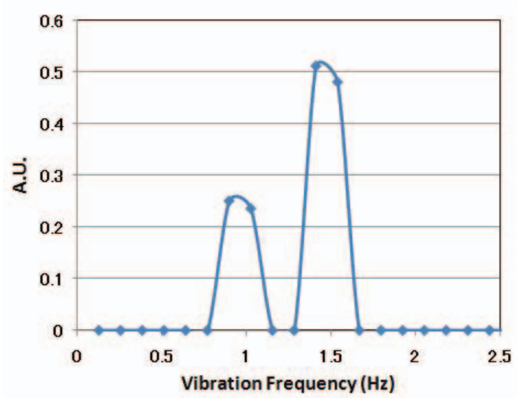

Fig. 2. Spectrum of pitch vibration:$f(t)$

5. REFERENCES

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