# LAND COVER CLASSIFICATION BASED ON SINGLE-POLARIZED VHR SAR IMAGES USING TEXTURE INFORMATION DERIVED VIA SPECKLE ANALYSIS

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## ABSTRACT

### Introduction

Speckle is a SAR specific noise effect caused by constructive and destructive interference from multiple scattering within the resolution cell of the imaging radar system that superposes the true radiometric and textural information of SAR images as grainy ‘salt-and-pepper’ pattern. Fully developed speckle basically follows circular Gaussian image statistics. However, this assumption is not applicable for very high resolution SAR systems and for data showing urban sceneries. In those cases the multiple scattering processes within a resolution cell show - subject to the true structuring of the imaged area – rather a directional behavior than a random distribution. Consequently, the speckle is no longer fully developed. In our study we demonstrate how information on the local development of speckle can be used to differentiate between basic land cover (LC) types such as water (W), open land (*OL*) – meaning farmland, grassland and bare soil –, woodland (*WL*) and urban area (UA) in single-polarized, single-date VHR SAR images. The research was based on a total of 12 TerraSAR-X (TSX) scenes distributed over all five continents.

### Methodology

In our research we pick up already presented techniques for the estimation of the speckle development in SAR data and further develop and combine some of the ideas with respect to a classification of basic LC types in single-polarized TSX images. For that purpose we first visualize the speckle behavior of W, OL, WL and UA by means of scatter plots and standardized histograms of the local coefficient of variation (CoV). The plots and histograms are calculated on the basis of image chips which are located within manually defined test areas solely showing one of the LC types W, OL, WL or UA. By doing so we could demonstrate that the development of speckle shows significant differences for the specified LC types, with the backscattering from homogeneous areas – e.g. W or OL - mostly complying with a multiplicative noise model, whereas structured regions – e.g. UA, WL

or border areas between different LC zones – significantly diverge from the statistical behavior of fully developed speckle (Fig. 1). Also using scatter plot and histogram analysis, we then introduce a straightforward, unsupervised approach to quantify the divergence between local heterogeneity and scene-specific heterogeneity due to fully developed speckle. In order to define the scene-specific level of heterogeneity induced by speckle we measure the local CoV based on image chips that are constantly distributed over the entire input SAR image. Based on the population of CoV derived from all image chips we define the minimum average level of heterogeneity for the SAR scene. This measure is supposed to provide the CoV for homogeneous image areas showing no true structuring – meaning that their heterogeneity is solely caused by speckle. Knowing the scene-specific heterogeneity due fully developed speckle we then define the difference between local image texture and speckle-induced heterogeneity in order to generate a texture image providing the true local texture – the so-called speckle divergence. The speckle divergence provides standardized and globally applicable information on the local level of true structuring in the SAR image. Using eight out of the twelve TSX images, we then analyze the histograms of the original intensity data and the derived speckle divergence image for the four specified LC types in order to determine thresholds for a separation of the categories W, OL, WL and UA. Using the determined thresholds we finally implement an unsupervised classification approach which is demonstrated and evaluated on the basis of the four remaining TSX images which were not used in the context of the threshold definition. The result of the classification procedure can either be provided as a thematic image with discrete classes or in form of a color composite image whose bands can be interpreted in terms of a fuzzy classification (Fig. 2).

**Results**

The study demonstrates that the scene-specific statistics of speckle noise can be derived from the SAR image by means of a fully automated, unsupervised analysis of the local mean and standard deviation. The calculated levels of speckle-induced image heterogeneity highly correlate to the theoretical values estimated via the number of looks. By averaging the divergence between local image heterogeneity and scene-specific heterogeneity due to fully developed speckle, it was also possible to generate a texture layer which provides standardized and therefore globally comparable information on the local level of true structuring in the SAR image. Based on supervised histogram analyses of the derived speckle divergence images, the relation between local level of true structuring – meaning the development of speckle - and basic type of LC could be quantified. Using the knowledge on this relation we successfully implemented a straightforward classification approach for single-polarized SAR images using discrete thresholds on the speckle divergence and the original intensity data – resulting in a thematic classification assigning the categories ‘water, ‘open area’, ‘woodland’ and ‘urban area’ – or fuzzy transitions leading to a color composite image. While the color composite image supports the visual interpretation of SAR data, the outcome of the fully-automated, discrete LC classification procedure represents a valuable pre-classification image showing overall accuracies of 75% to 85 %. Hence, this method might serve as an efficient approach for the pre-classification of single-date and single-polarized SAR data. The high accuracies regarding the assignment of urban areas – taking values of around 90% and more - document the specific potential of the presented analysis in terms of the identification and delineation of settlements.

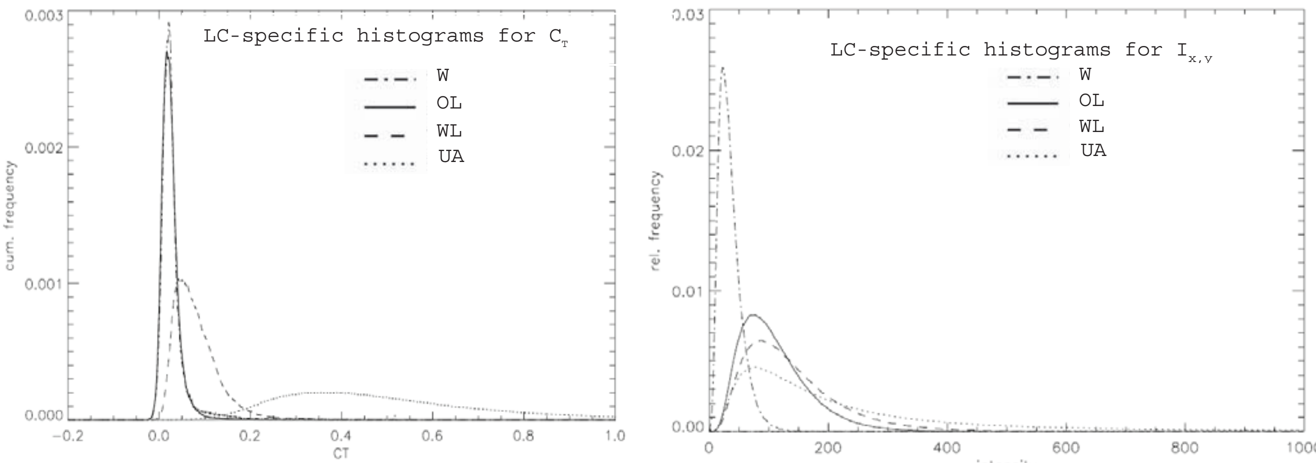


Fig. 1. Histograms for land cover types water (W), open land (OL), woodland (WL) and urban area (UA) derived on the basis of a total of eight texture (left) and intensity images (right) respectively.

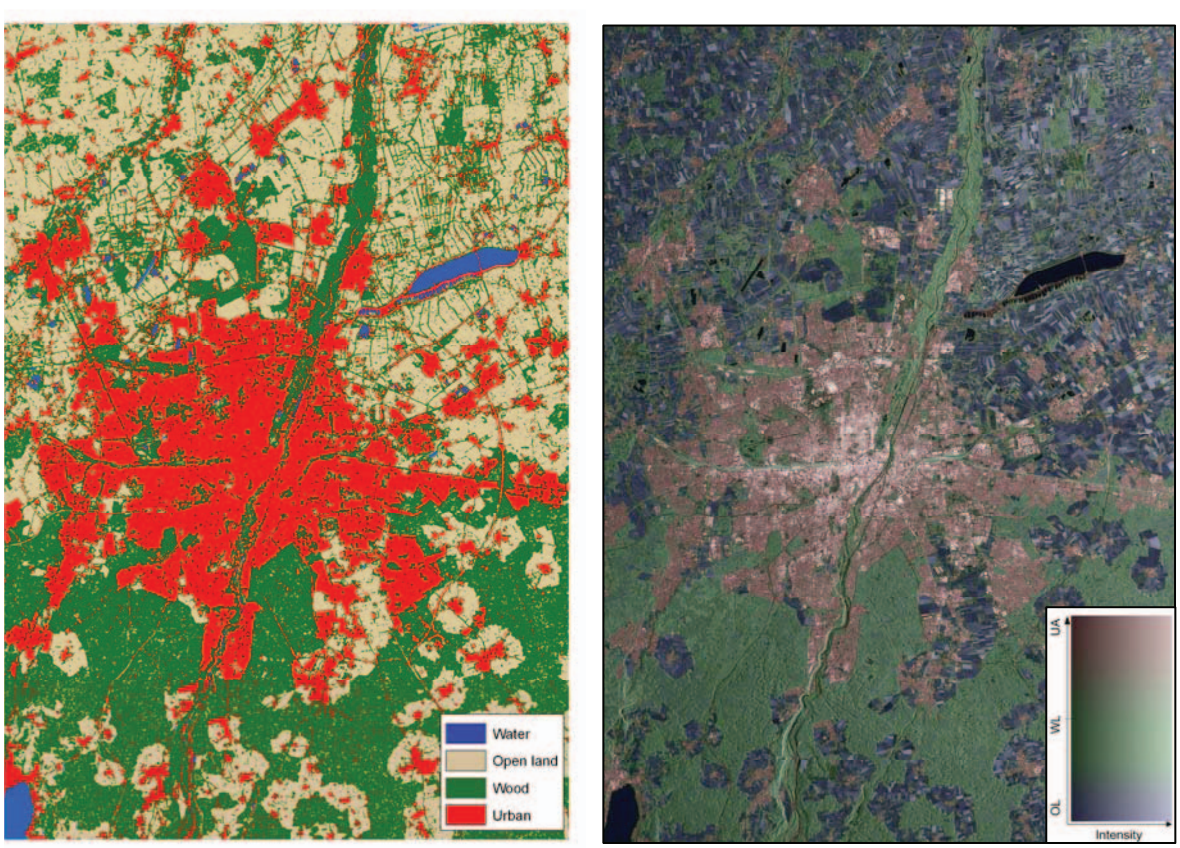


Fig. 2. Result of discrete land cover classification based on texture image and intensity data (left) and fuzzy classification methods of similar data set resulting in a colour composite image (right).

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