

# RELATIONS BETWEEN MULTI SCALE IMAGERY AND GIS AGGREGATION LEVELS FOR THE AUTOMATIC EXTRACTION OF VEGETATION AREAS

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**ABSTRACT:** This study deals with the automatic interpretation of digital imagery and focuses on natural topographic objects, in particular vegetation. As a first step for developing a sound strategy combining pixel based and model based image analysis, we investigate the possibilities and limitations of pixel based methods in large scale applications. Throughout the paper we assume multispectral imagery as the basis of our discussion.

Connections between different aggregation levels in GIS and the information content of imagery in different scales are discussed, and various properties of linear and morphological scale space in order to generate the individual image resolution levels are described. The paper continues with a case study dealing with the differentiation between sealed and non-sealed regions in urban areas. While this task proves feasible using pixel based methods, a further model based image analysis step is necessary to extract individual GIS landscape features.

## 1 INTRODUCTION

The automatic extraction of topographic objects from digital images has been and still is a major research topic in photogrammetry, remote sensing, and computer vision. Much effort was spent on the extraction of man-made objects such as buildings and roads for large scale applications using model based image analysis [see MAYER, 1999 for an excellent overview and EBNER et al. 1999 as well as FÖRSTNER et al. 1999 for a collections of recent high quality papers on this subject]. Natural objects such as vegetation and water, on the other hand were mainly interesting in smaller scales and have traditionally been acquired using low resolution multispectral imagery and pixel based methods. Today, multispectral classification for the extraction of topographic objects with area character (settlements, forest, agricultural areas, water) can be looked upon as operational for imagery with a ground sampling distance (GSD) of about 10[m] and coarser.

For a number of reasons, e .g. the increasing awareness for environmental issues, a trend can be observed towards using a growing

number of high resolution aerial and remote sensing images for applications dealing with natural objects. As a consequence new methods for the extraction of these objects from the higher resolution images have been developed. Examples include the detection and description of sealed and non-sealed regions in urban areas [BAYER and HILZ, 1997], forest mapping [BORGEFORS et al. 1999], precision farming [GRENZDÖRFER, 1998], and environmental monitoring [PAKZAD et al. 1999].

This study deals with the automatic interpretation of digital imagery and focuses on natural topographic objects, in particular vegetation. As a first step for developing a sound strategy combining pixel based and model based image analysis, we are interested to exploit the limits of pixel based methods in large scale applications. Throughout the paper we assume multispectral imagery such as the one to be acquired by the announced high resolution satellites [FRITZ 1997] as the basis of our discussion. This type of imagery is also increasingly being acquired by digital airborne CCD sensors.

Connections between different aggregation levels in geographic information systems

(GIS) and the information content of imagery in different scales are discussed in chapter 2. In chapter 3 various properties of linear and morphological scale space in order to generate the individual image resolution levels are described, and examples for forest, agricultural and settlement areas are given. The paper continues with a case study dealing with the differentiation between sealed and non-sealed regions in urban areas and concludes with a short summary and an outlook for further research.

## 2 GIS AGGREGATION LEVELS AND IMAGE GROUND SAMPLING DISTANCE

Usually GIS data models are built up in a hierarchical structure which “describes first extensive, then smaller and finally singular landscape features, corresponding to the point of view of a spectator who is approaching the earth from the space” [PETZOLD, 1998, p. 243]. On the highest level of abstraction one can distinguish *visible* and *non-visible* features. Non-visible are administrative features like legal boundaries. Visible are landscape features of the superclasses settlement, transportation, vegetation, and water. These superclasses can be looked upon as base classes for a class hierarchy, e.g. a class *forest* with the attributes stem volume, tree type etc. is a derived class of the superclass vegetation.

The four superclasses settlement, transportation, vegetation, and water can be looked upon as a small thematic resolution or *global context* [BAUMGARTNER et al., 1997], and the corresponding data acquisition can often be based on imagery of a rather coarse GSD of 10[m] or larger. At this image resolution the features of each superclass appear more or less homogeneous in the imagery, which is of course the underlying reason for the success of multispectral classification at this level, especially for the superclasses with area characteristics (settlement, vegetation, water).

The individual feature classes correspond to a large thematic resolution or *local context*. In order to carry out data acquisition for the individual feature classes the necessary GSD must be much smaller and can reach 0.1[m]. At this GSD the connection between a feature

defined in the GIS data model and its appearance in the image is much more complicated. Landscape features can be (partly) disturbed by shadows, and/or they can be occluded by other features. They can also be composed of different well identifiable (sub-) features below the resolution of the GIS data model. As a consequence automatic image interpretation becomes much harder, and is often carried out using the more involved model based approaches. The task becomes somewhat easier, if the global context is known. Global context can be obtained either from external sources such as existing GIS data or from processing of the imagery at a reduced GSD, e. g. using multispectral classification, possibly combined with texture classification. This observation is essential for the success of multi scale image interpretation based on scale space theory [KOENDERING, 1984, LINDEBERG, 1994]. An example for this strategy is the multi scale road extraction approach of [BAUMGARTNER et al., 1997].

## 3 SCALE SPACES IN IMAGE ANALYSIS

### 3.1 Linear and morphological scale space

Given the high resolution imagery the generation of imagery with reduced resolution can be carried out in different ways. Gaussian filtering is a standard tool for this task, and is often combined with the generation of image pyramids, e. g. for fast on-screen display or within image matching for automatic aerial triangulation or the generation of digital terrain models.

Gaussian filtering leads to the so called linear scale space. Another possibility is given by using rank filters which are linked to the morphological scale space. MAYER [1998] gives an overview of scale space theory and summarises the characteristics of the linear and the morphological scale spaces as follows:

- The linear scale space is related to the size and grey values of objects. As a consequence, objects or disturbances with high local contrast are visible up to a relatively coarse resolution, even if they are of small spatial extension.

- Since the morphological scale space is based on rank filters only the spatial extension of objects is important, local contrast does not come into play. Therefore, small objects are always eliminated in the filtering process, independently of local contrast.

As a result the lower resolution images in morphological scale space are rather homogeneous in brightness, and thus, pixel based classification methods have a good chance to yield the correct global context.

### 3.2 Examples for the behaviour of objects in the morphological scale space

The following figures illustrate the behaviour of images in morphological scale space. The depicted multispectral images have been acquired in summer 1997 using the DPA sensor [Digital Photogrammetric Assembly, see FRITSCH 1997 for details] and have a GSD of approximately 0.8[m]. Reduced resolution images were computed in morphological scale space with 3.2[m] and 12.8[m] GSD, respectively. These resolutions were found adequate for the given examples. It should be noted however, that the GSD at which an image starts to become homogeneous, depends only on the size of the depicted objects.

#### 3.2.1 Forest

Fig. 1 shows a part of a conifer forest area in the original resolution. An obvious texture is noticeable which leads to a lot of different spectral signatures in this region. Pixel based classification algorithms will therefore yield many different classes inside this area. The texture is much less visible in Fig. 2, and at 12.8[m] GSD (Fig. 3) the area is predominantly homogeneous.



Fig. 1: Forest in original resolution of 0.8[m]      Fig. 2: The same area as in Fig. 1 in 3.2[m] resolution      Fig. 3: The same area as in Fig. 1 in 12.8[m] resolution

#### 3.2.2 Agricultural Areas

Fig. 4 shows two agricultural areas and a field path with bushes in between. One can see that

in the 3.2[m] resolution the field path becomes a line between the two areas, see Fig. 5. Furthermore the disturbances – the stripes inside the field – disappear and the areas become homogenous. In the 12.8[m] resolution (see Fig. 6) only two homogeneous areas remain, and the field path is not noticeable any more.

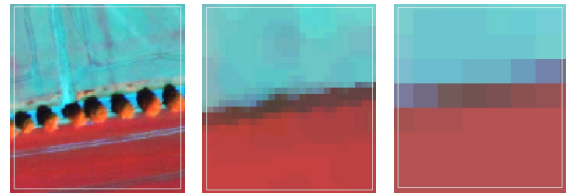


Fig. 4: Two agricultural areas with a field path and bushes, 0.8[m] resolution      Fig. 5: The same area as in Fig. 4 in 3.2[m] resolution      Fig. 6: The same area as in Fig. 4 in 12.8[m] resolution

#### 3.2.3 Settlement Areas

The third example shows the aggregation of a settlement area to a homogeneous region in the 12.8[m] resolution. The buildings, roads and trees which are identifiable at the original resolution in Fig. 7 and partly also at 3.2[m] in Fig. 8 merge to one region with similar grey values for this type of global context, see Fig.9.

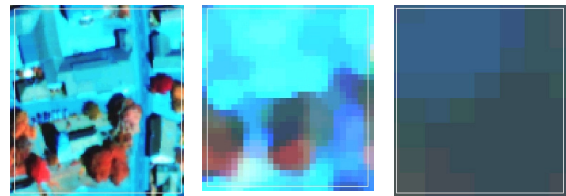


Fig. 7: Settlement area in original resolution, 0.8[m].      Fig. 8: The same area as in Fig. 7 in 3.2[m] resolution      Fig. 9: The same area as in Fig. 7 in 12.8[m] resolution

#### 3.2.4 Consequences

These three examples have been presented in order to motivate the use of the morphological scale space in order to provide global context necessary for image analysis at higher resolution. As could be seen in all three examples more or less homogeneous image patches were generated at a GSD of 12.8[m]. Therefore, there is a good chance that at this resolution global context can be extracted using pixel based methods such as multispectral classification. As mentioned before, the actual classification based on the reduced images itself is a standard task in remote sensing, and will not be discussed in detail here (see HEIPKE, STRAUB 1999 for a description of the approach we have adopted).

Rather we are interested in the possibilities and limitations of pixel based methods at higher resolution given the global context as prior information. We continue with an example dealing with the extraction of vegetation in an urban area in order to differentiate sealed and non-sealed regions.

#### 4 VEGETATION EXTRACTION IN URBAN AREAS

The differentiation of sealed and non-sealed regions in urban areas can be based on various pixel based methods, e. g. multispectral classification. However, in many cases different vegetation is present in the images, and multi-spectral classification leads to an undesirably large number of vegetation classes. Sealed and non-sealed regions can also be separated based on the difference between the grey values in the near infrared (NIR) and the red channel which can be expressed by the Normalised Difference Vegetation Index (NDVI):

$$\text{NDVI} = (\text{NIR} - \text{red}) / (\text{NIR} + \text{red})$$

The NDVI describes the vitality of vegetation and is a standard tool in vegetation mapping. For vital vegetation the grey values in the near infrared channel are significantly higher than those in the red channel leading to positive values for the NDVI. The sharp increase in reflectivity is also called the red edge in the spectral signature of vegetation objects. In regions with non-vital or without vegetation this increase in grey values between the red and the NIR channel does not exist. Thus, the NDVI can be used for a rather robust separation between sealed and non-sealed regions.

The image we want to illustrate our approach with is shown in figure 10, containing part of the multispectral DPA image described earlier (green, red, and near infrared channel) at the original GSD of 0.8[m]. The two superclasses or global context regions agricultural and settlement area are clearly visible. Figure 11 depicts the related NDVI image. Note that within the settlement area the NDVI image seems to only consist of black and white pixels corresponding to non-vital and vital vegetation as discussed above. In figure 12 the multispectral image at a GSD of 12.8[m] after reduction in morphological scale space (see chapter 3) is shown, while figure 13 contains



Fig. 10: Multispectral image at 0.8[m] GSD



Fig. 11: Corresponding NDVI image

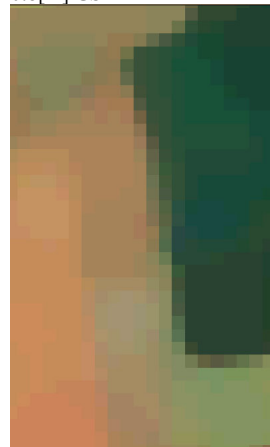


Fig. 12: Multispectral image at 12.8[m] GSD



Fig. 13: Result of multispectral classification

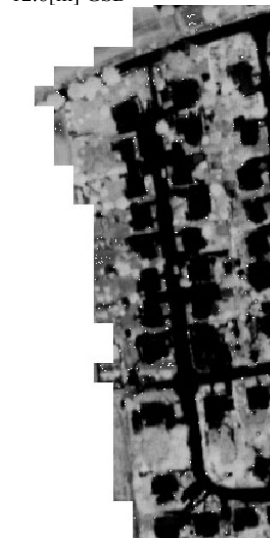


Fig. 14: Settlement area in NDVI image, enlargement

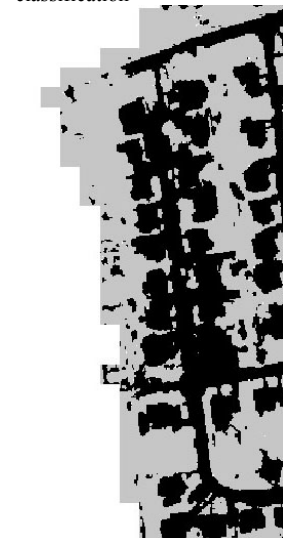


Fig. 15: Result of separation between sealed and non-sealed regions shown in Fig. 14

the results of a multispectral classification with automatic generation of the training areas as described in [HEIPKE, STRAUB 1999]. It can be seen that a clear separation between the two global context areas was achieved. An enlargement of the NDVI image of the settlement area is depicted in figure 14. Within this area a histogram based segmentation of

the NDVI image in the original resolution was sufficient to separate the two classes 'sealed' and 'non-sealed'. These two classes constitute our final result and are shown in figure 15. Grey signifies non-sealed regions while black stands for sealed regions. Of course, while the derived result is already adequate for a number of applications, it needs to be further refined in order to generate individual landscape features for other applications. This refinement is necessary due to two main problems: (1) Vegetation can occlude sealed regions, this is true mainly for trees. (2) Landscape features at the aggregation level concerned may by definition consist of sealed and non-sealed regions. As an example consider the landscape feature 'residential area' of the German ATKIS (Authoritative Topographic-Cartographic Information System, [ADV, 1989, 1995]). A residential area is defined as a part of a city or village and contains all parcels (buildings and surrounding vegetation), and is bordered by roads. Thus, in order to generate a landscape feature 'residential area' from our results described above the non-vegetation area has to be differentiated into buildings and roads, and the road network has to be extracted.

These problems cannot be solved using pixel based methods, and thus they constitute the limitations of these approaches. In order to overcome them model based image analysis taking into account an explicit modelling of the available prior knowledge (among others the definition of the landscape features) and relations between neighbouring features is seen as a promising solution.

## 5 SUMMARY AND OUTLOOK

In this paper we have discussed the relations between the behaviour of some topographic objects in multi scale imagery and different aggregation levels in GIS. We have shown that a number of superclasses in the hierarchically structured GIS data model correspond to global context regions used in image analysis. With the help of three examples we have shown that given a multispectral image with a ground sampling distance of 0.8[m] a reduced resolution image of 12.8[m] GSD can be generated in morphological scale space containing the global context regions forest, agricultural areas, and settlement as more or less homogeneous areas. We have further

shown that because of this homogeneity multispectral classification can be successfully used to derive the global context in the lower resolution images.

The prior information needed for the multispectral classification consists only of a few training areas. They can be easily defined by an operator or – if available – taken from existing GIS data. Given this global context pixel based methods can be used with some success also at the higher image resolution (0.8[m] in our case), e.g. for separating sealed and non-sealed regions in an urban area. However, as was to be expected a number of deficiencies shows up in the result. Model based image analysis is seen as a promising tool to overcome these deficiencies. In further research we will exploit the possibilities of model based image analysis to refine the obtained results and will apply the whole procedure to imagery of the announced high resolution satellite sensors.

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