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Remote Sensing, Formation of Objects and Determination of Quality

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Abstract

Object-oriented procedures are gaining increasing importance in the theory and practice of the analysis of remote sensing data. Unlike pixel-based procedures, object-oriented procedures are based on a priori defined objects or segmentation of regions. A priori defined objects can be derived e.g. from the ATKIS. Using computer-assisted segmentation, the picture is divided into more or less homogeneous regions. These regions can be characterized by features of different origin, e.g. spectral features, texture features, form characteristics and context relations. The representation and combination of the knowledge gained is implemented by modelling task-oriented concepts in semantic networks. At present the image interpretation system AIDA and the commercial software eCognition provide specially adapted environments for the object-oriented analysis of remotely sensed images. The operation requires the construction of proper rule networks which support the task-oriented extraction of objects. Beyond this procedures are to be developed which support the selection of relevant features, specify the force of an expression of a feature in relation to a target object, permit reliable classification of the object and allow quantitative predictions about the quality or classification accuracy of an object.

1. Why use Object- and Knowledge-Based Techniques?

The last decade, especially the past few years in remote sensing work, have seen rapid progress in research and development work object- and knowledge-based techniques aimed at automatic image interpretation. This trend has been driven in part by the awareness that traditional approaches (e.g. pixel-based Maximum Likelihood classifications) fail to deliver the kind of information demanded by the consumer. Most remote sensing activities to date have been projects performed in specific locations and over a specified time, with classification techniques adapted to the specific domain. To this extent it may be claimed that, except for some applications, remote sensing cannot be called operational! Even if remote sensing is

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accepted by the consumer as a possible method of data acquisition. The situation can be summarized in five theses:

1. The consumer needs value added data for specific fields (e.g. nature conservation, planning, forestry, etc.) and various types of work (building up and updating the data of information systems and digital maps, monitoring, etc.).
2. In many cases the desired scale and level of information have not yet been attained. Moreover, land use and not land cover is the required information in many applications.
3. The consumer wants geometrically and semantically accurate data. While in some cases relative high accuracy rates are achieved, concepts of overall accuracy for remote sensing data do not satisfy the demands, mainly because what is required is the explicit accuracy of an individual object.
4. Most remote sensing specialists will hopefully be aware of the spatial and temporal constraints, since too little attention is paid to the transferability of the methods applied.
5. A change in the traditional way of work will only be accepted if it comes up with a reasonable reduction in costs and the data can be easily integrated into the current GIS- and working environment.

The upcoming new generation of high resolution satellite sensors (e.g. Ikonos) is linked with high expectation of solving at least the problems addressed in the first two theses. While available mid-resolution remote sensing data (NOAA, Landsat, Spot, etc.) may not segment some desirable object due to the spectral and spatial resolution of the sensor, in high resolution data the same object may even be separated into parts with different spectral features. Moreover, as stated above, often not land cover but land use is the required information. This calls for the development of appropriate application methods, involving not only the spectral features but also texture, form and in particular, spatial context relations with the environment in which objects are embedded. For example, a park in town can only be distinguished from a meadow by using the local context. Object segmentation combined with rule-based classification methods might solve a lot of existing problems, but by requiring proper systems for the representation, combination and judgment of knowledge. Additionally it should be noted that besides the enthusiasm for high resolution data sets, global and regional applications still need to be implemented on the basis of medium resolution data. These can indeed profit from the usage of object-oriented techniques, too.

2. Evolution of Object- and Knowledge Based Image Interpretation

Object-oriented and knowledge based approaches were used quite early for the interpretation of remotely sensed images. Ketting and Landgrebe (1976) already pointed out the advantage of the extraction of homogenous objects and implemented a pre-segmentation algorithm called ECHO[2]. Wharton (1987) designed a spectral knowledge expert system for urban land cover classification. An aerial scene analysis system called SIGMA is described by Matsuyama (1987). Ton (1991) combines a spectral expert system with contextual information. An overview of computational image interpretation models till 1990 is given by Arigialis and Harlow (1990) who already pointed out: "*Knowledge based image interpretation can upgrade the state of image analysis capabilities from brute force mathematical and statistical approaches to analysis techniques based on interpretation logic and heuristics*."

Since then, various image interpretation systems have been described which use blackboard architectures, frame systems or semantic nets (Growe 1999). Flack (1995) defines feature type frames[3] *as a means for encapsulating knowledge concerning a particular feature type with the three main components: applications constraints, descriptors and process network*. In the image interpretation system AIDA (Liedtke et al. 1997) knowledge about objects is formulated in semantic nets and control knowledge is represented by rules. The semantic net in AIDA is based on the semantic network ERNEST (Niemann et al. 1990).

The first commercially available object-oriented image interpretation system is the software eCognition which extends the idea of representing knowledge in semantic nets by the so called fractal net evolution approach (Delphi 2 1999a). The methodical principles consists of two basic domains (Figure 1):

1. Construction of a hierarchical network of image objects where every object knows its context in hierarchy and neighbourhood
2. Classification based on a conceptual hierarchical network of classes and fuzzy logic for combination and judgment of rules.

Additionally eCognition provides the user with numerous spectral, form, texture and context features and an easy interface to formulate complex semantics for the extraction of objects. But all this does not exempt the user from selecting the appropriate object features or representative training data. eCognition has a couple of instruments for the selection of single features but it does not provide instruments for multivariate and structural data analysis[4]. Furthermore it can not support the user

[2] ECHO = Extraction and classification of homogenous objects

[3] Flack´s definition of feature is synonymous with target object in this paper.

[4] Analysis can be perfromed by exporting the object features and using another software package.

in the formulation of concepts and judgments for the combination of features. Some basic items concerning this problem are discussed in the next section.

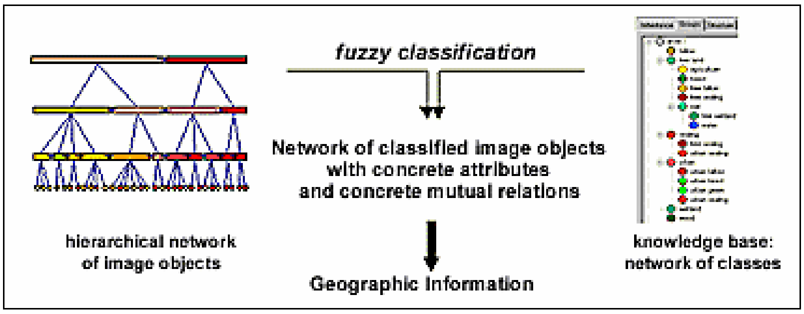

Figure 1
Methodical principle of eCognition, source: Delphi 2 (1999a)

3. Formation of Objects

3.1 What We Are Looking For?

Environmental objects are parts, fragments of the real environment for which information can or should become available, e.g. a settlement, a building a forest or a tree. As soon as we reflect real world objects as formal data objects in a spatial dimension, this representation is subject to some kind of classification - a systematic delineation and order of objects. This systematic order is always characterized by a specific point of view and task (function, land use, land cover, degree of some cover, etc.), which is reflected in the structure, the semantics and spatial definition and the characterization of the entities – the target objects. Moreover, the registration and the semantic and spatial delineation of an object is mainly determined by the method of inquiry, the resolution and the scale.

3.2 Segmentation of Remotely Sensed Images

The reflection of objects on the earth's surface is determined by physical and chemical properties, always depending on the spatial, spectral and radiometric resolution of the observing sensor. By segmentation[5], defined here as the process of finding an object in the spatial dimension, the image is segmented into more or less

[5] An overview and description of the different segmentation methods are given in Blaschke (1999). Hierarchical segmentation is described in Baatz & Schäpe (2000)

homogenous regions (a group of connected pixels) which we call image objects or image primitives. Area, form and homogeneity of the segmented image objects are defined by the selection and controls of the segmenting procedure and the features used. This is of major importance for further analysis, because only by assigning the image objects to a priori defined structure entities are the target objects formed. Moreover all subsequently derived object features are heavily dependent on the spatial dimension of the segmented image objects. Also we have to keep in mind the influence of the state of land use and phenology. As discussed before, no segmentation of an image can be considered as the “only right one”, rather the “right” segmentation is defined by the task of the consumer. Some of the stated problems may be overcome by using existing digital land use plots as an additional input or by using a hierarchical segmentation for separating objects in an appropriate spatial dimension.

3.3 Feature Extraction

To get image objects and target objects in relation we can describes image objects by features which characterize an image object by different concepts: spectral value and indices, form, texture and context relations. These can be stored as attributes of the image objects. An object feature describes an object by a specific value or range of the selected feature. The importance of an object feature is defined by its range and the overlap with the classes to which it is compared. The narrower the range of an object feature compared to the global range, and the smaller the overlap, the more important the feature is. This requires the use of pre-knowledge or learned knowledge about the specific values or ranges of the target objects in the feature dimension (a set of vectors), as well as some kind of analysis of the separability achieved by a specific feature. We can specify an extraction method as one or a collection of routines which may be combined in a structured rule network to supply extraction techniques for one or more specific object types. The extraction method can cover pixel-based and feature-based processing steps. Feature extraction in particular embraces the following steps:

1. Generation of features by specific routines
2. Selection of features by analysis of separability from the objects compared
3. Selection of features by analysis of the transferability or the specific constraints
4. Combination and judgment of features; this involves the representation of complex knowledge and the process of rule-based classification, and will be discussed in section 4.

3.3.1 Automation of Feature Extraction

In an more automated approach feature selection and combination can be performed on the basis of existing or generated reference data by analysing the separability between target object classes with statistical measures and a structural analysis of the context relations of the objects. Steinnocher and Bauer (2000) use the SAMS software, which is based on the graph theory, to analyse the structure of classified images. The results are then used for the construction of the rule network in eCognition. Delphi-IMM is currently developing ParaMaus, which supports automatic feature generation and selection. At present the software is especially adapted to analyse the features generated by eCognition. To support the construction of complex semantic networks, analysis of logical feature combinations and the generation of structured knowledge is necessary.

3.3.2 Representative Measures

Segmentation and the spectral and textural features of the objects are controlled by:

1. **Global dependencies** like atmospheric conditions at and before the acquisition date, time of acquisition (shadow), the state of land use and phenology or plant stress.
2. **Object-based specific constraints**: the impact of size and form must be taken into account by selecting representative training samples. By contrast with pixel-based training, the number of samples are limited and decrease with increasing object size. Object relations also have to be considered in the selection of samples if one wants to use contexts between unclassified objects in classifications.

3.3.3 Application Constraints

Application constraints are essential to limit the concepts (object features and extraction methods) to a domain of validity producing stable and reliable results. Constraints may exist in the location and temporal domain, as well as in radiometric, spectral and spatial resolution of the specific sensor. Application constraints are therefore a measure of the transferability of a feature.

3.4 Classification or Object Extraction

3.4.1 Representation of Knowledge

The traditional method of pixel-based classification is mostly based on statistical approaches such as unsupervised clustering or a supervised maximum likelihood classification. GIS data may be applied for stratification and Context is used in post classification process. Most statistical approaches rely on the normal distribution of the data and an adequate sample size. These demands cannot be met by training with image objects and features like texture, form and context relations. Hence there are systems like AIDA and eCognition using semantic networks for the representation and combination of knowledge. Following the description by Bückner et al (1999) semantic nets are directed acyclic graphs that consist of nodes, the objects and links that form the relations between them. Attributes define the properties of the nodes and links. A formal approach to the modelling of semantic nets in AIDA is given in Bückner et al (1999) and Growe (1999). The philosophical concept of eCognition consists of the basic idea that a system is described through its objects and an objects does not exist in itself, but in a context by mutual relations: the turtle (Figure 2). While image objects are represented on multiple scales, target objects or classes are expressed in the concepts of class hierarchies, involving inheritance to pass on properties form general classes to subobjects, grouping to address different classes by a single context and structure for the aggregation of heterogeneous objects (Delphi 2 1999b).

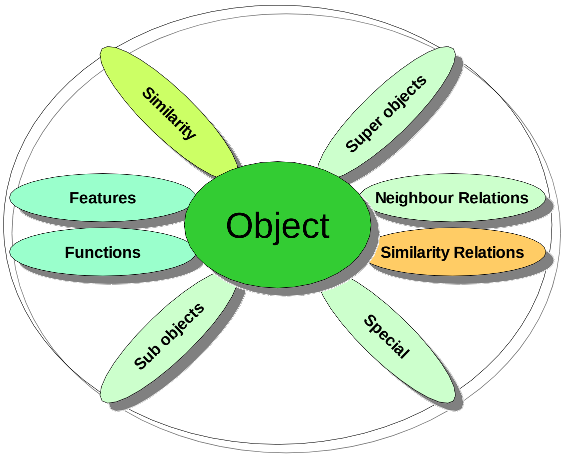

Figure 2
The concept of the turtle, modified according to Baatz et al. (1999),

The concepts for the class hierarchy may be data driven or concept driven, bottom up or top down or combinations of both approaches. The nodes in the class concepts contain expressions of the object features.

3.4.2 Combination and Judgement of Knowledge by Fuzzy Logic

In Figure 3 two possible concepts are given for the extraction of target objects. In the upper part the extraction of two distinct classes D and E is attained by the direct formulation of object specific distribution functions. In the lower part a hierarchical approach is used. As also seen in Figure 3 the assignments of the object features are described by fuzzy measures. For the combinations of different features for a node the logical fuzzy operators *and*, *or* and *mean* can be used. The chosen concept for the modelling of the target objects and the assignment of the fuzzy measures to the nodes, as well as the proper use of the fuzzy operators are the heart of any rule-based classification. No overall rules can be given for the design of these networks, while it surely will be possible to develop task-oriented networks that can be transferred by only minor adjustments.

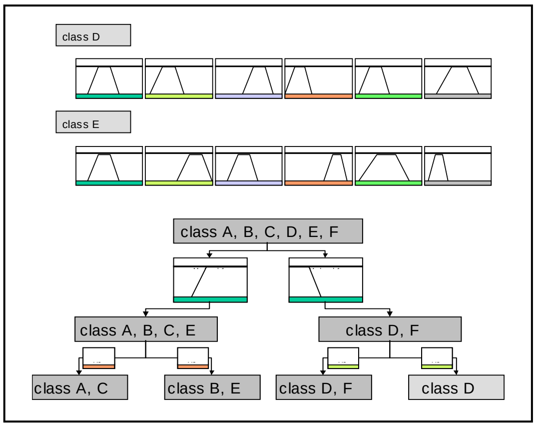

Figure 3
Different concepts for object extraction

4. Determination of Object Quality

4.1 Requests of the Object Quality

Determination of the classification quality of remote sensing data is performed with reference data. These data are given by the user. It is assumed that the reference data for these areas are 100% correct. The quality is determined by calculating the agreement between classification and reference data. The quality is specified for each class (in %) and for the entire scene.

The change to an object-oriented approach also changes the requirements concerning the quality of the data. While the global quality of the classes was sufficient with the usual approach, object-oriented classification places the quality of the individual object at the focus of attention.
The quality of an individual object consists of the view of the user from at least four aspects:

- the memorandum between two objects
- the form of the objects
- the quality of the surfacing edge line
- the classification of an object

4.1.1 The Memorandum Between Two Objects

The memorandum between two objects must correspond to the memoranda existing in nature. This demand is not satisfied in particular if the spectral signature of two objects is very similar. If meaningful fixing of the boundaries took place on the basis of segmentation, the user must be sure that the same boundaries are fixed during renewed segmentation with the same parameters.

4.1.2 The Form of the Objects

The user expects an object-oriented classification to produce objects with a form which corresponds to nature. This means that an area of arable land should not have merged with the adjacent area of arable land. Besides the usually square form of the area of arable land should be found. This demand is particularly problematic with urban objects which entail a flowing transition to another class.

4.1.3 The Quality of the Surfacing Edge Line

The results of a classification of remote sensing data usually will be integrated into other special data (GIS data). From this reason it is desirable that the object boundary lines are as linear as possible according to the yardstick for which they were produced. This demand is not fulfilled a priori by remote sensing data.

4.1.4 The classification of an object

Then the user needs a measure of how reliable the classification of each object is. This puts him into s position to decide whether the classification of an object must be checked or not. This demand means judging the quality of the set of rules which led to the respective classification. Thus the classification of remote sensing data acquires a new dimension.

4.1.5 Status of the Development of Object-Based Quality estimates

The determination of qualities for each object requires procedures which permit a comparison between the individual objects. Fuzzy approaches suggests themselves for this purpose in combination with sets of rules. There is only one software package currently on the German market which performs both segmentation and object classification by means of fuzzy technology. eCognition determines the probability of identification based on integrated rules for each object. This is used primarily in addition to object classification. But it can also be used to determine the quality of the objects among themselves. However there is no guarantee that this classification will be also absolutely correct. It requires further investigation.

- The problems with a determination of the quality of an object can be divided at present into the following groups:
- The quality of segmentation can be judged only by performing the classification. Since however the classification is closely correlated with the quality of segmentation, it cannot be judged whether the optimum selection was made for segmentation or classification in the respective case.
- There are only procedures which permit segmentation of the whole scene. It is to be expected however that the type of segmentation will also correlate with the objects which are looked sought Roads possibly need a different procedure / segmentation to coniferous forests.
- The classification of an object is based mostly not only on a rule, but on a network of rules. From it results a combination of fuzzy values, whose linkage regulations ('and' or 'or') can lead to different values in each case. Which linkage is necessary for which object must currently be decided in each individual case.

4.2 Resumé of Quality Identification

It may be held that object-oriented classification represents a new and promising way of analysing remote sensing data. However it appears already now that the request increase to the quality of the results. Moreover, the variety of the solution types increases and thus the complexity of the system to be mastered by the user. It is to be hoped that in the very near future procedures will be established which will support the process of analysis and procedures for quality regulation at the same time.

5. Design of a Framework for the Extraction of Objects

To formalize the given concepts a framework for the extraction of objects is described in figure 4. An object extraction frame is defined as a framework or a concept that contains application constraints, object features, extraction methods and procedures for the verification of quality. The left side of the figure shows the three main extraction procedures: segmentation, feature extraction and object extraction. Though present in a hierarchical manner, the network should be seen as a iterative process with reverse and forward links. The right side shows the criteria and procedures used for verification of each processing step.

6. Conclusion

At this time no final conclusion can be drawn to what extent object-oriented classifiers can fulfil the demands set out in the first chapter of this paper. Nevertheless there are some case studies (Bauer and Steinnocher 1999, Growe 1999, Bückner et al. 1999, Kok et al. 1999) which indicate the new perspectives brought into remote sensing analysis by object- and rule-based classification strategies. It is obvious that classification accuracy and depth can be improved by these techniques. But operational use does require the development of adaptive rule networks and complex knowledge bases. Beyond that the extraction of transferable and stable object features and the exact definition of the lasting constraints should be a task for research. Last but not least, procedures need to be developed which can qualify the still remaining uncertainty in the design of rule networks and the reasoning of fuzzy logic operations. Some single solutions will certainly become operational in the near future, with a noticeable reduction in costs.

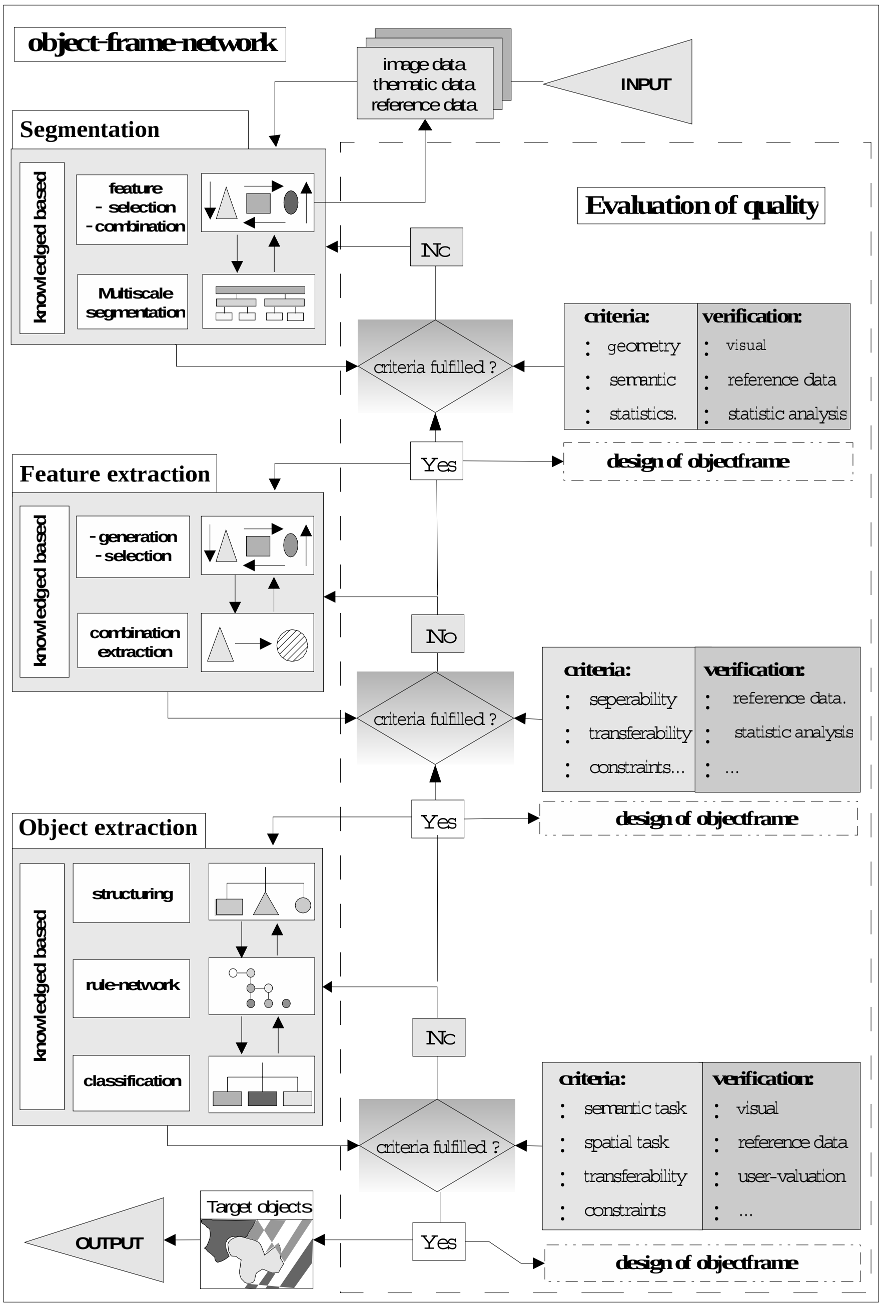

Figure 4: Framework for task-oriented object extraction

References

Argialis, D. P. & Harlow, C. A. (1990): Computational Image Interpretation Models: An Overview and a Perspective, Photogrammetric Engineering and Remote Sensing, Volume 56, No. 6, pp. 871-886

Baatz, M. & Schäpe, A. (2000): Multiresolution segmentation – an optimization approach for high quality multi-scale image segmentation. Angewandte geographische Informationsverarbeitung XII: Beiträge zum AGIT-Symposium Salzburg 2000, pp. 12-23

Baatz, M., Lessing, R., Rott, T., Schäpe, a. (199): Objekt-orientierte, fraktal-hierachische Auswertung von Fernerkundungsdaten, Rundgespräche der Kommission für Ökologie, Band 17 – Fernerkundung und Ökosystemanalyse, München

Blaschke, T. (1999): Objectextraction und regelbasierte Klassifikation von Fernerkundungs-daten: Neue Möglichkeiten für GIS-Anwender und Planer, 5. Symposium "Computergestütze Raumplanung" CORP 2000, pp. 153-162

Bückner, J., Koch, H., Pakzad, K. (1999): Knowledge Based Interpretation of Objects in Topographic Maps and Moorlands in Aerial Images, SMATI'99, Semantic Modelling for the Acquisition of Topographic Information from Images and Maps, München, ftp://ftp.tnt.uni-hannover.de/pub/smati99/proceeding.pdf

De Kok, R., Schneider, T., Ammer, U. (1999): Object-Based classification and Applications in The Alpine Forest Environment, International Archives of Photogrammetry and Remote Sensing, Volume 32, Part 7-4-3 W6, Valladoid, Spain 3-4 June 1999

Delphi 2 (1999a): Image quoted from http://www.delphi2.de/

Delphi 2 (1999b): Manual eCognition Beta Version

Flack, J. (1995): Interpretation of remotely sensed data using guided techniques, Ph.D. thesis, School of Computer Science, Curtin University of Technology, Western Australia

Growe, S. (1999): Knowledge Based Interpretation of Multisensor and Multitemporal Remote Sensing Images, SMATI'99, Semantic Modelling for the Acquisition of Topographic Information from Images and Maps, Munich ftp://ftp.tnt.uni-hannover.de/pub/smati99/proceeding.pdf

Kettig, R. L. & Landgrebe, D. A. (1976): "Computer Classification of Remotely Sensed Multispectral Image Data by Extraction and Classification of Homogeneous Objects," IEEE Transactions on Geoscience Electronics, Volume GE-14, No. 1, pp. 19-26

Liedtke, C.-E., Bückner, J., Grau, O., Growe, S. Tönjes, R. (1997): AIDA: A system for the Knowledge Based Interpretation of Remote Sensing Data, 3rd International Airborne Remote Sensing Conference July 7-10 1997, Copenhagen, Denmark, ftp://ftp.tnt.uni-hannover.de/pub/papers/1997/IARSC-CELJBOGSGRT.pdf

Matsuyama, T. (1987): Knowledged-Based Aerial Image Understanding Systems and Expert Systems for Image Processing, IEEE Transactions on Geoscience and Remote Sensing, Volume GE-25, No. 1, pp. 305-316

Niemann, H., Sagerer, G., Schröder, S., Kummert, F. (1990): ERNEST: A Semantic Network System for Pattern Understanding, IEEE Trans. On Pattern Analysis and Machine Intelligence, Volume 12. No. 9.

Steinnocher, K. & Bauer, T. (2000): Objektbasierte Auswertung von hochauflösenden Fernerkundungsdaten in urbanen Räumen. Angewandte geographische Informationsverarbeitung XII: Beiträge zum AGIT-Symposium Salzburg 2000, pp. 31 -38

Ton, J., Sticklen, J. & Jain, A. K. (1991): Knowledged-Based Segmentation of Landsat images, IEEE Transactions on Geoscience and Remote Sensing, Volume GE-29, No. 2, pp. 223-231

Wharton, S. (1987): A Spectral-Knowledge-Based Approach for Urban and Land-cover Discrimination, IEEE Transactions on Geoscience and Remote Sensing, Volume GE-25, No. 3, pp. 272-282