AUTOMATIC IMAGE ORIENTATION AND DSM EXTRACTION FROM ALOS-PRISM TRIPLET IMAGES

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ABSTRACT

The Japanese satellite ALOS carries the PRISM sensor, composed by a triplet line scanner, which is dedicated to the extraction of relief data by stereoscopic means. It has a spatial resolution of 2.5 m and a base-height ratio of 1 between Forward (FWD) and Backward (BWD) images. PRISM is intended to produce elevation data according to the positional accuracy standards of topographic maps of scale 1:25,000 [1]. Although the extraction of a digital surface model (DSM) can be largely automated by means of digital image matching, the image orientation requires the use of ground control points (GCPs) which must have positional accuracy better than the image ground sampling (2.5 m). GCPs with these characteristic will normally have to be acquired in the field, by GPS survey. This may be difficult or very expensive especially in remote areas were remote sensing is important for topographic mapping purposes.

This paper describes a methodology for a fully automatic image orientation and DSM extraction. It uses the SRTM (Shuttle Radar Topographic Mission) DSM, as a ground control surface, instead of conventional GCPs. The SRTM-DSM covers about 80% of the earth land mass, in a resolution of 3 arc-seconds (approximately 90 meters at the equator). Although it has a much smaller resolution and poorer accuracy than what can be obtained from ALOS-PRISM stereo imagery, the SRTM-DSM proved to be appropriate, by means of surface matching, to calibrate the ALOS image orientation, both in horizontal and vertical terms.

Typical procedures for ALOS PRISM photogrammetric processing require images in original sensor geometry (levels 1A or 1B1). The method presented here is applicable to images of level 1B2, which are the most frequently available for users. Images of this level went through a geometric correction, by projecting from image space to the ground, assuming the terrain to coincide with the reference ellipsoid WGS84. Since approximate exterior orientation (position and attitude) derived from on board navigation instruments is very accurate, of the order of 10 meters [2], the Nadir image (NDR) is nearly correctly georeferenced. For points on the NDR image the displacement due to terrain elevation can be predicted with good accuracy using an approximate value of the height. The remaining error in is due to the uncertainty in the sensor attitude.

A matching program based on correlation was developed to be used in two situations. One is to obtain a few points for correct registration of BWD and FWD images to the NDR image space. In this case the search for conjugate points is done in two dimensions. The second situation is for actual disparity determination, which is done in one dimension, along epipolar lines.

The method for DSM generation comprises the following steps:

- Step 1: To register images FWD and BWD onto the NDR image. This is done by means of the affine transformations (projection from image space to UTM coordinates) given for the three images.
- Step 2: Image matching - a least squares matching with region growing (BLUH software, Jacobsen, 2009) was used to obtain conjugate points between image pairs NDR+FWD and NDR+BWD. A window of 10 pixels and a tolerance of 0.8 for the correlation coefficient were used to extract one conjugate point at every 4 pixels (a 10 meter grid). Only those points that were matched on the three images were kept.
- Step 3: The matched points show a very small systematic shift in x direction (up to 3 pixels in the tests carried out). After eliminating a few wrong matches, with very large difference, these shifts were determined, with an accuracy of 0.3 pixels.
- Step 4: The disparities in y direction (py) between FWD and BWD images were used to calculate approximate heights (h). At this stage a factor of 2.504, calculated from the nominal FWD and BWD sensor incidence angles, was used: h=2.504*py.
- Step 5: From the NDR image coordinates of the matched points the corresponding terrain coordinates (in UTM projection) are calculated. They include a correction of the relief displacement estimated from the approximate height determined in the previous step.
- Step 6: From the extracted 3D coordinates a DSM can be calculated. These DSM represents the terrain surface but has horizontal and vertical errors due to the small errors in the sensor exterior orientation. The DSMs normally show some gaps in areas of poor contrast, which is a problem in ALOS-PRISM images.
- Step 7: Correction of the horizontal error - a surface matching is done to the SRTM-DSM, which is known to be possible with an accuracy of around 5 meters [3]. This can be done for small patches (e.g. 4 km by 4 km), where local displacements in Easting and Northing are determined.
- Step 8: Correction of the vertical error - the relation between disparities and heights used in step 3 requires a calibration. Now that the horizontal calibration was carried out the corresponding heights taken from the SRTM-DSM can be used in order to determine a calibration between y-disparities and heights. Figure 1 shows a plot of a set of a few thousand points. A linear relation could be determined by least squares fitting to the points.

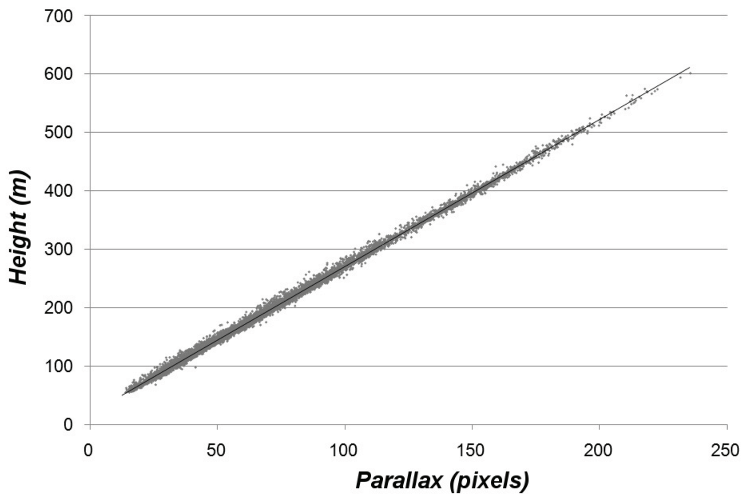

Figure 1 – graphical plot of height vs. parallax, and best line fit, for heights obtained from the SRTM DEM

This methodology was tested with a set of three ALOS-PRISM images of Portugal. Verification of horizontal and vertical errors of the resulting DSMs was done with independent check points surveyed on the field, using GPS, and with data taken from large scale topographic maps (1:2,000 scale). In general a horizontal accuracy of 3 to 4 meters could be achieved. For well defined points on the ground, heights could be determined with an accuracy of 2 meters, which agrees with published results where GCPs and photogrammetric sensor models were used. These results are well within the accuracy requirements of topographic mapping scale 1:25,000. The method has the main advantage of being possible to apply to large number of images without GCPs and with small user intervention.

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