

# DEM generation from optical satellite stereo

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## 1 Intro

Digital elevation models (DEM), or digital terrain models (DTM) are widely used in research by scientists in governmental, university and private organizations. It is particularly useful for geoscientific applications such as glaciers and rockglaciers, geomorphology and georisk, hydrology, and land cover/ land use (Toutin, 2008). DTMs can, among other things, be used to find where a landslide might originate, locate precipitation zones or find the volume changes of a glacier. All researches based on DTMs will be directly dependent on the quality of the DTM. The quality of a DTM depends on the method of how it was collected and generated. DTM can be generated with InSAR, LiDAR, and with stereoscopy. The last method will be discussed here, and are based on Toutin (2008) and Toutin (2001).

## 2 Generating DEM

Everything we see is in 3D, this is thanks to the fact that we have 2 eyes that catch the light waves from the objects in a slightly different angle. Knowing this, we can create 3D images with the help of 2 cameras, or by taking the picture from two slightly different angles. It is these principles that help us create DEMs with optical satellite stereo. The difference/parallax between the two images will help us find the elevation of an object. In principle, we have 2 methods of achieving stereo photos with satellites. Across-track stereoscopy from two different orbits, and along-track stereoscopy from the same orbit using one downlooking camera (NADIR) and one backlooking. The across-track stereoscopy will have photos taken on different dates, while the along-track stereoscopy photos are acquired within seconds apart from each other. This makes the images more similar, and therefore more suited for image matching.

Image matching is important to find the parallax of objects in the two different photos. The process to extract elevation parallax is applied using the image grey-levels, the image features or a hybrid approach. Toutin (2001) describes the different processing steps to produce DEMs from stereo images in broad terms and follows:

1. to acquire the stereo image data with supplementary information such as ephemeris and attitude data if available;
2. to collect Global Control Points (GCP) to compute or refine the stereo-model geometry;
3. to extract the elevation parallax;
4. to compute the 3D cartographic co-ordinates using 3D stereo-intersection; and
5. to create and post-process the DEM (filtering, 3D editing and smoothing).

### 3 Acquiring data

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is a satellite with both a downward looking sensor, and a backward looking one. ASTER was sent up to obtain high spatial resolution of the earth. The objectives of the along-track stereo experiment were: to acquire cloud free stereo coverage of 80% of the Earth's land surface between 82° N and 82° S, and to produce, with commercial software, standard product DEMs at a rate of one per day (Toutin, 2008). Due to the high temporal resolution provided from ASTER, its stereophotos are now one of the most used in DEM generation. There are several commercial off the shelf (COTS) softwares for processing stereo ASTER data and for generating DEMs. ASTER produces two types of data, level 1A and level 1B. Level 1A is the preferred data by photogrammetrists, and is the only source for generating the higher-level data products like DEMs and ortho-images. It is annotated with a lot of spacecraft ancillary information, such as radiometric and geometric coefficients and georeferencing parameters computed and appended. Level 1B are projected to the map using the radiometric calibration and geometric correction coefficient for resampling. Global Control Points (GCP) are collected in order to obtain a cartographic standard accuracy. GCPs are collected by finding a point in both images where you know the coordinates and/or elevation. The GCPs should cover the full elevation range of the terrain, and to avoid extrapolation in planimetry, it should be spread at the border of the stereo-pair.

### 4 DEM accuracy

Accuracy refers to the closeness of a measured value to a standard or known value, precision refers to the closeness of two or more measurements to each other. When making DEMs, both high accuracy and precision is desired.

## References

- Toutin, T. (2001). Elevation modelling from satellite visible and infrared (vir). *REMOTE SENSING*, 22(6):1097–1125.
- Toutin, T. (2008). ASTER DEMs for geomatic and geoscientific applications: a review. *International Journal of Remote Sensing*, 29(7):1855–1875.