ESTIMATION OF BUILDING DENSITY USING TERRA-SAR-X-DATA

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1. INTRODUCTION

A continuous urbanization process can be observed worldwide in most developing and developed countries – a phenomenon causing a significant expansion of build-up areas and transport-related infrastructure. In Germany, for instance, on average about 100 ha of natural or agricultural area is converted into residential or industrial area and traffic infrastructure per day. In the course of this highly dynamic expansion, there is an increasing demand of up-to-date and spatial detailed information for urban planning and management. With the establishment of very high resolution (VHR) sensors in the recent years remote sensing can provide a valuable contribution to a cost-efficient and repeated monitoring of settlements. Especially VHR SAR systems such as the German TerraSAR-X satellite, combine the advantages of a high spatial resolution and the ability to record data independently of atmospheric conditions and illumination.

In recent years approaches towards an exact and robust detection of urban footprints have been developed using VHR SAR systems [1]. An interesting research field addresses now the potential of these systems towards a thematic characterization of build-up areas. The main goal of this study is the development of an approach towards an estimation of the building density based on first order statistics and texture measures derived from TerraSAR-X imagery. The building density is the ratio between the area covered by buildings and the total area. To establish the relationship between the building density and the SAR imagery we use reference data on the true building density.

2. METHODS

The developed technique is demonstrated on the basis of three single-polarized TerraSAR-X intensity images recorded in stripmap mode for the German cities Munich, Ludwigshafen and Leipzig. In a first step the urban footprints for the cities is mapped by using an approach based on speckle divergence and intensity information developed by Esch et al. [1]. In a second step the density of buildings is derived. The diversity and geometric complexity of built-up areas complicate the derivation of building density information using VHR SAR data – in particular since SAR backscatter is rather related to the density of the scattering centers than to the building density itself. Moreover, the data are strongly affected by SAR inherent distortions and shadowing. For this reason we decided not to operate on the scale of single buildings but on the more generalized scale of city blocks. Therefore a moving window approach is used to derive the building density. The window size was adjusted according to the mean size of relevant city blocks, that was determined via GIS-analysis of the reference data.

Because of the limited significance of single-polarized radar intensity data, we take first order statistics and textural information into account. Texture measures such as the co-occurrence measures according to Haralick have already shown their potential in extracting information on urban environments in single SAR images [2]. However the challenge remains to identify the relevant and at the same time reliable features that describe the urban characteristics of interest.

To establish the relationship between the calculated SAR features and the building density we utilize Breiman's random forests algorithm for regression [3]. Random forests can be used for mining in multidimensional data spaces and form an ensemble of decision trees using bootstrapping. They have the advantage to be widely insensitive to noise or overtraining. However they have the disadvantage of being not able to take more than one feature into account at the same step/split. To overcome this shortcoming, we perform a Principal Component Analysis (PCA) of the extracted features and join the principal components to the random forests additionally.

3. RESULTS AND PERSPECTIVE

First results of the regressions computed on the TerraSAR-X scene of Munich show a promising correlation coefficient of 0.72. Thereby the PCA-features increased the correlation coefficient significantly compared to the results based only on the texture related features. Therefore we additionally consider a combination of PCA and Independent Component Analysis (ICA) in order to enhance the results further. Whereas PCA describes only linearly dependent structures in the SAR data, ICA could be more appropriate since it gets higher order statistics. Such a combination has already proved to be more informative in high resolution SAR images than working with PCA and ICA separately, because the features extracted by each method describe the data from different angles and thus provide special interpretation of the data [4].

4. REFERENCES

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