ASSESSMENT OF ALOS PRISM DIGITAL ELEVATION MODEL EXTRACTION OVER JAPAN

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ABSTRACT:

This article presents technical work done with DAICHI ALOS PRISM data in order to assess the feasibility and quality of Digital Elevation Model extracted from ALOS PRISM triplet of images. Thanks to its configuration, the PRISM instrument is capable of simultaneous stereoscopic acquisition of the observed landscape which should easier the automatic processing of such data for Digital Elevation Model extraction. By analyzing ALOS data available over an area in Japan, with other reference information, this article will present both the current possibilities available with PRISM data and their limitations.

1. INTRODUCTION

Remote sensing and earth observation satellites are nowadays used in a broad range of applications: mapping, resource management, simulation, risk and disaster management, and recently on online geo-applications such as GoogleEarth or equivalent. A good example of the healthy situation of this spatial industry can be derived by the successful launch of many earth observation satellites during the last two years, and upcoming launch on new satellites, such as WorldView-1, DAICHI, CBERS, TERRASAR-X, KOMPSAT-2, THEOS, PLEIADES and so on.

Considering the specific case of DAICHI (Advanced Land Observing Satellite: ALOS) satellite, it has been successfully launched on the 24th of January 2006 by the H-IIA #8 at Yoshinobu Launch Complex located in JAXA's Tanegashima Space Centre, Japan. The objectives of the ALOS are mainly cartography in small scale, regional observation for "sustainable development", disaster monitoring, and resources surveying, around the world. To realize them, ALOS took sun synchronous sub recurrent orbit, and the platform comprises of three different instruments: two optical sensors (AVNIR and PRISM) and one SAR sensor (PALSAR). AVNIR instrument is mainly designed for multispectral optical data collection for land observation. PALSAR instrument, L-band Synthetic Aperture Radar, is aimed for day-and-night and all-weather land observation. PRISM panchromatic instrument has been designed mainly for mapping purpose with a specific aim towards Digital Elevation Model extraction. Indeed, PRISM is capable of simultaneous stereoscopic acquisition of the observed landscape which should easier the automatic processing of such data for Digital Elevation Model extraction. However few studies have already been done concerning the qualitative validation of PRISM (Tadono T. and all, 2004) stereoscopic acquisition with respect to Digital Elevation Model extraction. One reason may be the recent commercial availability of PRISM data along with geometric information provided as RPC models. Another reason may be the short list of available digital processing solution which can generate high quality Digital Elevation Model from PRISM stereoscopic acquisition.

Concerning Digital Elevation Model extraction and automatic processing of stereoscopic images, a full range of different methods are available and have been already published such as automatic window-based correlation, least-square matching-based correlation, feature-based matching and so on. However, few of these techniques have been fully implemented into an operational production tool which can be used on large dataset. In order to take as much benefit of a large coverage of simultaneous stereoscopic acquisition as possible, automated production tools should be used in order to remove burden of manual processing and easier management of large dataset. Indeed, an integrated and automated system for Digital Elevation Model processing will take the most benefit of ALOS PRISM data collection. As a matter of fact, the proposed analysis of this article will be conducted by using one of such digital software package which offers an extensive automated framework to process digital aerial and satellite data. Moreover, results will present a qualitative analysis of PRISM Digital Elevation Model compared with reference data on the same area.

2. ALOS PRISM INSTRUMENT

As introduced previously, the PRISM instrument (JAXA, 2007) is capable of simultaneous stereoscopic acquisition of the observed landscape thanks to its three panchromatic cameras with a resolution of 2.5 meters at nadir angle. Each camera consists of several CCD detectors to achieve a large number of detectors per line (14.000 for the backward / forward cameras and 28.000 for the nadir camera).

Geometric information about the ALOS platform is available in addition to RAW images in order to rigorously model the sensor geometry and to achieve high accuracy measurements from these instruments.

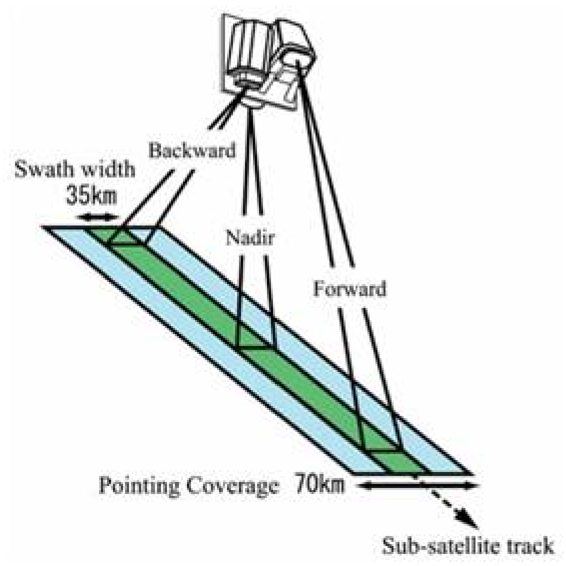

Figure 1: PRISM acquisition geometry (© JAXA EORC)

3. EXPERIMENT DESCRIPTION

3.1 Dataset

The test site, Kanagawa prefecture, is located on the western side of Tokyo metropolitan area. It is a good mix of mountainous area (i.e. Tanzawa), major cities (i.e. Yokohama), and medium cities (i.e. Sagamihara etc.), bay (i.e. Sagami bay), etc. We can observe hill zone in the eastern part, and low-lying area in the center part. Concerning the southwest parts, there is a foothill of Hakone volcanic region.

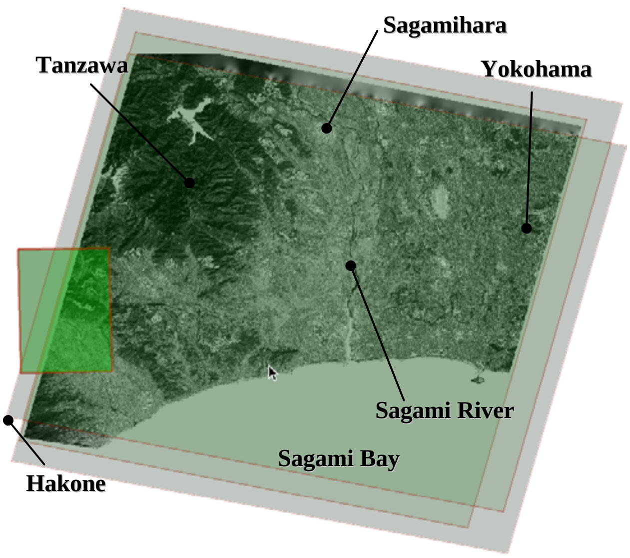

Figure 2: PRISM data and overlapping IKONOS data on west

As illustrated by previous figure, dataset is comprised of a triplet of PRISM images, along with IKONOS images in order to check accuracy of the extracted information. Moreover an aerial orthoimage mosaic was used to help in the accuracy assessment.

3.2 Methodology

Accuracy assessments conducted in this article focus mainly on the quality of automated Digital Elevation Model extracted from PRISM triplet of images. In order to conduct such validation, workflow using Pixel Factory software (F. Bignone, 2003) has been investigated.

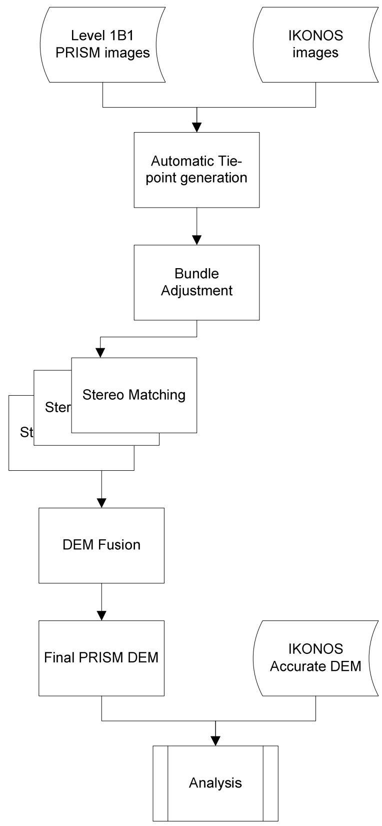

Figure 3: PRISM Digital Elevation Model validation workflow

The Pixel Factory software package offers a rigorous push broom sensor model for ALOS, without any approximation. It means the available sensor model take into account all the physics involved in line scanning acquisition. By using external geometric information provided in the level 1B1 of PRISM data, it is then possible to take most benefit of the satellite a-priori spatial localization and to correct images from all geometric distortion induced by the push-broom, line-scanning, acquisition. Concerning the stereo-matching algorithm used in this software package, it is a multi-resolution matching algorithm with sub-pixel accuracy. Fusion of height information extracted from different views is then realized in order to increase accuracy and robustness of all height measurements. By combining this matching and fusion algorithms, it is then possible to extract automatically dense Digital Elevation Model from multiple stereoscopic images with higher accuracy.

Using previous described reference dataset, statistical analyses of PRISM performance for Digital Elevation Model production will be conducted on overlapping area. Qualitative analysis of PRISM imagery will also be provided on the complete coverage of available dataset.

4. RESULTS

4.1 PRISM Image quality

PRISM images showed some radiometric artifacts that can be categorized in two different groups: black reference calibration between detectors, and image compression artifacts.

The first category of radiometric artifact visible on the PRISM image is induced by an incorrect calibration of each CCD sensors, resulting in column stripes with different inconsistent illumination. It has been reported by some scientist with early PRISM images (Wolff K. and al. 2007). However, it looks like JAXA is now providing better images as this artifact is no more visible in images currently available.

Second category of radiometric artifact seems to be induced by on-board image compression which uses a loss compression scheme (like JPEG compression scheme). It is impossible to correct this artifact through some post-processing algorithms as some information in the initial image has been lost. This artifact can have a bad influence on the stereo-matching algorithm as it will introduce some false patterns that may confuse the matching process, as shown in next figure.

Figure 4: Block artifacts in zoomed window

A side-effect of this compression artifact is also some geometric distorsion in the image. It can be seen along some image blocks (8 pixels width) on a complete stripe of pixels. As illustrated by the next figure, this artifact seems to induce some local geometric image distortion: blocks of images are shifted by few fractions of pixels. As previous artifact, this will also have a bad influence in the matching process.

Figure 5: Geometric distortion inside highlighted rectangle

4.2 Geometric quality assessment

By computing individual Digital Elevation Model between all pairs of images (backward, nadir and forward) and analyzing them, it was possible to highlight some repeating undulations in the resulting elevation images as illustrated by the following figure.

Figure 6: Undulation observed in resulting elevation image

These undulations are probably resulting from vibrations of the satellite platform that are not well measured and not available in the ancillary geometric information provided with Level1B1 data. Those vibrations have an impact on the resulting elevation image of 3 meters (with a frequency of 8 Hertz) and 1 meter (with a frequency of 93 Hertz).

4.3 Digital Elevation Model extraction

In order to have a consistent comparison between Digital Elevation Model from IKONOS and ALOS dataset, the bundle adjustment has been done with all data together. This prevents from introducing position bias error between the resulting elevation images.

In order to attenuate effects of undulation illustrated in this article, and also false matching due to the radiometric artifact, it seems important to merge individual elevation measures with an output posting around 10 meters (from initial GSD of 2.5 meters). Resulting merged elevation image will provide better robust and accurate elevation measures. Next figure show the resulting Digital Elevation Model for those datasets.

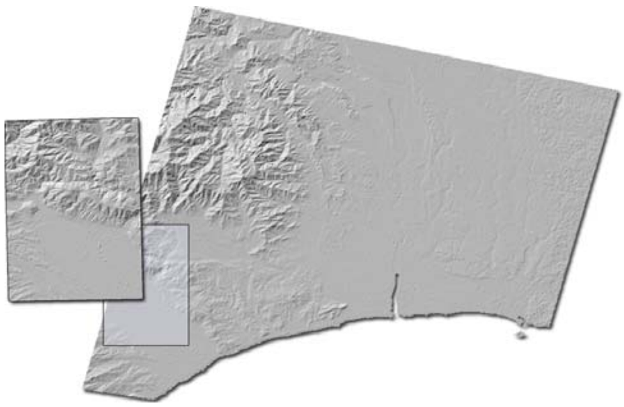

Figure 7: ALOS PRISM DEM and overlapping IKONOS DEM

Statistical analysis of IKONOS and ALOS DEM shows a standard deviation around 4.0 meters which is consistent with ALOS PRISM DEM expected accuracy and IKONOS known altimetry accuracy. When partionning this statistical analysis between mountainous area and plain areas, we end-up with standard deviation around 2.3 meters for plain area, and 5.2 meters for mountainous area. Those results are consistent with other reports (Wolff K. and all, 2007) available in the scientific literature about PRISM derived DEM.

	Statistics		
	# points	**Bias (m)**	**RMS (m)**
Global	539670	0.28	4.07
Mountains	271110	0.13	5.24
Plains	269465	0.43	2.34

Table 1: Height accuracy of PRISM DEM

Due to the limited size of our overlapping reference dataset, it was not possible to conduct this statistical analysis all over the area. Nevertheless, the overall DEM shows a consistent rendering of the landscape without major artifacts, except those already mentioned.

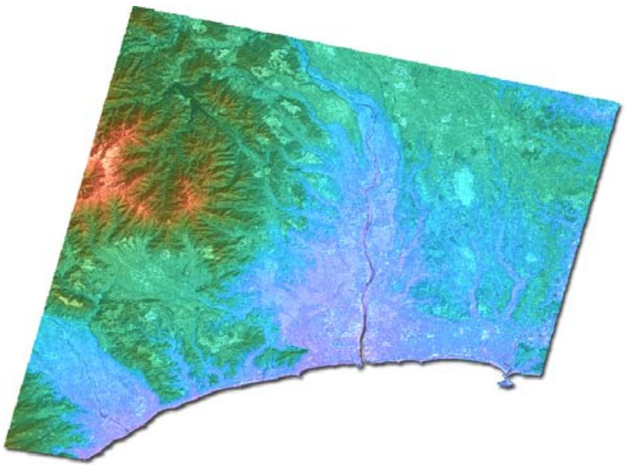

Figure 8: Overlay of PRISM orthoimage with PRISM DEM

5. CONCLUSION

Despite the quality of initial input images, it is possible to extract globally accurate dense terrain elevation information from PRISM data. However, some local artifacts are still preventing from precise local stereoscopic measurements which are only overcome by merging multiple elevation information derived from the different views of PRISM triplet acquisition. Variations have been measured inside the resulting DEM and a more systematic analysis of multiple PRISM acquisition is certainly needed in order to assess rigorously origins of such vibration.

The software package used for this validation process named Pixel Factory proves its robustness as generated Digital Elevation Model had few blunders, even with strong radiometric artifacts inside the input PRISM images. All results shown in this article were done on full automated extracted DEM, without any manual filtering.

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