BUILDING DETECTION BY FUSION OF OPTICAL AND SAR FEATURES IN METRIC RESOLUTION DATA

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1. INTRODUCTION

The new generation of satellite optical and SAR sensors (TerraSAR-X, Quickbird, CosmoSkyMed ...), delivering images with metric or sub-metric resolution, offers great challenges in the field of building extraction and 3D building reconstruction in urban areas.

Some well known technics, such as stereovision with optical images and interferometry or radargrammetry with radar data, have already been proposed to deal with this problematic and have proved to provide efficient results. Nevertheless, two main difficulties can be pointed out. First, optical images are not always available, depending on weather conditions. Secondly, SAR interferometry or radargrammetry still give limited results (noisy and incomplete data).

In this paper, we propose to investigate the joint use of an optical image and a SAR image for building extraction and 3D reconstruction. The objective is to propose a method providing, in a semi-automatic way, the detection and the reconstruction of buildings in large urban areas. We will see how it is possible to extract and combine two kinds of information from both data. We will assume that our 3D building model is a simple parallelepiped (vertical frontages and flat roof), described by two kinds of parameters: its planimetric rectangular boundary and its height. In a first part, we will present a method for building boundaries extraction from monoscopic optical data. We will get, by this way, information about the building shape and location. In a second part, we will develop our framework of fusion with SAR data, in order to improve or validate building detection and to get height information.

2. BUILDING EXTRACTION FROM MONOSCOPIC OPTICAL DATA

First, a process based on morphological and geometrical tools is proposed to extract 2D building boundaries from monoscopic optical images. The adopted methodology consists in the two main following steps. In the first place, the Differential Morphological Profile (DMP) of the initial panchromatic extract is built, by using “opening and closing operators by reconstruction”, with an increasing structuring element size. This profile refers to the size and contrast of the objects in the image and provides a progressive simplification of the scene at different scales. Then, the different images composing the DMP are hierarchically processed: at each level, a geometrical criterion (adequation with a rectangular surface of reference) is tested in order to validate or not a building detection. Shape preservation properties of the DMP allow us to use such a criterion.

The result of this process is a binary map, identifying potential rectangular building location. As we are working on optical data with a quasi vertical look angle, this map refers essentially to roof boundaries, whose planimetric locations can be associated to the ones of building footprints. Illustrations of the results are presented on Quickbird urban sub-scenes (resolution of 0.6 meter) located in the test areas of Marseille, Marignane and Saint-Mandrier (France).

A quantitative evaluation of the process is done: computation of the detection and false alarm rates and computation of the number of misclassified pixels. Its main advantages (satisfying detection, potential maps of reliability) and drawbacks (rectangular shape limitation) are underlined.

3. FUSION WITH SAR DATA

Then, the framework of fusion with SAR data is developed. We are dealing with two aspects: the bidimensionnal building classification and the building height retrieval.

3.1. Building classification: validation and improvements

In a first step, we focus on the building classification aspect: SAR data are used in order to validate (or reject) the initial building detection from optical data and to increase our performances. The SAR data allow also us to improve some building characteristics such as orientation and dimensions.

We are consequently led to apply functions to project characteristic features from the optical data into the SAR ones and vice versa. These transformations, based on the fundamental optical and SAR equations, compute the coordinates of 3D points in a common cartographic referential and require the knowledge of the sensor acquisition system parameters. A stage of matching between optical and SAR ground features is also performed in order to refine altimetric information provided by a DTM and used for the projection. As the optical - SAR registration resulting from the physical model of projection and improved with a few control points is already good, only some local small translations are envisaged. If we assume that double bounces linear echoes from ground / wall building corners are mainly present in the SAR image, optimum local translations can be found by the minimization of a cost function, referring to the superposition of optical building ground ridges and SAR bright ground / wall echoes.

The validation step aims to reduce the false alarm rate. The ground corners defining the potential rectangular building footprints in the optical image are projected into the SAR one and are generating research areas. In order to validate a building presence, we are looking for SAR characteristic building features such as linear bright echoes, layover or shadows, inside or beside these research areas. In the case where no specific SAR feature is detected, we conclude to a false detection.

The improvement step is then processed. First, we aim to refine the location of the true positive buildings by integrating the direction and the length of the SAR linear echoes located near the research areas. Then, we try to increase our building detection rate. Potential SAR areas, for which some building features with high intensity have been previously detected on the SAR data, are projected into the optical image. In the case where no building is detected in these favorable areas on the initial optical building map, the proposed method for building boundaries extraction is locally re-tested on the optical image with lower criterion thresholds.

3.2. Height retrieval

In a second step, we focus on the building height retrieval step for a 3D reconstruction. This time, as we apply the operation of projection to the building roofs (which are structures with an elevation), we have to add a potential building height value to the ground altitude provided by the DTM. The planimetric parameters of the 3D building model are deduced from the improved building map, meanwhile the height parameter is retrieved by the following optimization scheme. For each test height value belonging to an [hmin, hmax] interval, characteristic test regions (“roof region”, “double bounces echo region”, ”layover region”, “shadow region”), whose geometry and location depend on the parameters of the 3D building model, are precisely generated on the SAR image. An energetic criterion (for instance the Likelihood criterion) is computed on these regions, characterized by proper radiometric signatures. The optimization of the criterion enables us to retrieve the most likely height. In this way, the relevance of the reconstructed building model is ensured.

Results of this approach are shown on a Quickbird image (resolution of 0.6 meter) and on a TerraSAR-X image (resolution of 1 meter) located in the same urban area of Marseille (France).

4. CONCLUSION

In the frame of optical and SAR data fusion, we have proposed an approach for 3D building reconstruction in large urban areas. This framework allows us to benefit from the complementarities of two kinds of sensors and provides, in operational conditions, satisfying results, which could not be achieved by the only use of an optical or a SAR image. First, a methodology for planimetric building extraction from monoscopic optical images has been presented. Secondly, the frame of fusion has been developed: We have shown how to concretely manage with the different building features present in both data, in order to propose a joint interpretation of optical and SAR urban scenes. We have seen that the introduction of SAR data could improve the optical results for building detection and could add relevant height information for the 3D reconstruction.