Reconstruction of Titan Topography Using CASSINI Radar Images And Generic Stereo Processor

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Introduction: Topographic reconstruction is a high priority task for the solid plane and satellite exploration missions. Laser/radar altimetry and stereo analyses have been widely used for this purpose and achieve high quality 3D topographic data over various planetary surfaces such as Venus, Mercury, Moon and Mars. However, in contrast with inner plane and satellite, the base data sets to compose digital topography over outer planets and satellites are very limited. Titan, the largest satellite of Saturn has also too limited data inventory to achieve sufficient spatial resolution in topographic data, in spite of increasing interests about the detailed topography owing to the recent interesting discoveries on methane fluvial system, aeolian geomorphologies and possible tectonic activity. Therefore the endeavours to increase the coverage of digital topography employing radargrammetry (Kirk et al. 2009) [1], radar altimetry (Elachi, et al. 2005) [2] and SARtopo (Stiles et al. 2009) [3] have been actively conducted. Although these efforts result in the construction of a global topographic map, the consequent spatial resolutions of global topography is still poor and cover the resolution ranges from 520m to 1700m (Lorentz et al. 2013) [4].

In this study, we tried to improve the coverage and the quality of Titan digital terrain model employing approaches as follows; 1) A semi-automated stereo matching scheme manipulating low signal-to-noise SAR image pair incorporating adaptive filtering and base topography, 2) the geodetic control improvement of stereo SAR pair based on generic sensor model and the tie points, 3) introduction of radarclinometry to refine the topography from stereo analyses. The developed scheme was applied for a few testing areas especially over the fluvial channels and the lakes which are only the acting hydrological system in solar system except terrestrial one and well covered by SAR images. The constructed topography revealed many interesting geomorphic features such as drainage networks, rugged terrains and impact craters in detail.

Technical bases: The sensor model of SAR images of Cassini can be represented by Range and Doppler equation. As Basic Image Data Records (BIDRs) are products projected on Titan sphere surface, location of every image point could be calculated with projection formla. Velocity and position of spacecraft, derived from Short Burst Data Records (SBDRs) files, are used to get range and doppler shift values with the nominal ground coordinates. Then, we performed parameter calculation of Rational Function Model (RFM). Refer Kim et al. (2007)[5] for the use of RFM in the planetary mapping. Sensor modelling based on non-rigorous sensor model has distinguished merits as follows

- Easy geodetic control : fewer geodetic control points were required
- Easy application for image matching
- Common sensor model type and application program for all sensors

For the stereo image matching, the improved adaptive algorithms combining with the radarclinometry was employed for finalizing image matching procedure. The overall procedure can be sumrized as shown in Figure 1.

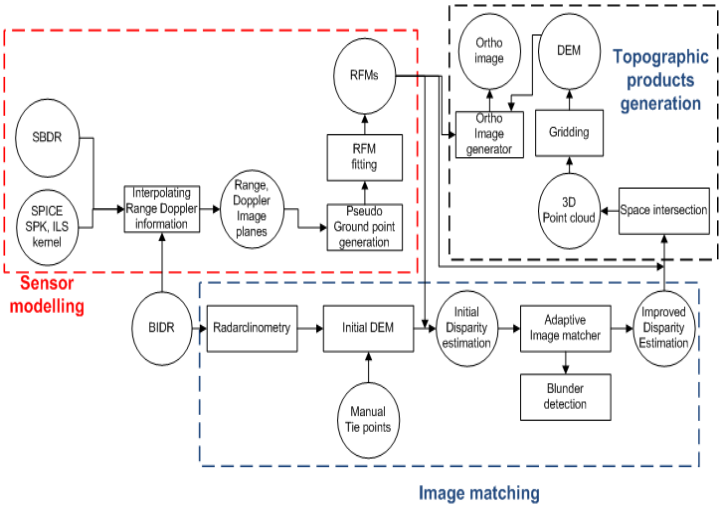
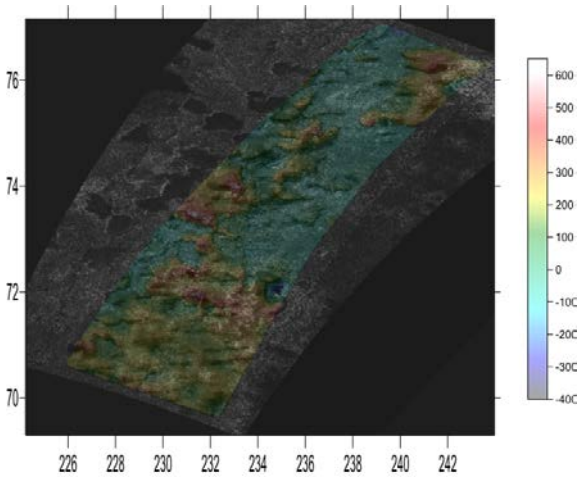


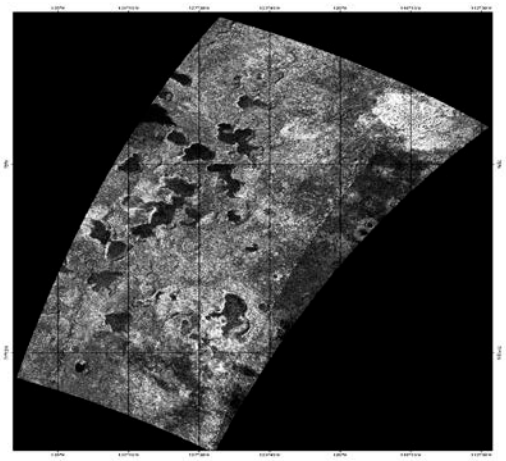
Figure 1. Overall procedures for CASINI stereo radar image processor

Processing results : CASSINI stereo radar processor based on the proposed generalized sensor model and adaptive image matcher constructed topographic data sets over two test sites where the hydrological channels and the lakes are widely populated. Since geodetic controllability is better than 3-4 pixel when the images were projected onto the zero height plane, it was evaluated that the stereo processed using generic sensor model produced stable DTM and ortho image. Estimated max resolution of DTM is 0.7km. Figure 2 and 3 demonstared the products from the established stereo

Conclusion and Future works : It has been proven that CASSINI stereo radar processor employing generalized sensor model and adaptive image matcher effectively reconstruct Titan topography with sufficient accueracy. Since geodetic accuracy of DTMs are consequently guaranteed compared with the known height ranges, it will be possible to apply the constructed DTM for the interpretation and modelling of Titan surface processes. Future extensions and improvements are as follows. Together with the technical improvements to exploit SAR stereo pair, the possibility to mine height information from Visual Infrared Mapping Spectrometer (VIMS) by photoclinometry was actively explored. The introduction of improved radarclinometry considering radar illumination conduction will be further developed, together with, improved image matcher incorporating contouring matching. Once after satifactable performances is achieved, systematic processing of Titan stereo images will be conducted. Overall, to fully demonstrate the potential of these approaches, technical details will be continuously improved and applied over more test areas. On the other hands, extension to Magellan image for Venus stereo SAR processing will be considered.

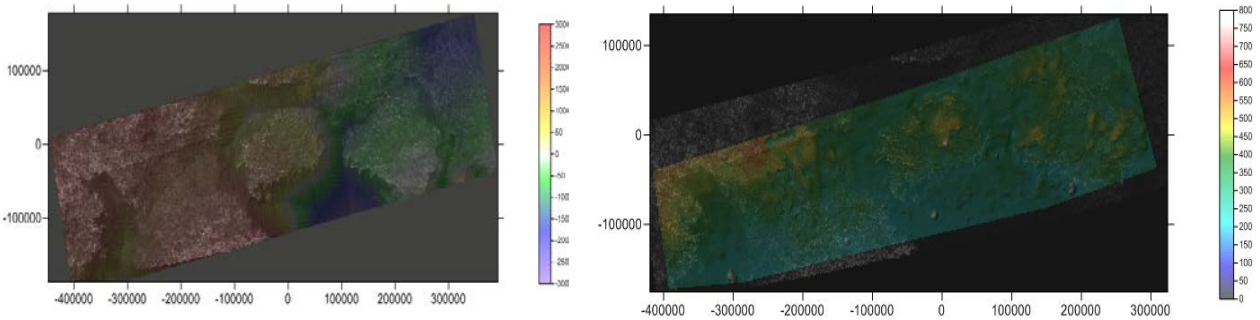


(a) Stereo DEM by space intersection (500m) by T16-T19 pair



(b) Orthorectification and mosaic of T19 and T16 using RFM

Figure. 2. T16-T19 pair analysis result using CASSINI stereo radar image processor



(a) Hill shaded images based on radarclinometry of T25 image

(b) Hill shaded images based on stereogrammetry of T25-T29 pair image

Figure. 3. T16-T19 pair analysis results using CASSINI stereo radar image processor

References: [1] Kirk, R. L., Howington-Kraus, E., Mitchell, K. L., Hensley, S., & Stiles, B. W. (2007). In *38th LPSC abstract* (Vol. 1427). [2] Zebker, H. A., Gim, Y., Callahan, P., Hensley, S., & Lorenz, R. (2009). *Icarus*,*200*(1), 240-255 [3] Stiles, B. W., Hensley, S., Gim, Y., Bates, D. M., Kirk, R. L., Hayes, A., ... & Veeramacheneni, C. (2009). *Icarus*, *202*(2), 584-598. [4] Lorenz, R. D., Stiles, B. W., Aharonson, O., Lucas, A., Hayes, A. G., Kirk, R. L., ... & Barnes, J. W. (2013). *Icarus*,*225*(1), 367-377. [5] Kim, J-R., Muller, J-P., Balme, M., Murray, J.B., (2007) In *38th Lunar and planetary lunar and planetary science conference, Houston*