UTILIZATION OF AIRBORNE MULTI-ASPECT INSAR DATA FOR THE GENERATION OF URBAN ORTHO-IMAGES

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1. INTRODUCTION

Since imaging radar was established as a powerful remote-sensing sensor independent from weather and daylight conditions, especially the mapping of urban areas has been a challenging area of research [9]. Owed to the side-looking SAR imaging geometry, man-made structures elevated above an even ground level are mapped inconveniently to the human interpreter, while effects like layover and shadowing make the analysis of urban areas a non-trivial task. One possible way to cope with these problems is to utilize images recorded from different aspect angles [2]. This paper proposes a method to produce true radar ortho-images of urban areas from high-resolution airborne InSAR data. Using the height information implicitly available from the interferometric phase, the corresponding amplitude image can be orthorectified and then combined with other images recorded from different viewing angles to fill in missing parts.

2. GEOCODING AIRBORNE INSAR DATA

The rectification of SAR images has been covered by many authors [3], [5], [7]. For this paper, a method specifically designed for interferometric SAR data inspired by [3] was used. The method proposed in [3] is based on satellite repeat-pass SAR and uses the implicitly available height data derived from the interferometric phase information as well as the navigation data of the flight to determine the 3D coordinates of each pixel in the world coordinate system. For that purpose, first the orbit parameters of both satellite acquisitions are adjusted using ground control points in a least-square estimation. Thereafter, the corrected orbit parameters are used to iteratively compute the object coordinates of each interferogram pixel.

We adapted this rectification procedure from the dual-pass spaceborne to the single-pass airborne case forgoing the usage of ground control points. As each pixel supplies interferometric phase, slant range and Doppler centroid frequency, the three-dimensional world coordinates of the pixels can be reconstructed by solving the following non-linear equation system:

$$\Phi = \frac{4\pi}{\lambda}\left(\left|\vec{P}-\vec{S}_1\right|-\left|\vec{P}-\vec{S}_2\right|\right) \quad (1.1)$$

$$r = \left|\vec{P} - \vec{S}_1\right| \quad (1.2)$$

$$f_D = \frac{2\left(\vec{P} - \vec{S}_1\right)\vec{v}_1}{\lambda\left(\left|\vec{P} - \vec{S}_1\right|\right)}, \quad (1.3)$$

where Φ, r and f are the interferometric phase, slant range and Doppler centroid frequency. $\vec{P}$ and $\vec{S}$ are the world coordinates of the object point and the sensor positions, respectively. $\vec{v}_1$ is the velocity vector of the master sensor, while λ stands for the radar wavelength. Since the flight trajectory is known precisely from the airplane's GPS navigation data, only three unknown parameters remain, symbolized by $\vec{P}$.

This equation system has to be solved for each pixel separately using a trust-region dogleg algorithm [6], leaving out only pixels that have previously been masked unreliable. First tests have been carried out using the coherence value as single indicator for reliability. However, the utilization of a more sophisticated measure, e.g. derived from a preceding classification, should be examined. It is also very important to consider the phase noise since smoothing the phase values prior to 3D reconstruction will - due to the non-linear radar imaging geometry - lead to a significantly different result than only smoothing the height data afterwards. We have used a specially adapted form of the edge-preserving filter presented in [1] to keep the original shape of any objects contained in the scene.

3. SMOOTHING OF THE HEIGHT DATA AND ORTHO-PROJECTION

Despite the edge-preserving phase filtering, the interferometrically reconstructed point cloud still contains noise and blunders. To smoothen the height data for orthoprojection, the scene has to be segmented into more or less homogeneous regions. We have used a region-growing algorithm based on [8]. Additionally, constraints to the height of each region can be applied, which will result in fewer blunders in the elevation data. Consequentially, the final ortho-projection of the corresponding SAR image will be less erroneous.

After the InSAR data has been geocoded, the corresponding SAR amplitude image can be projected into world geometry. Of course, especially due to the shadowing effect, not all parts of the scene will be covered with meaningful image data. Therefore, the same procedure can be carried out for another dataset recorded from a different viewing direction. Intuitively, orthogonal or antiparallel configurations complement best.

Both images are then located within the same coordinate system and can be fused to create an ortho-image covering the whole scene.

4. FUSION OF THE MULTI-ASPECT DATA

When two or more SAR amplitude images recorded from different viewing directions have been ortho-rectified as described in sections 2 and 3, they still have to be combined. For the coregistration, a feature-based matching algorithm will be used, e.g. based on the centers of gravity of homogeneous image regions or SIFT features [4] specially adapted to radar imagery.

After the images have been registered, the intensity values are fused into one single image by averaging the pixels supported by more than one image. Pixels containing no information in all but one image are simply filled with the information from that image.

4. CONCLUSION AND OUTLOOK

In this paper we have proposed an approach for the generation of true radar ortho-images from high-resolution airborne multi-aspect InSAR datasets. First tests on real data showed the feasibility of the approach as well as the potential ortho-rectified SAR images of urban areas provide to image interpretation by human operators or for thematic mapping purposes.

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