Classification of Vegetation Fusing Multichannel SAR Data by a Fuzzy Approach

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Abstract: The improved spatial resolution of modern SAR sensors allows the distinction of significant areas in rural as well as in urban environments. For this purpose additional information layers such as coherence and Coefficient of Variation are derived from a single pass InSAR data set and a classification is performed by means of the commercial software tool Definiens Professional. The focus is on a distinction between typical SAR backscatter. The resultant classes are compared with classification results in an optical image to derive the relation of these SAR-classes to vegetation areas with different natural cover.

1 Introduction

Nowadays a wide spectrum of remote sensing data such as multispectral, hyperspectral and radar imagery in different spatial resolutions is available. For many applications multispectral data are preferred, particularly for classification of vegetation, there different approaches exist. In the current development of SAR remote sensing multichannel sensors offer the possibility to classify different land use [BW96]. The advantage of SAR is the all weather capability, which becomes also in the civilian domain more and more important under topicality demand. Contrary to the electro-optical domain, the SAR signature is dominated by the roughness and dielectric properties of the illuminated objects and has usually different information content. Significant features of extractable classes can be e.g. based on magnitude values, deduced Coefficient of Variation CoV values, coherence values and phase differences. These data are fused and classified using an object oriented approach. The used software allows the individual formulation of concepts and knowledge about relevant image content by means of fuzzy rules [De04].

This paper is structured as follows. In section 2 the considered InSAR as well as the electro-optical data sets are introduced. The classification of both sensor data is presented in section 3 and 4. The comparison of the results and the conclusions are given in section 5.

2 Considered Data Sets

The investigated InSAR data set was recorded by the multichannel airborne system AeS -1 of Intermap Technologies [SM99] operating in X-band, with a spatial resolution of about 38 cm in range and 16 cm in azimuth direction. The flight height was 3000 m and the baseline approximately 2.4 m. The test area Dorsten (Germany) is characterized by flat terrain covered by wood areas, agricultural land use, grassland and building development, industrial areas as well as residential areas. The InSAR configuration allows next to the magnitudes as well the consideration of the coherence of the backscatter signal. The third InSAR input is derived by the calculation of the CoV.

The electro-optical data set was acquired from the satellite IKONOS-2 with a spatial resolution of 1 m (panchromatic) and 4 m (multispectral). The recording date of the InSAR data set was 2003-03-13 and of the Ikonos image 2003-08-05. Therefore the observable differences are mainly caused by seasonal vegetation changes, and structural rebuilding is expected as minimal.

3 Classification of Significant Areas in InSAR Images

The classification of the InSAR images was performed using combinations of fuzzy sets on object features, defined by membership functions (weighting functions). Here, concepts and knowledge about the relevant image content can be formulated by means of fuzzy rules [De04]. The used input layers are magnitude, CoV and coherence *Coh* images (Figure 2), given by the following equations

$$\mathrm{CoV} = \frac{\sigma_{s_i}}{\langle s_i \rangle} \quad \text{and} \quad \mathrm{Coh} = \frac{\langle s_1 \cdot s_2 \rangle}{\sqrt{\langle s_1^2 \rangle \cdot \langle s_2^2 \rangle}},$$

where i stands for the image, for σ_{s_i} local standard deviation and $\langle s_i \rangle$ for actuarial expectation value of the signal s.

In the first step segments are generate from the three input layers, using the multiresultion segmentation based on a bottom up region-merging technique starting with one-pixel objects [De04]. By a pairwise clustering process an optimization procedure minimizes the layer weighted heterogeneity of the image object. Based on the final segments object features (e.g. mean value, area, standard deviation) are calculated. These features are used for the formulation of the rules. In [BW96] relations between backscattering coefficient and interferometric coherence are denoted for several vegetation and different surface types. This knowledge is included in the rule system to discriminate between classes of *Volume Scatter Area*, *Medium Rough Area*, *Smooth Area* and *Scatter Area*. The suitable membership functions (condition), which are adapted to every class and the three input layers are given in Table 1.

Figure 2: Input layers of InSAR classification, magnitude (left), CoV (middle) and coherence (right) image

The representative object feature is the mean value of the segment, which is calculated in all three layers (A, CoV, Coh). Focused on the first class, which is characterized by mean magnitude value, homogenous backscattering and low coherence, the conditions have to be defined as followed. The *Approximate Gaussian* membership function chosen for the magnitude layer is located in the interval centre. The CoV value of a homogenous area ($CoV_{homogen.}$) is expected to be ≤0.5 for all single look magnitude images, so that the interval border of the function *Smaller than* are [0;1]. For the coherence evaluation the same membership function is considered in the interval [0;1]. Membership functions and interval borders for the other classes are listed in Table 1.

Table 1: Membership functions and interval borders

	Magnitude	**Coefficient of Variation**	**Coherence**
Volume Scatter Area	$[A_{mean}-2\cdot A_{std}; A_{mean}+2\cdot A_{std}]$	$[CoV_{min}; 2\cdot CoV_{homogen.}]$	$[C_{min}; C_{max}]$
Medium Rough Area	$[A_{mean}-2\cdot A_{std}; A_{mean}+2\cdot A_{std}]$	$[CoV_{min}; 2\cdot CoV_{homogen.}]$	$[C_{mean}; C_{max}]$
Smooth Area	$[A_{min}; A_{mean}]$	$[CoV_{min}; 2\cdot CoV_{homogen.}]$	$[C_{min}; C_{max}]$
Scatter Area	$[A_{mean}-2\cdot A_{std}; A_{max}]$	$[CoV_{homogen.}; CoV_{max}]$	$[C_{mean}-C_{std}; C_{max}]$

The combination of the conditions is implemented by using the *and (min) operator*, so that the lowest membership value of all conditions is returned and defining the resulting class. The results are depicted in Figure 4. The assessment of the classification results by considering electro-optical data is given in section 5.

4 Classification of Vegetation Areas in Electro Optical Images

The classification of the electro-optical images was performed with the Definiens fuzzy approach of nearest neighbor classifier. Individual image objects (training areas) are marked as typical representatives of a class, and then the rest of the scene is classified.

The creation of segments is done by considering five layers (pan, red, green, blue, nir, Figure 3). Afterwards the Normalized Difference Vegetation Index (NDVI) [Al01] and other object features are calculated for these segments.

Figure 3: Input layers of electro-optical classification, panchromatic (left), multispectral (middle) image and high-resolution orthophoto (right) for definition of training areas

The subsequently definition of training areas is based on a high-resolution orthophoto with a spatial resolution of 30 cm (Figure 3). Due to the fact that the assessment of the SAR classification results will focus on vegetation areas, the electro-optical classification comprised only two classes: high (e.g. trees) and low (e.g. grass) natural cover. Based on the training areas interval borders are defined for the NDVI and the mean value of the green channel amplitudes for both classes. The step of classification evaluates the membership probability of the objects to the classes. The results and the comparison with the SAR results are given in Figure 6.

5 Results and Conclusions

The multiresolution approach implemented in Definiens Professional used for the object segmentation showed good results for both data sets. For the classification of the multichannel SAR-Data five classes were introduced. Figure 4 (left) shows the classification result for the multichannel SAR input.

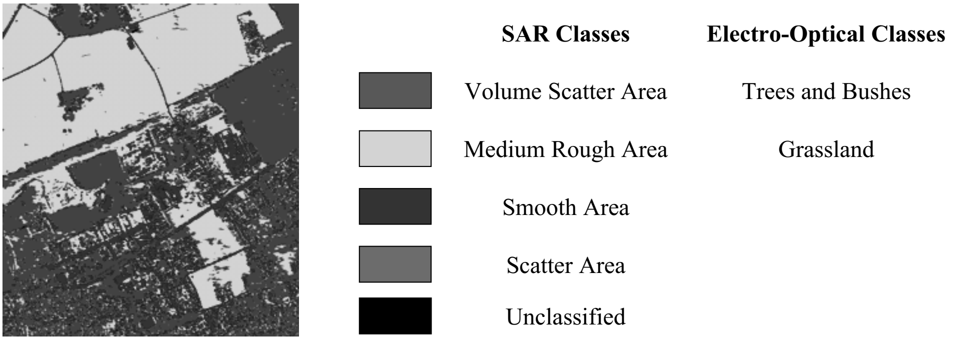

Figure 4: Result of multichannel SAR classification; SAR and electro-optical class description

The class *Smooth Area* describes areas with very low coherence and backscatter like shadow areas and smooth surfaces. The class *Volume Scatter Area* represents relatively good areas with leaf vegetation (trees, bushes).

Figure 5: SAR magnitude image (b) overlaid with vegetation classification result (full scene a, zoom area b, c)

The classification results for vegetation areas are depicted in Figure 5,6. The results are mainly comparable to the results of the electro-optical class *Trees and Bushes* but show partially also significant differences.

Figure 6: Electro-optical image (b) overlaid with classification result (full scene a, zoom area b, c)

The differences result from the fact that the features used for classification reflect not the same information. This is quite obvious in the scene detail depicted in Figure 5b and Figure 6b: The *Medium Rough Area* comprises all areas under cultivation including already harvested fields. The class *Grassland* includes only areas where a chlorophyll fraction is obviously present. Harvested fields or fields with vegetation without chlorophyll fraction are not present in this class. Because of the different information content of the input data a thorough comparison is not applicable. But it can be stated that the information content in the multichannel SAR-Image enhance the knowledge of the scenery and helps to interpret the SAR scenery. An additional information source is the interferometric height, which will be considered in future work.

References

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