GENERATION OF DIGITAL ELEVATION MODELS WITH HIGH-RESOLUTION OPTICAL SATELLITE IMAGES

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ABSTRACT

The SPOT family of satellites is made up of a constellation of Earth observation satellites. SPOT satellites have the ability to capture stereoscopic images of the same portion of land, which allows the extraction of digital elevation models (DEM). This paper describes the process for extracting DEMs from SPOT-6 satellite images, which increase the ability to obtain results with higher resolution at a scale of 1/10,000; the study area includes the province of Caylloma in the department of Arequipa. The digital model obtained will be used later in the generation of interferograms to detect changes and/or deformation in the Maca landslide.

KEYWORDS: *Interferogram, Photogrammetry, Lidar, Stereo pair, Epipolar geometry*

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INTRODUCTION

A digital elevation model is a visual and mathematical representation of the height values with respect to the average sea level, which allows characterizing the shapes of the relief and the elements or objects present in it. Such digital models (DEM) represent in a simplified way the variables measured by a three-dimensional undulating surface (Forest 1997). Two of these dimensions refer to the orthogonal axes X and Y and the third measures the height Z of the thematic variable represented at each point in space (Bosque 1997). Digital elevation models are the basis for any geographic information system, and are essential in geomorphological, hydrological, geological, vulnerability, and telecommunications studies, among others.

There are various ways to obtain a DEM, either by applying point data interpolation, from digitized level curves, by extracting them from stereoscopic pairs of aerial photographs or satellite images by photogrammetric procedures, from radar images by interferometry or more recently by Lidar.

Digital photogrammetry uses image comparison techniques to estimate the elevation of objects in the field from stereo pairs. Subsequently, the creation of DEMs focuses on automatic processes that maximize the computational resources available today.

Two satellites, the SPOT family, are launched into orbit, one in 1986 and the other in 1990, with several earth stations receiving data. The main characteristic that distinguishes them is their lateral rotation capacity, which increases the temporal resolution, being able to observe any point of the terrestrial surface with a periodicity of between one and several days. This makes it possible to generate stereoscopic pairs of the observed zone, these data are contained in a file of type raster with regular structure, such elevation models (DEM) are generated using computer equipment and specialized software.

METHODS Y MATERIALS

STUDY ÁREA

The present study was carried out with SPOT-6 satellite images, which mainly cover the Sabancay volcano, and a part of the Colca Canyon where the Maca, Lari landslides are located, in the province of Caylloma in the department of Arequipa ($71^{\circ} 52' 12.09''$ W, $15^{\circ} 44' 20.33''$ S), is an Andean mountainous area characterized by a range of heights that varies between 100m and 3000m, its orography is quite irregular with slopes that vary between 0° and 84° with the presence of water filtrations which are embedded at the foot of the slides, overloading the slope and favoring the slide. This zone is mainly characterized by the presence of areas of cultivation such as corn, quinoa, kiwicha, potatoes and others.

Figure 1 : Preliminary Evaluation of damages

EXTRACTION OF DIGITAL ELEVATION MODELS

In general, to extract the digital elevation model it is necessary to perform the process summarized below

Figure 2 : Diagram of the extraction of digital elevation models

ACQUISITION OF STEREOSCOPIC IMAGES OF THE STUDY AREA

The CMG gyroscopes allow the execution of quick maneuvers in all directions to observe several areas of interest in the same pass (30° in 14 s, including the stabilization time). Forward and backward stereocapability - Stereo and tri-stereo in one pass.

The coverage of the SPOT-6 scene for this work is 30Km by 50Km. These images capture information simultaneously in the 5 bands of the electromagnetic spectrum, Panchromatic: 0,450-0,745 μ m Blue: 0,450-0,520 μ m Green: 0,530-0,590 μ m Red 0,625-0,695 μ m Near Infrared: 0,760-0,890 μ m.

Pairs and trios of stereoscopic images captured in a single pass and in the same orbit are used to generate DEM data. The SPOT-6 satellite can acquire pairs and trios of images over the areas of interest with observation angles between two consecutive images that are only 15° or 20° apart, with a base/height ratio of between 0.27 and 0.4.

Figure 3 : SPOT 6 images shooting range

NORMALIZATION OF THE SAME IN ORDER TO OBTAIN EPIPOLAR IMAGES

Before the extraction of the DEM, it is necessary that the stereoscopic pair is transformed into a pair of normalized epipolar images which are parallel to the XY plane of the object space. When transforming the acquired images into epipolar ones, only the parallax in one direction is produced and the corresponding points are aligned in the same row or column. Therefore, the time required to perform the process of superimposing the images, which will then allow the calculation of the magnitude of the parallax and based on it the elevation, is considerably reduced. The normalization of the acquired stereoscopic pair is commonly done by applying epipolar geometry criteria, the process can be summarized in the following points: (Morgan, 2004).

- It begins with the location of a pixel in the normalized image (x_n, y_n).
- The corresponding location in the original image (x_n, y_n) is calculated using the collinearity equations

(equations numbers 1 and 2).

- The gray levels $g(x, y)$ in the original image are calculated using an appropriate interpolation method such as nearest neighbor, bilinear interpolation or cubic convolution.
- The interpolated gray value is assigned to the pixel of the normalized image $g(x_n, y_n) = g(x, y)$.
- The process is repeated for all pixels in the normalized image.
- The process is generally repeated for the other image of the stereoscopic pair.

The relationships between the sensor, the image and the ground can be determined on the basis of the collinearity condition which specifies that the position of the sensor, the point on the ground and its corresponding point on the image must be placed on a straight line, that is they must be collinear.

Figure 4 : Epipolar images taken from SPOT 6 stereo pair images

GEOCODING THE EXTRACTED DEM USING GROUND CONTROL POINT

In the present work we used a SPOT 6 image dated 02 and 28 January 2014 respectively, with a cloud coverage percentage of 5% and the extraction process was carried out applying PCI Geomatics 2014. To extract a georeferenced DEM, it is necessary to have a series of control points (GCPs) with perfectly known position and elevation, from which it is possible to assign real elevation values to each of the pixels of the extracted DEM.

Additionally, in places where no GCP is available, it is convenient to collect points common to both images, which are located interactively on the screen and whose position is known, requiring only an approximate elevation of them. The points contribute to increase the accuracy of the mathematical model used in the extraction of the DEM.

Control points were collected in the field using differential GPS. The points were collected in easily identifiable places in the image and in the field, distributing them throughout the image and covering the altitudinal variation that the study area

presents. With this procedure, approximately 28 points were collected in the field.

Figure 5 : Location of control points and tie points, for the correction of the stereo pair SPOT-6.

The accuracy of the procedure to generate DEM from SPOT images is high given the fact that the collinearity equations on which the algorithms are based allow to obtain a direct relationship between the image coordinates and the target coordinates. In this way, relative orientation and model coordinates are obtained, and calibration parameters can be included in the systematic error adjustment.

RESULTS

In the digital elevation model of the district of Maca obtained, it can be seen that in the lower part of the image, there is no consistency in the relief of the terrain (see Fig. A), due to the fact that there are no reference points in that area, compared to the upper part of the image where the relief of the terrain is more consistent (see Fig. B), and it is precisely where most of the control points were placed.

Figure 6 : Digital elevation model (DEM) of 5m spatial resolution obtained from the process with Geomatica PCI 2014 software.

CONCLUSIONS

- One way to improve the quality of stereoscopic data is to reduce the time between the two shots, i.e. by capturing the data simultaneously.
- The capture of control points must be carried out independently of any other previous mapping source and with a high degree of accuracy.
- The extraction of a DEM with good accuracy is subject to the accuracy of the control points used to georeference it.
- The quality of the DEM depends largely on the quality and location of the GCPs
- It is important to take into account the values of the GCP and Tie Point obtained at the time of calculating the errors to obtain a DEM with the adequate quality for the generation of the products derived from it.
- Obtaining digital elevation models as a source of data can be used for orthorectification of satellite images, generation of cartography and data modeling.

REFERENCES

1. Bosque, J., 1997, *Sistemas de Información Geográfica*, Madrid, Riapl.
2. Morgan, M., 2004, *Epipolar Resampling of Linear Array Scanners Scenes*, Ph.D Thesis, University of Calgary.
3. Campbell J., 2011, *Introduction to Remote Sensing*, New York
4. Taylor & Francis Group, 2008, *Advances in Photogrammetry, Remote Sensing and Spatial Information Sciences: 2008 ISPRS Congress Book*, Florida.
5. Wegmüller, U., Santoro, M., Werner, Ch., Strozzi, T., 2009, *DEM Generation Using ERS-ENVISAT Interferometry*, Gumligen, Switzerland
6. Gelautz, M., Paillou, P., Chen, C. W., Zebker, H. A., *A Comparative Study Of Radar Stereo And Interferometry For Dem Generation*, Frascati, Italy.