OSCAR – Object Oriented Segmentation and Classification of Advanced Radar Allow Automated Information Extraction

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Abstract – **DEFiNiENS is a new innovation oriented German company which developed a powerful image analysis software, eCognition. One of the current research projects within the company is to expand the capabilities of eCognition for SAR information extraction. These developments will help remote sensing on its way from a research oriented to an operational technology with commercial benefit. To support this development, the German Aerospace Center (DLR) co-funds the project ProSmart II and therein the sub-project OSCAR (object oriented segmentation and classification of advanced SAR data). In OSCAR, DEFiNiENS improves the suitability of eCognition for automatic information extraction and validates the results together with ProSmart II partners on exemplary applications.**

1. OSCAR IN PROSMART II

The possibilities of remote sensing for many applications become visible more and more for "scanning the present and resolving the future" for scientific approaches. However, automatic information extraction for operational use is still in the very beginning. This is important to increase the public awareness for the advantages of remote sensing.

Three main requirements have to be fulfilled for operational remote sensing: 1) reliable, periodical data delivery of sufficient and constant quality. Due to atmospheric disturbances this is hardly possible with optical data. Commercial entities such as infoterra – an Asrtium company - have therefore decided to develop a SAR satellite, TerraSAR, which should be launched in 2005; 2) delivery of appropriate information instead of a huge amount of data. For commercial use excellent quality of information extraction has to be maintained, and automatic methods have to be applied to allow sufficient throughput and to decrease information costs for the customer. 3) fusion of data and information, because no sensor data alone will be sufficient to achieve the required information quality for all considered applications.

ProSmart II started in October 2000 and lasts until April 2002. It is a project to prepare operational product generation from TerraSAR data. Suitable information products have to be identified, requirements for data and algorithms specified and reliable and stable methods for information extraction developed. Precision farming, forestry and urban mapping with focus on change detection have been identified as important fields for demonstration projects. DLR's airborne SAR, E-SAR delivers polarimetric SAR data in high resolution and quality and in simulated TerraSAR quality. Those project partners, who are responsible for application development, map ground measurements to the data. Several companies including DEFiNiENS and universities work together as innovation and technology partners. They adapt segmentation algorithms and automatic classification to SAR, consider overall automation of the process, investigate possible synergy of the methods, and study embedding of all the developed algorithms in an upgraded ERDAS IMAGINE or prepare close interaction with ERDAS environment.

Technology development for information extraction and automation are mainly performed on two test sites located in the middle of Germany (Erfurt) and in the southern part (Ehingen). These regions cover urban areas as well as forest and agricultural fields, flat and rough terrain. Available are fully polarimetric L-Band and X-Band data sets in HH and VV-polarisation. Data are provided with different incidence angles, different geometric resolution, detected and comples data in slant range, detected data in ground range and geocoded. Data takes took place at different times in the vegetation period. These test sites serve not only to develop algorithms for information extraction but also to develop interfaces between the various technologies. See http://www.infoterra-global.com for further details.

The task of OSCAR within ProSmart II is to improve eCognition's capability for information extraction from polarimetric SAR data in L-Band and X-Band with resolution from 1m to 3m. These technological developments will be transferable for advanced SAR data of various modern sensors, e.g. Radarsat and Envisat, to a large extent and thus lead to an increased general utilizability of eCognition.

2. OBJECT BASED IMAGE ANALYSIS WITH ECOGNITION

A new approach in image analysis was developed by DEFiNiENS and implemented in a powerful software, eCognition [1][6]. Here, analysis of images mainly bases on features, spatial and hierarchical relationships of objects instead of single pixels. The relationships are represented with fuzzy rules, which are capable to deal with vague models and well suited to describe dependencies between different kinds of information [2]. Fusion of data from several sources can be easily performed and thus, reliability and meaning of the extracted information can be significantly increased. ECognition has started shipping to the global market in October 2000 and meanwhile has been applied to many remote sensing data. eCognition consists of two main steps, multi-resolution segmentation and objects based classification.

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A. Segmentation in eCognition

Adjacent, similar pixels are aggregated to segments where the increasing heterogeneity in spectral and spatial domain is minimized. Neighbouring segments are fused to a new segment, if the resulting increase of heterogeneity is minimum and below a specified level. The definition of heterogeneity is flexible and a trade-off between homogeneity in spectral domain (e.g. backscattering values of various channels) and spatial domain of segments is possible. Homogeneity in spectral domain is defined by a channel dependent weighted standard deviation. Homogeneity of shape considers a) the ratio of an object's border length to the object's total number of pixels (compactness), and b) the ratio between the object's border length to the length of the object's bounding box (smoothness). Compactness is minimum for a square, smoothness is minimum if the object borders are not frayed.

Considering shape as well as backscattering values for segmentation takes into account Tobler's first law of geography, which states a high spatial dependency between pixels. This leads to more meaningful segments which can be easier compared and combined with usual GIS, an important topic for commercial use of remotely sensed information.

Hierarchical approach - eCognition's technology mimics the hierarchical approach of image and scene analysis by humans: They analyse usually on several resolutions and more or less intuitively the best suited level is used for each object of interest. Humans explore the object's relations between different levels successfully to overcome ambiguities. This strategy is a basic concept in eCognition's analysis. The scale for each segmentation level is defined by the maximum allowed level of heterogeneity increase.

B. Rule Base Development in eCognition

Secondly, in eCognition the segments – so called objects – are assigned to classes. There are two major strategies implemented: a) Nearest neighbour classification and b) rule base development using fuzzy sets and fuzzy logic. In any case, no more features of single pixels are considered, only features assigned to objects. This has several advantages: a) significantly increased signal-to-noise ratio in the objects, b) decreased computational requirements and c) – most important - additional object features, which are not available or less meaningful for pixels: geometry (length, width, smoothness, compactness), relationships to neighbours within one level and between levels.

In case of rule base development the features are fuzzy variables. Fuzzy sets, e.g. "low backscatter value" are defined by fuzzy membership functions. Fuzzy if-then rules are used to create the rule base: *if object feature "backscatter value" is element of the fuzzy set "low backscatter value" then the observed surface belongs to the fuzzy set "smooth surface"*. Fuzzy "and" and "or" operators allow combinations of conditions and hierarchical class descriptions. Example: *If the backscatter value is member of "low backscatter value" and the form is element of "high length to width ratio" the object belongs to "street", which is a subset of "smooth surface"*.

Each object belongs typically to several classes. The ratio of membership degrees represent reliability of class assignment and class homogeneity of the object.

3. Envisaged Improvements of eCognition for SAR Data Evaluation Within OSCAR

Main applications of radar and especially polarimetry in remote sensing are land-cover classification for agricultural, forest applications and urban area mapping. Crop and tree type classification, estimation of soil and vegetation moisture content, biomass and vegetation height, monitoring of deforestation and forest re-growth are some of the major topics of current research.

However, to extract the bio-physical parameters relevant for these topics, combinations of measurements in various frequencies and polarisations and at various incidence angles and acquisition times have to be combined. Complex systems arise which use not only intensity data, but also complex data and possess a high potential for efficient data and information fusion.

Though all current multipolarized SAR systems have a more or less research status, the exploitation algorithms are very promising. With OSCAR we want to enable the remote sensing community to get customized to these powerful data, help them to apply the new algorithm developments and gain advantage for their applications. We think that eCognition is best suited to support the necessary data and information fusion, to deal with still vague models and link the results to GIS.

First, *input data format for eCognition is extended by complex format*. We split complex data in real part, imaginary part, amplitude and phase. All of these four channels or subsets, e.g. Cartesian format or polar format are possible inputs for segmentation.

A *special import filter* for the polarimetric airborne radar data of DLR's sensor *E-SAR* was developed. These data are used in OSCAR not only for algorithm development on high resolution polarimetric data but also for simulation of the expected Terra SAR data.

In addition to sensor independent features available in eCognition *radar features* are integrated, e.g. radar brightness, s^0 or - to characterise dominant scattering mechanism for each object – a) single bounce: $abs(\langle HH\rangle+\langle VV\rangle)$, b) double bounce: $abs(\langle HH\rangle-\langle VV\rangle)$, c) volume scattering: 2 $abs(\langle HV\rangle)$

These features are not available for single pixels, but – according to the object oriented approach in eCognition - on image objects. They are built by segmentation which gathers several adjacent pixels in one closed area with a certain homogeneity of polarimetric backscattering and (if selected) of shape. This averaging is marked in the above formula with brackets <> and reduces the speckling effect. This is very similar to a usual moving window approach, except for the automatic consideration of heterogeneities.

However, for some applications this approximation is not sufficient and segmentation should already be performed on the components of target vector $\vec{k}$ itself. Therefore we compute from the single polarimetric channels as *advanced channel representation* the *target vector* $\vec{k}$ [3]. The three complex vector components are new selectable inputs for eCognition segmentation.

An alternative yet implemented channel representation is the *span of the scattering* matrix. Using this information for segmentation nearly all heterogeneities in the polarimetric data are detected requiring a minimum of data storage, computational power and segmentation time. Features can be extracted from single polarimetric channels – even if they were not used for segmentation. Thus, mean brightness, s^{0} and dominant scattering mechanism are - as long as the necessary input data are fed into the system - still selectable and can be used to develop the classification rule base.

Further polarimetric representations are considered in current studies and topic of follow on developments.

As mentioned above, the creation of objects already decreases the disturbing amount of the typical speckle in SAR images. However, filtering prior to segmentation reduces the "artificial" heterogeneity due to speckle in the data and leads therefore to significantly improved segmentation. However, any filtering process must not disturb the possibilities for later polarimetric evaluation or blur small details in the high resolution data. Therefore we decided to *implement Lee's polarimetric filter* [5]. The *speckle standard deviation is estimated* according to Frulla [4]. to achieve some independency from the data and assist the less experienced user. This default value for the despeckling process can be manually replaced by a new *input parameter: degree of speckle* and thus various settings can be tested to achieve optimum segmentation for the desired application.

High resolution data give the possibility to extract information out of texture. Usually in eCognition texture of one object is evaluated using relations between its sub-objects. It will be studied, if this method can be enhanced if *traditional texture measures*, e.g. Haralick parameters) are evaluated on the data and used *as additional input* and to which degree these methods can be transferred to *object based texture extraction*.

Side-looking SAR geometry causes difficulties for information extraction. It *can be considered* to improve classification employing the already available geometrical features and the possibilities to consider spatial (e.g. mean direction) and contextual neighbourhood (relative border to an already classified object). Additionally incidence angle, relative orientation to flight direction and height information of objects – if a DEM is available – will soon be accessible as object information.

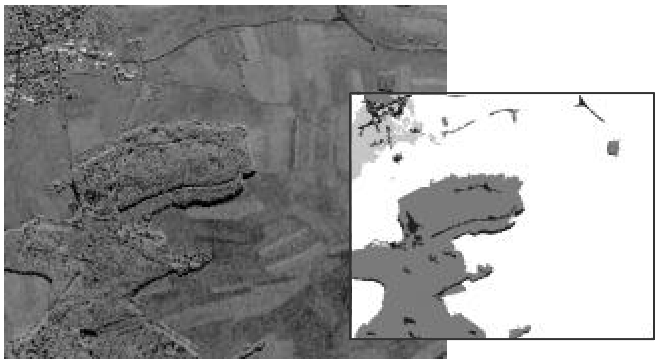

Figure 1: Data set taken within ProSmart, (X-Band,Subset of testsite Ehingen), large image: layer mean after initial segmentation, small image: three land cover types are classified: forest areas, settlements and shadow, which are important for further creation of street network.

4. Conclusion

OSCAR enables important developments for eCognition to increase its capability for SAR data evaluation. Yet complex data can be used, additional features for (polarimetric) SAR are integrated, despeckling can be performed and some distortions due to SAR geometry are already correctable. These developments will be refined and extended by textural analysis and advanced geometric features during the remaining project time. The developments within OSCAR are first and basic steps on eCognition's way to SAR analysis. They prepare further improvements, e.g. the implementation of higher order object features. These can include special polarimetric evaluations and *models for the derivation of bio-physical parameters.* Detailed studies on these topics together with universities and research centres will be part of the radar research activities at DEFiNiENS beyond OSCAR to enhance the existing feature extraction possibilities of eCognition.

References

[1] M. Baatz, "Object-Oriented and Multi-Scale Image Analysis in Semantic Networks" *Proc. 2nd Int. Symp. on Operationalization of Remote Sensing,* August 16th – 20th 1999. Enschede. ITC.

[2] U.C. Benz, "Supervised Fuzzy Analysis of Single and Multi-Channel SAR Data", *IEEE TGARS*, vol. 37, no. 2, pp. 1023-1037, March 99

[3] S.R. Cloude, E. Pottier, "A Review of Target Decomposition Theorems in Radar Polarimetry, IEEE TGRS, vol. 37, no. 2, pp. 498-518, Sept. 1995

[4] L. A. Frulla, J.A. Milovich, D.A. Gagliardin, "Automatic computation of speckle standard deviation in SAR images", *Int. J. Remote Sensing*, vol. 21, no. 15, pp. 2883-2899, 2000

[5] J. S. Lee, M. R. Grunes, G. de Grandi, "Polarimetric SAR Speckle Filtering and Its Implication for Classification", TGARS, vol. 37, no. 5, September 1999

[6] User Guide eCognition, www.definiens.com