A Framework for SAR-optical Stereogrammetry over Urban Areas

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Introduction
Today, a growing number of satellites equipped with various kinds of sensors provide remotely-sensed images of our planet. Each kind of sensor has its own distinct properties regarding, e.g., wave-length, resolution, accuracy and coverage. As a result, large archives of satellite imagery acquired by different sensors are available and will not stop to grow in the future. Data fusion can be applied for integrating datasets with different specifications to enhance information extraction by beneficially combining the individual sensors properties. Of particular interest in that regard is the fusion of optical and SAR imagery for different purposes. One of the purposes is 3D reconstruction by SAR-optical stereo-grammetry, which also rectifies the optical imagery with modern SAR sensors such as TerraSAR-X. In this context, the main idea of this paper is to investigate the applicability of the semi-global matching (SGM) algorithm for SAR-optical stereogrammetry, and to design a framework for accomplishing this task.  

Reconstruction Building Model from SAR-Optical Stereogrammetry
A full framework for stereogrammetric 3D reconstruction from SAR-optical image pairs is presented in Fig.1. It consists of several steps:
- generating rational polynomial coefficients (RPCs) for each image to replace the different physical imaging models by a homogenized mathematical model;
- RPC-based multi-sensor block adjustment to enhance the relative orientation between both images;
- establishing a multi-sensor epipolarity constraint to reduce the matching search space from 2D to 1D.

The main step in SAR-optical stereogrammetry, however, is to estimate disparity values by using a dense matching algorithm such as semi-global matching (SGM). In the following, more details of SAR-optical dense matching along with experi-
mental results of TerraSAR-X/WorldView-2 stereogrammetry over urban areas will be presented.

**Fig. 1:** Framework for stereogrammetric 3D reconstruction from SAR-optical image pairs

**Fig. 2:** Display of study subsets located in Berlin, left: WorldView-2, right: TerraSAR-X

**SAR-Optical Dense Matching by SGM**

The core challenge in SAR-optical stereogrammetry is to find disparity maps between two images by using a dense matching algorithm. I have investigated the application of classical SGM for that purpose. SGM computes the optimum disparity maps by minimizing an energy functional which is constructed by a data and a fidelity term. While the data term is defined by a similarity measure such as mutual information (MI), the fidelity term employs two penalties to smooth the final disparity map. Because of aggregating cost values computed by a cost function in the heart of SGM along with a regularizing smoothness term, SGM is relatively robust against noise, which seems to make it a good choice for SAR-optical stereogrammetry. For the experiments a high-resolution TerraSAR-X/WorldView-2 image pair acquired over the city of Berlin (Germany) is used. After multi-sensor bundle adjustment, sub-images from the overlapped part of the study area were selected. These sub-images are displayed in Fig. 2.

**Results and Discussion**

The achieved point cloud by using MI as a similarity measure is shown in Fig. 3. The accuracy of the resulting 3D point clouds respective to the LiDAR point cloud using least squares plane fitting method was 2.75 m that indicates the potential of SAR-optical stereogrammetry for 3D reconstruction of urban areas.

**References**