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**Topic: New Methodologies**

# Object-Oriented and Multi-Scale Image Analysis in Semantic Networks

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## Abstract

Important semantic information necessary to interpret an image is mostly not represented in single pixels but in meaningful image objects and their mutual relations.

Delphi2 Creative Technologies has developed a new technology and software for object-oriented and multi-scale image analysis. The procedure is based on the so called 'Fractal Net Evolution' approach which is a efficient method to describe complex semantics within largely self constructing and dynamic networks. It combines insights in the fractal structure of the world and of semantics with object orientation.

The procedure first extracts image objects which afterwards are classified by means of fuzzy-logic. Basic strategy is to build up a hierarchical network of image objects which allows to represent the image information in different resolutions simultaneously. By operating on the relations between networked objects it is possible to classify local context information**.** Beyond the pure spectral information this often essential information can be used together with form and texture features of image objects to improve classification significantly.

A basic part is a new patented technique for object segmentation. It extracts image object-primitives in arbitrary resolution - fine or coarse structures - and high quality. This technique has especially been adapted to find image objects in textured data, such as SAR images, high-resolution satellite imagery, airborn data or medical images. Additionally it is used to construct a hierarchical network of image objects, where each object 'knows' its context, its neighborhood and its subobjects.

The knowledge base for analysis comes in form of a hierarchical network of classes. It is threefold and distinguishes between inheritance of features, semantic grouping of classes and collection of classes into structure groups for the purpose of knowledge based object extraction. Features are evaluated by means of next-neighbour and membership functions.

The procedure allows the description and analysis of complex semantic tasks even on textured data. It works on an arbitrary number of channels and allows the treatment of arbitrary data types simultaneously, e.g. different resolution, GIS-layer, alivation etc.. It includes a new method for object oriented texture analysis and object oriented form analysis, both based on the analysis of subobjects. Finally it can be used to extract and export image objects for GIS applications in vectorized form. For different fields of applications, especially bridging remote sensing and GIS, the method proofed its far-reaching potential.

## *Introduction: The necessity for integration of remote sensing and GIS*

Nowadays GIS is becoming the basic tools to prepare spatially related decisions. But for a GIS database the same fact is true as for each kind of database: it can only be as good and as useful as the quality and actuality of it's data allow. For this reason it would be desirable to utilize results of exploited remote sensing data to a great extend for updating a GIS. The necessity for integration of remote sensing and GIS therefore is always emphasized again.

Especially it would be desirable to do this in a resource and therefore cost-saving way. But unfortunately there are some methodic obstacles preventing extensive automatic processing:

- One is the question of how to gain geo-information directly from remote sensing data. The operationalization of remote sensing is of course in general an objective of many studies and research. But there are two main issues: what to do about the automatic analysis of textured image data such as VHR-data or radar imagery? And, what to do about more complex problems which additionally require the consideration of local context-information?
- The updating of GIS demands polygons of classified image information. But automatic image object extraction is a open field, still today the digitalization of polygons requires in most cases extensive manual resources.
- In many cases it would be helpful to include already existing data with the GIS – for instance cadastral or landscape model data - for interpretation of remote sensing data. But there are no systematic methods which allow image fusion or data fusion for different applications in an operational way.

In fact, the described problems are so difficult that up until now one could not speak of an effective integration of remote sensing and GIS.

This contribution presents a new technology for image analysis which addresses exactly those problems hampering a successful brigding of Remote Sensing and GIS. It is based on the concept that important semantic information necessary to interpret an image is not represented in individual pixels but in meaningful image objects and their contextual relations.

## *Object-Oriented and Multi-Scale Image Analysis in Semantic Networks*

The procedure is based on the so called 'Fractal Net Evolution' approach developed at Delphi2 Creative Technologies which is an efficient method to describe complex semantics within largely self constructing and dynamic networks. For image analysis there are three main points resulting:

- Object orientation
  The procedure first extracts image objects which afterwards are classified by means of fuzzy-logic
- Representation of the image information in different scales simultaneously.
  Each image contains of different semantic levels in the same time. Basic strategy is therefore to build up a hierarchical network of image objects which allows to represent the image information content at different resolutions (scales) simultaneously. By operating on the relations between networked objects, it is possible to classify local object **context information.** Beyond the pure spectral information this often essential context information can be used together with **form** and **texture** features of image objects to improve classification.
- Description, processing and analysis of image information by means of semantic networks

The procedure contains two basic domains:

**Construction of a hierarchical network of image objects**

- New procedure for automatic extraction of object primitives in any chosen resolution
- knowledge based collection of image objects on the basis of classified object primitives

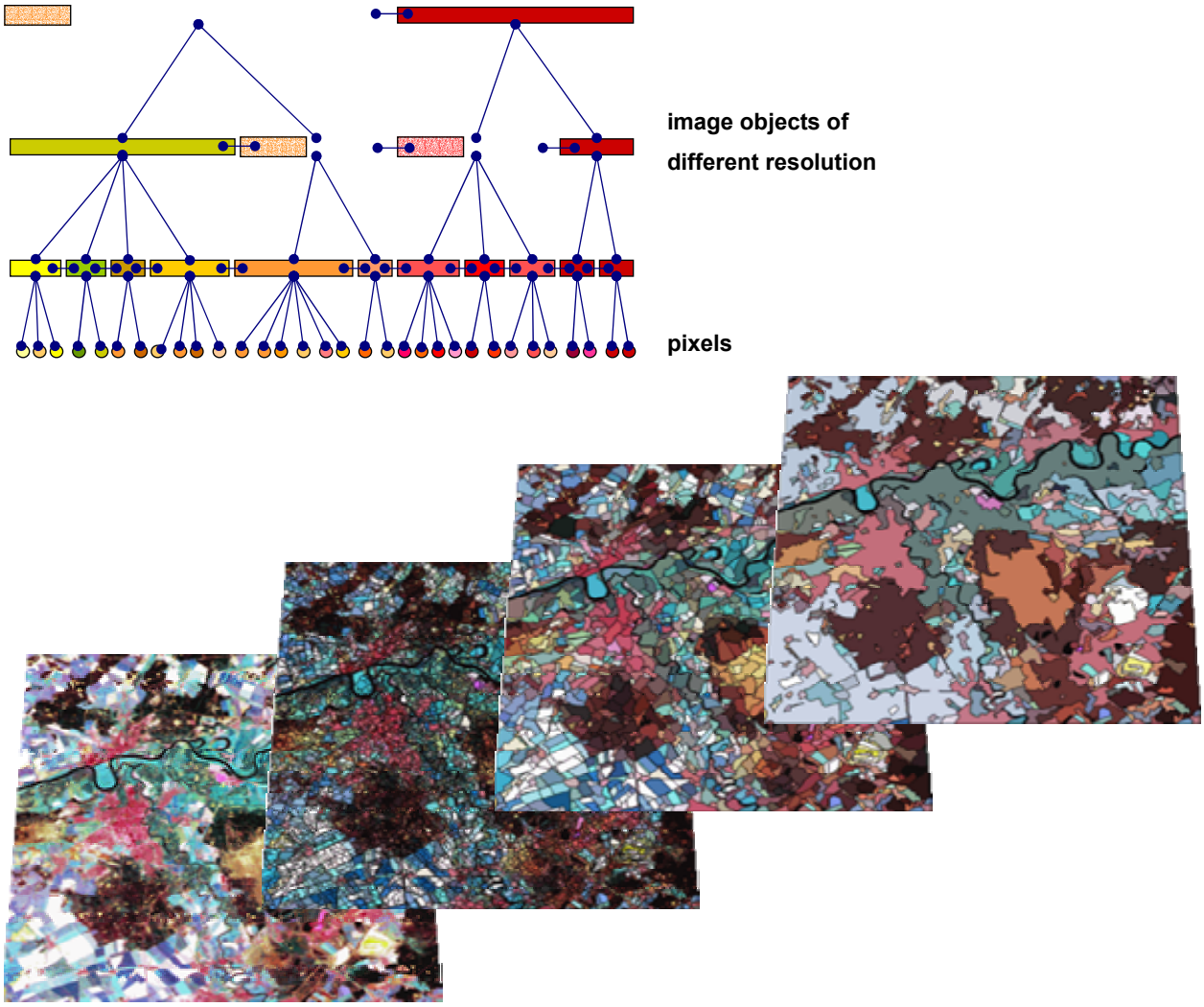
**Classification of image objects by means of fuzzy logic**

- on features of objects
- on relations between networked objects operating on the semantic network

### Hierarchical network of image objects

A basic part of the procedure is a new technique for object segmentation which is able to find image objects in any chosen resolution (fine or coarse structures) and high quality. This technique has especially been adapted to extract image objects from textured or low-contrast data, such as airborne and satellite SAR and high resolution optical image data, or from medical images. Beyond the pure spectral information, image-objects are characterized by a number of additional features such as **texture** and **form**. All this additional information can hardly be exploited using pixel-based approaches.

The possibility to extract image objects in any chosen scale is an important feature in practical operation: the image object resolution can be adapted to the specific imagery and to the specific problem at hand.




Representation of image information by means of a hierarchical network of image objects
Above: schematic view; Below: image objects on different levels of the hierarchical network

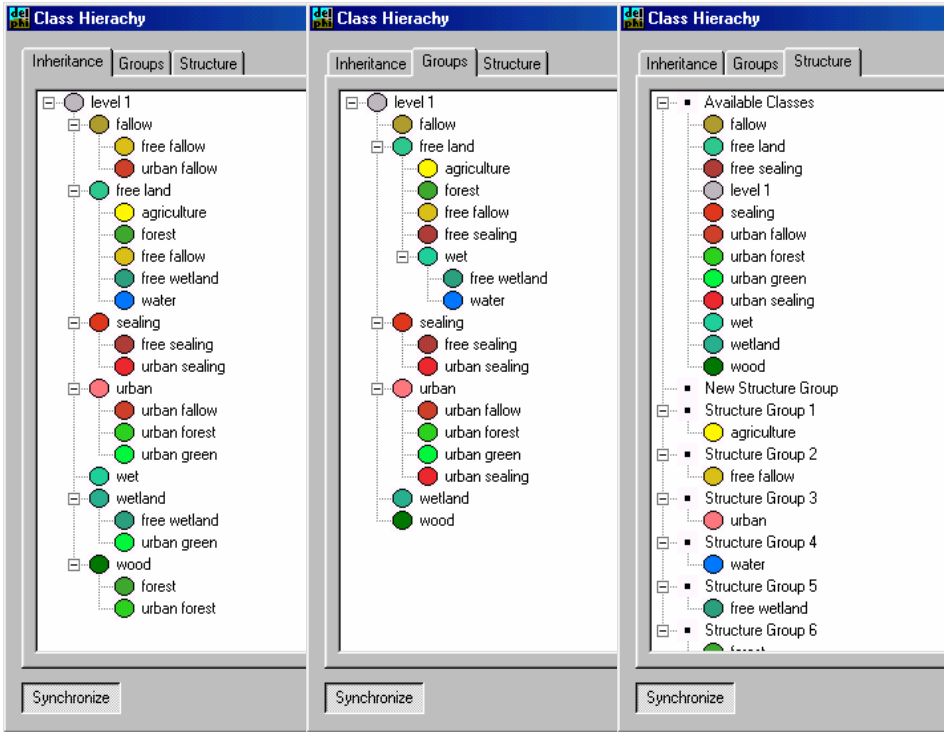
By means of this segmentation technique a **hierarchical network of image objects** can be constructed in which high resolution objects are subobjects of coarser structures. The hierarchical structure represents the information of the image data in different resolutions simultaneously. Each object 'knows' its context, its

neighborhood and its subobjects. Thus, it is possible to define relations between objects, e.g. 'relative border length to class *forest*', and to utilize this additional and often essential **context information**.

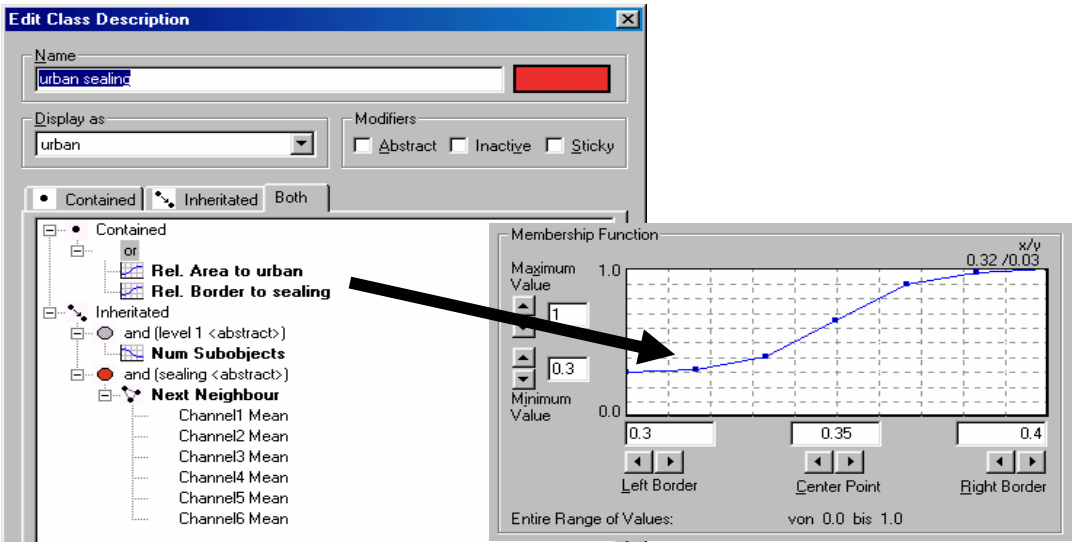
On the basis of the analysis of subobjects the procedure provides new interesting methods for **object oriented texture analysis** and **object oriented form analysis**.

### Classification of image objects

The knowledge basis for analysis comes in the form of a second semantic network, the class hierarchy. It is threefold and distinguishes between inheritance of feature descriptions to subordinate classes, semantic grouping of classes and the collection of classes into structure groups for the purpose of knowledge based object extraction. The advantages are structured semantics, the possibility to formulate even complex semantics, and the possibility for reduction of complexity at formulating a feature description.




Classification is done based on fuzzy logic. The advantage of fuzzy-logic is the possibility to integrate most different kinds of features and to connect them by means of (fuzzy-) logical operators. Thus complex class descriptions are possible. Compared to neural networks the advantage is a transparent and adaptable set of classification rules. Each single step of classification can be retraced for each image object in detail. The classificators used for the class descriptions are next neighbour or membership functions.




**Class description and membership function**

All steps of an image analysis can be recorded as a complete procedure. Thus, the whole strategy for solving a particular problem can be applied to other data of the same type.

Furthermore, the object oriented approach allows the use of **locally different strategies** for image analysis depending on the classification of objects.

**Advantages of the procedure**

- Analysis even on textured or low contrast data, e.g. VHR-satellite imagery, airborne or radar data
- Formulation and analysis of complex semantic tasks
- Transparent and adaptable fuzzy logic classification
- Analysis on an arbitrary number of channels
- Data Fusion: analysis of arbitrary data types simultaneously; e.g. different resolution, GIS-layer, elevation
- Export of vectored image objects as classified polygons for GIS applications

## *Conclusion*

The procedure described above solves some main problems encountered to date whenever geo-information is to be extracted from remote sensing imagery applying standard, pixel-based operations. This especially includes main problems of the integration of remote sensing and GIS. By first segmenting

an image into objects, the approach eliminates misclassifications of single image pixels, which make the transformation of image information into polygons of land-use information a time consuming and often inaccurate process. Using the object-oriented approach instead, whole image objects are classified yielding GIS-type land use map information in a most direct way. In addition, the knowledge based classification of image objects within semantic networks offers a high level of flexibility, but also of accuracy to the operator of the software. At the same time, the method creates by means of fuzzy logic reproducible results of image classification, and is thus advantageous over neural network classifiers often applied.

A software for image analysis based on this procedure will be available on the market by January 2000.