DIGITAL ELEVATION MODELING USING TERRASAR-X STEREO PAIRS

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ABSTRACT

As repeat pass InSAR processing for elevation modeling shows limitations due to the sensibility of X-band SAR data the methodology of Radargrammetry using TerraSAR X data was developed at Infoterra. TerraSAR-X StripMap and SpotLight stereo data pairs are used as input for the radargrammetric processing. The results of the DEM generation and the influence of different acquisition parameters and scenarios are discussed in this paper.

Index Terms— TerraSAR-X, DEM, Radargrammetry

1. INTRODUCTION

A digital elevation model (DEM) is the basis for all geospatial related questions: it is used for orthorectification of airborne and spaceborne imagery, for topographic mapping, for the simulation of stream flows and various other applications. DEMs are available from a variety of providers with different accuracies. The data sources used for the DEM processing can be manifold: terrestrial data can be used as well as data acquired by airborne or spaceborne systems. As spaceborne acquisitions can cover larger areas in a short timeframe it facilitates the elevation modeling in a time and cost efficient way.

2. DIGITAL ELEVATION MODELLING USING DAR DATA

For synthetic aperture radar (SAR) systems, like TerraSAR X, there are two ways of DEM generation: (a) interferometric SAR processing (InSAR) and (b) radargrammetric SAR processing. In this paper the radargrammetric approach with TerraSAR X data is discussed.

As data from SAR systems are remote sensing data from an active system detailed information about sending and receiving of the electromagnetic signal are available. Depending on the acquisition parameters of the data two different methods of digital elevation generation are possible. Because of changes on the earth's surface and atmospheric influences between two acquisitions repeat pass interferometric SAR processing (InSAR) with X Band radar data result in poor coherence in vegetated areas. A better solution for SAR processing is the stereo method (Radargrammetry) where the changes in the backscatter are not that relevant like for InSAR processing [4, 6]

2.1 Radargrammetry

Similar to Photogrammetry, Radargrammetry uses the parallax between two acquired images of the same area with different incidence angles. In a first processing step the orbit parameters are taken into account for a co-registration of the two images. This co-registration is followed by one of the main steps of the DEM generation, the stereo matching. An algorithm is searching for pixels representing the same area on the ground. In this step the disparity between each pixel in both images of the stereo pair is calculated which results from the slightly different illumination due to the different incidence angles. The result of the matching process serves as input for the calculation of the 3D location of each pixel based on triangulation. With the knowledge of the two satellite positions during the acquisition of the stereo pairs the distance to a certain point on the surface is calculated. In a last step the location of the points are projected to map coordinates using the orbit and acquisition parameters [2, 5].

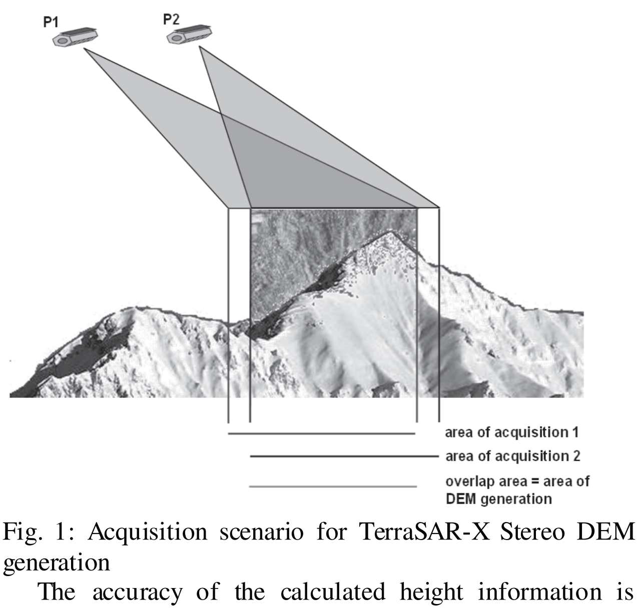

Fig. 1: Acquisition scenario for TerraSAR-X Stereo DEM generation

The accuracy of the calculated height information is influenced by the following factors:

- Sensor based
  - accuracy of the orbit parameters
- Processing based
  - Co-registration of the images
  - Stereo-matching algorithm and its results
- User
  - choice of best suited acquisition options for the specific area (see chapter 3)

Also the accuracy of the resulting DEM is depending on the spatial resolution of the input data. Higher resolution of the input data results in better stereo matching. More details are present in the output elevation model which results in better accuracy [3].

3. TERRASAR-X STEREO DEM

Depending on the acquisition mode TerraSAR-X can collect data from all over the world at varying resolutions ranging from 1 m (HighResolution SpotLight) to 18.5 m (ScanSAR) with different incidence angles [1]. Due to the high flexibility of the sensor every area on earth can be acquired within one to four days using different incidence angles. After 11 days the satellite passes the same point on the same orbit.

Two data takes from one orbit direction with different incidence angles are taken as input for the TerraSAR-X Stereo DEM processing (Figure 1). With respect to the satellite system parameters a TerraSAR-X StripMap footprint (30 x 50 km) can be acquired in less than 11 days. A combination of data from different orbit directions is used to improve the results of the modeling.

The standard inputs for radargrammetric processing are data acquired in StripMap mode with a resolution of approximately 3 m. The output of the data processing is a digital elevation model (DSM) with a spacing of 10 m. Depending on the relief conditions and availability of incidence angles, which is depending on TerraSAR X orbits, a disparity angle range between 15° - 25° for the stereo pairs is selected. The processing is carried out on Single Look Slant Range Complex (SSC) data in the internal Infoterra processing environment for TerraSAR-X. As the radar signal is backscattered at the top of any features on the earth surface the resulting elevation model is a DSM which includes all features like trees and houses. A digital terrain model (DTM) can only be produced with an increased effort of manual editing.

During the development of the Radargrammetry processor experience was gained with regards the optimal choice of the acquisition parameters. The most relevant parameters are:

- Polarization: singe polarization: HH
- Disparity angle: depending on relief:
  - higher disparity angle for flat terrain
  - lower disparity angle for strong relief
  - trade off between geometric robustness and layover/shadow effects
- Seasonal effects: Depending on landcover:
  - Agricultural area: times with less change (e.g. early spring or late autumn); in winter season only in areas with little snow chance
  - Forrest areas: acquisition dates should be close together to avoid changes of the crowns
  - Desert: acquisition dates should be close together to avoid changes of the dunes etc.; higher disparity angle should be selected in areas with flat terrain
  - Snowy and icy areas: spring or autumn, when snow/ice is slightly wet

Overall a short temporal baseline improves the results of the DEM generation.

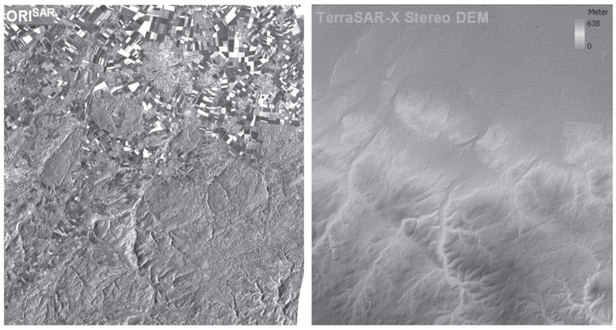

Fig. 2: TerraSAR-X ORI^{SAR} and TerraSAR-X Stereo DEM of testsite Euskirchen, Germany

4. CONCLUSIONS & OUTLOOK

The capabilities of using TerraSAR X data as input for Radargrammetry show good results. Due to the high impact of vegetation and atmospheric changes on the X band using InSAR technique for DEM generation is limited. The discussed method is more stable and shows comparable results. Radargrammetry using TerraSAR X data is a well suited method to generate elevation models from high resolution SAR data (Figure 2). As the acquisition parameters have a strong influence on the resulting DEM accuracy intensive tests have been archived during the development period of the Radargrammetry processor at Infoterra.

The archives accuracy of the TerraSAR X Stereo DEM shows improvements in comparison to global DEMs available at the moment. Thus, it gives already a preview on the quality and level of detail to be expected from the DEM, which will be acquired within the TanDEM X mission.

5. REFERENCES

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