BUILDING HEIGHT EXTRACTION VIA A DETERMINISTIC APPROACH USING A TERRASAR-X DATA STACK

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1. INTRODUCTION

The reconstruction of building heights is a key application in urban remote sensing. Using synthetic aperture radar (SAR), this can be done in several different ways. High-resolution SAR interferometry [1] or radargrammetry [2] can be used to retrieve the building height. For an unambiguous building model reconstruction multi-aspect angle approaches are more feasible [3]-[5]. But these methods require two or more SAR images of the scene.

Building heights can also be determined by monoscopic measurement [6], [7]. Comparing SAR simulation results with real SAR images for building reconstruction is another possible approach [8]. Based on a backscattering model [9], the height of a building wall can also be determined by the strength of the double-bounce reflection of the wall [10], [11].

In this paper, we will demonstrate the applicability of the deterministic approach for building height determination using TerraSAR-X data. Using an electromagnetic model for urban environments developed by Franceschetti *et al.* [9], the building height is determined based on geometrical optics (GO) approximation. The approach is explained in section 2. Following this approach, the backscattered field is calculated as the sum of elementary contributions from simple objects which form the whole structure. For the building height reconstruction assumptions about the material properties are necessary. In section 3 we describe our assumptions about the material properties for our experiments and introduce several parameters based on the assumption of GO.

In the full paper we present our results using several high-rise buildings as test objects. Finally, conclusions will be drawn including evaluation of the approach and its limitations.

2. BUILDING HEIGHT ESTIMATION USING A DETERMINISTIC APPROACH

The amplitude of the double-bounce backscattering in SAR depends on the wavelength, the material properties, the incidence angle θ, the area of the dihedral and the aspect angle φ. In our case we analyze the backscattering of buildings and their surroundings. We assume geometrical optics (GO-GO) for the double-bouncing [9].

The aspect angle φ strongly influences the strength of the double-bounce reflection. As it is schematically shown in Figure 1, the angle is defined as the angle between the wall and the azimuth direction. The strength of the double-bounce reflection also strongly depends on the wavelength and the material properties of the building wall and the surrounding ground. In this paper we assume the building wall as well as the surroundings to be planar and to only consist of one material. This is a strong simplification which affects our results, as we can see in section 3.

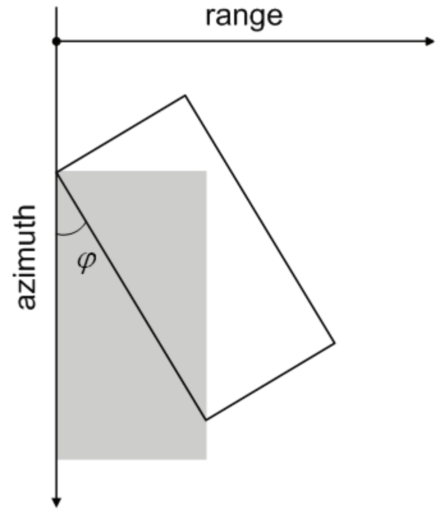

Figure 1. Aspect angle φ

The material is defined by its dielectric properties and roughness in relation to the wavelength of the SAR sensor. The relevant values are the complex dielectric constant of the material ε and the standard deviation σ and correlation length L of the stochastic process describing the roughness of the material in relation to the wave-length.

To calculate the building height according to Franceschetti *et al.* [10], [11], we need to know the backscattering strength σ^o, the building length l, the incidence angle θ, the aspect angle φ, the dielectric constants ε of the wall and the ground, and σ and L representing the stochastic process describing the roughness of the material in relation to the wavelength. If all these values are known, the building height h can be calculated [11] with

$$h = \left|\sigma^o\right| \frac{8\pi^2 \cos^2\theta \cdot \sigma^2\left(2/L^2\right) \cdot \exp\left[\frac{\tan^2\theta \sin^2\varphi}{2\sigma^2\left(2/L^2\right)}\right]}{\left|S_{pq}\right|^2 l \tan\theta \cos\varphi\left(1+\tan^2\theta\sin^2\varphi\right)}$$

where S_{pq} is the generic element of the scattering matrix, with p and q each standing for the horizontal or vertical polarization. In our examples we use TerraSAR-X images acquired in VV polarization. The dielectric constants ε of the wall and the ground are the key values for the calculation. They are unknown, but reasonable values can be assumed if the materials are known. In the following section we describe methods used to estimate the material properties.

3. ESTIMATION OF THE MATERIAL PROPERTIES

The material properties for the backscattering model used in our experiments consist of the dielectric constant ε as well as the soil roughness parameters σ and L describing the standard deviation and correlation length of the surface roughness. Our test buildings are surrounded by asphalt. Therefore, we assume a relatively low standard deviation σ, but a relative high correlation length L. As basic values we assume $\sigma = 0.02$ m and $L = 2$ m. These assumptions are based on the available literature [12]. Jaselskis *et al.* [13] measure typical dielectric constants of ε'=6.2 and ε'' = 0.02. They also show that microwaves of 10 GHz, which is comparable to TerraSAR-X with a center frequency of 9.65 GHz, penetrating to approximately 12 cm in the asphalt pavement [13].These values can be changed depending on the weather situation. Wet or water covered asphalt has a higher dielectric constant.

4. PRELIMINARY CONCLUSIONS

In our paper we analyze a method which can be used to determine the height of buildings with TerraSAR-X data in dense urban environments. Various conditions have to be fulfilled for this method to be applicable. Therefore, it does not work that well with all the buildings in our first experiments. Actual and reliable ground-truth information remains a necessary requirement. In the future we will compare the results achieved between different polarizations and calibration of the results will also be further accessed.

5. REFERENCES

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