GIS TECHNIQUES AND HYBRID PARAMETRIC/NON-PARAMETRIC IMAGE CLASSIFICATION: A CASE STUDY SHOWING THE POTENTIAL FOR SIGNATURE TRAINING AND ACCURACY ASSESSMENT

Thomas Blaschke
Salzburg University
Austria

Commission II, Working Group 2

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ABSTRACT

A landuse/landcover map has been developed for a 900 km^2 area of a planned National Park in the Salzburg Calcareous Alps (Austria). The resulting map should serve as a supplement to the adjacent National Park Berchtesgaden on the German side of the border. The remote sensing approach employed the analysis of Landsat TM-data in conjunction with a partly available forest map and geological and terrain data to derive a thorough classification procedure. The goal was the highest possible compatibility to an existing classification developed through airphoto interpretation. Existing data from the Berchtesgaden National Park cover a third of the used subscene and were integrated in order to design a comprehensive protected area system to support environmental assessment, monitoring, and restoration activities. Because the airphoto classification scheme was too detailed for the satellite data, a remote sensing classification scheme was developed not analogous to the airphoto interpretation but comparable through hierarchical organisation. A hybrid parametric/non-parametric classification strategy (followed by post-classification processing techniques) was used to map 15 main classes. The study provided a description of the classification procedures and a baseline for more detailed mapping and monitoring using remote sensing-supported change detection techniques.

INTRODUCTION

The availability of landuse/landcover data for nature conservation is a growing issue in most parts of the world. Until recently, in highly structured and densely populated areas as Central Europe, there was a strong preference for air photo interpretation and a kind of „mental reservation" concerning the use of satellite data except for small scale climatological studies. These reservations are not only a question of spatial resolution, but also the level of information that can be extracted from the satellite imagery and the relatively poor accuracy of classification of these machine-classified data compared to the hand-classified cartographic data (Mason et al. 1988). Natural and near-natural ecosystems are rare and the need for protecting such environments is more and more recognised. Among other projects, a National Park is planned in the Salzburg Calcareous Alps (Austria) next to the existing National Park Berchtesgaden on the German side of the border. The border divides a great and unique ecosystem administratively into two countries. As a first step towards a more comprehensive protection of this alpine ecosystem and the implementation of a National Park administration, a digital data base of the whole area was developed. In this paper, the issue of a landcover classification is elucidated because it is generally the most common theme extracted from remote sensing data.

Because the existing aerial photo classification scheme is too detailed for the satellite data, extensive field work and statistical analysis of the environmental, biological and remote sensing data were performed to develop a remote sensing classification not analogous to the vegetation but comparable through hierarchical organisation. A hybrid parametric/non-parametric classification strategy (followed by post-classification processing techniques) was used to map 15 main classes. While both classifiers have advantages and shortcomings, newer software products provide a high level of integration between image space and feature space for a hybrid approach to classification. A mixed set of signatures derived from both image and feature space required decision rules where both the parametric and non-parametric class definitions were considered. The combination allows for great visualisation and analytic capabilities. The ERDAS software was used and contains various tools not only to interactively digitise graphic objects in both feature and image space but also for cursor linking and object-to-mask mapping in-between image and feature space. This study provided a description of the classification procedures and a baseline for more detailed mapping and monitoring using remote sensing-supported change detection techniques.

STUDY AREA AND OBJECTIVES

The study area was located in Austria south of the city of Salzburg. It covers mostly an alpine landscape in the Northern Alps with elevations up to 2700 m above sealevel. Only the Salzach valley is highly populated while the alpine parts are covered by very few settlements. The satellite data rectangle covers the study area itself as well as great parts of the National Park Berchtesgaden (Germany) on the other side of the border. The idea is to implement a National Park adjacent to the existing one consisting of the same ecosystem and divided only by artificial boundaries. For the Berchtesgaden area, various data in digital format exist and GIS-techniques have been used for more than ten years. A landcover map was derived in 1985 at an original scale of 1:10000 from airphoto interpretation using a very detailed classification theme. The objective of this work was to use existing information for supervised classification and accuracy assessment. Thus, a hierarchical classification scheme was developed, but even with generalisation, not all original classes could be assigned to new classes. Therefore a hybrid parametric/non-parametric classification procedure was chosen to 'cover' additional parts of the feature space.

METHODOLOGY

The Landsat TM data were chosen for use in this project over SPOT data because they contain spectral information from a broader portion of the electromagnetic spectrum. This was seen as being more important for vegetation discrimination than the better spatial resolution of SPOT data. Aerial photography was used as an ancillary source of information, especially for the image processing procedures of geocorrection, data enhancement and supervised classification. ERDAS software was used for image processing and the *Arc/Info* Geographic Information System (GIS) for vector data manipulation. The six non-thermal bands of a TM-scene from August 1990 were classified. Image normalisation was applied on the basis of a 50 meter Digital Elevation Model (DEM).

Different unsupervised classification techniques were tested. The lower parts surrounding the study area were excluded prior to clustering. Repeated experiments with different numbers of classes were performed but classes that fell in forest sites could not be comprehensively identified. The maximum likelihood decision rule for a supervised classification approach was chosen. This type of classifier, called parametric, has been the most commonly applied classification technique because of its well developed theoretical base and its successful application with different data types and different applications (Bolstad and Lillesand 1991). With the parametric technique, the classifier must be trained with class signatures defined by a statistical summary of the mean vector and the covariance matrix normally acquired by the analyst selecting samples. It is known that problems arise if samples are too homogeneous in any one band or the sample size is too small. The classifier also assumes that the distribution of the sample data is normal in all bands, a condition which is sometimes violated for certain classes (Ince 1987). Therefore, Kloer (1994) suggests the complementary use of the parametric and non-parametric approaches. He underlines, that the non-parametric classification method has potentials and limitations as well. Some researchers have used non-parametric methods mainly for the classification of natural surfaces (Skidmore and Turner 1988). These methods make no assumption about the shape of the spectral distribution of data sets except that they can be grouped by a discriminant function and are expected to present advantages in spectrally irregular situations. Masseli et al. (1992) looked upon them as an attempt to overcome the well known problem of the low correspondence between cover categories and defined spectral classes. These authors state, that in practice, non-parametric methods have been demonstrated to perform far better than the conventional parametric procedures in many applications. The feature space object-based classifier has the problem of overlap. Since no probabilities are computed, the only means of resolution is to consider the order in which the classes are processed. The pixel in an overlapping area is assigned to the first or last class for which it is tested and many pixels of an image will not be assigned to any class in an output classified image.

APPLICATION

As previously mentioned, the Landsat-TM data were chosen for use in this project because they contain spectral information from a broader portion of the electromagnetic spectrum than SPOT. This is a very important fact especially in the subalpine vegetation zone approaching the tree line, where vegetation is sparse and the spectral information of an area may depend largely on the combination of trees and shrub and/or the combination of single trees or shrub and alpine meadows (Blaschke 1992). Analysis of the Landsat-TM data was supplemented with airphoto interpretation and mapping using a derived SPOT-PAN/TM merge as a base map and visual interpretation. This assessment results in a reduction of the hybrid classification output to a 15 master-class system. The new classes can promote a coarse scheme where aerial photo derived classes fit in. The new classification system is based on the realities of achieving mappable units using satellite remote sensing data with varying levels of analysis.

Terrain data were also used to derive slope and aspect areas by class and to determine study area borders ('not below 900 meters above sealevel') which were not clearly defined by other restrictions like administrative boundaries. Management data for the park were also compiled and/or updated from the remote sensing data including trails, cultural features, and primary and secondary park boundaries. It was also attempted to use these DEM data to correct pixel radiances for varying terrain slope and aspect. These topographic normalisation algorithms are today implemented in commercially available software like ERDAS IMAGINE. In this case study, topographic normalisation could not provide better classification results.

For the German part of the subscene, belonging to the National Park Berchtesgaden, *Arc/Info* polygon coverage of the aforementioned landuse derived from airphoto interpretation consisted of very detailed classes as well as very small patches (some less than one TM-pixel). To use these existing data not just as visual support but digitally, they were modified with GIS-techniques. Patches less than 2500 m^2 were deleted and others were shrunk (using negative polygon buffer) by 30 meters to avoid edge effects in the spectral signatures and spatial inaccuracy. Some of the resulting isolated patches were used for signature training and other parts of this data layer were later used for accuracy assessment.

The classification herein is not hierarchical but the resulting classes can be seen as upper-level classes for the detailed aerial photo derived landuse map. They are not equally distinct. Some classes were readily recognised and quite distinct from most other classes (e.g. water, wetland). Others were quite heterogeneous (coniferous forest) or tend to overlap with other classes (e.g. urban and rock). It has been shown that post image-processing and GIS techniques make it possible to clearly distinguish between some classes utilising additional information like DEM data. It has also been shown, that the use of ancillary data during and after multispectral image classification is not only useful but necessary if a single class of objects is not represented by a single spectral class.

Signature training and editing is first done 'traditionally' with well approved *parametric tools*. Polygons representing training sets are either created spatially with drawing tools or spectrally using a region growing function determined by the spectral parameters of neighbours relative to chosen seed pixels and a spectral distance threshold as described by Kloer and Brown (1991) for the ERDAS software. Existing evaluation tools allow for presentation of the sample statistics and histograms, image alarms (quick screen parallelepiped classifications), and pairwise divergence measurements. Parametric signatures can also be generated with unsupervised clustering algorithms, which were not used within this case study. Varying tools provide a comprehensive parametric classification process and may be used independently of the non-parametric tools (Kloer 1994).

The *non-parametric* tools are built on the concept of feature space. It is an n-dimensional space which encompasses all the data values of the image. Practically, it is visualised partly in 2-dimensional scattergrams or scatterplots. This feature space is handled in the ERDAS software with the same data structure as all raster images and a lot of tools can therefore be applied. The feature space image is displayed using the standard visualisation tools which provide identical interactive capability as for the image space.

Both approaches were integrated. First, training classes derived from supervised signature training ('parametric') were displayed and evaluated in various feature space images. Signatures were analysed and manipulated in order to look at the homogeneities, spectral distances, and overlaps. For the maximum likelihood decision rule, Transformed Divergence (TD) was used (Swain and Davis 1978) for separability listing of every class pair and band combination. Fifteen classes resulted and are listed below. *Cursor linking* and *image to feature space masking* between image and feature space windows supported the decision process of merging, deleting, and redefining signatures. Parametric signatures from objects in feature space may be drawn from those pixels that fall inside the object.

A hybrid classification approach was used to utilise these different class definitions. Within the same process, maximum likelihood as an parametric rule and feature space as an non-parametric rule were performed. An option was chosen: if the number of non-parametric class definitions in which the pixel lies is 0, the pixel will be submitted to the parametric rule. Among four possible options in the used software (Kloer 1994), this decision option provided the best results.

RESULTS

As discussed before, the selected classification scheme was designed to include all the major land covers encountered in this area whereby the valleys outside the proposed park boundaries were excluded prior to classification.

After the initial classification the accuracy of the new land cover layer was compared based on random sites interpreted on 1:10000 scale orthophotographs. Blocks of 3 x 3 pixels around randomly located points were used as sample sites. These blocks were stratified according to class prevalence. The verification was supported partially by available biotope maps. Therefore, these maps were digitised and converted to Arc/Info vector format. Accuracy assessment was performed according to Story and Congalton (1986). These binomial probabilities are based on the percent correct and do not account for errors of commission or omission (Lunetta et al. 1991).

Table 1: Final land cover classes and accuracy

Class	Area (km^2)	Row. Marg.	Accuracy
1 rock, no vegetation	138	67	91%
2 rock, debis, sparse vegetation	37	24	77%
3 meadow	75	48	71%
4 subalpine/alpine *pinus mugo* societies	120	64	84%
5 shrub and bush	26	19	71%
6 water	4.7	7	100%
7 moor	4.1	7	100%
8 subalpine shrub and bush	83	35	76%
9 hardwood/conifer mixed	175	80	70%
10 deciduous trees	45	24	77%
11 pine	37	26	86%
12 pine, young plantation	35	24	81%
13 coniferous trees	59	35	84%
14 alpine meadow	41	26	88%
15 residential, streets	19	14	68%
overall		500	80,3%

An overall accuracy level of 80 percent was attained (table 1). This level is generally high but it is not fully satisfying when the availability of existing landcover data for a third of the area, additional data and hybrid parametric/non-parametric image classification techniques are taken into account.The combination of GIS and satellite imagery provides a huge potential not only within this case study. The GIS allows for the overlaying of multiple forms of data which makes signature creation and accuracy assessment much easier.

DISCUSSION

This small study cannot solve the well known problems of using data derived from photo interpretation for supervised classification of satellite data. Nevertheless, it is considerable, that even with very good data availability and the use of advanced hybrid image classification techniques, it is obviously difficult to raise the overall accuracy over 80 percent. Using graphic tools in feature space layers, non-parametric techniques allow for the „complete" utilisation of the area covered by the scattergram. In some cases it is difficult to interpret the corresponding pixels in the image using image alarm tools and previews. Similar to the integration of supervised and unsupervised techniques, it should be possible to gain from the advantages of two different techniques rather than to be handicapped by the disadvantages of both. Commercially available software provided us with sufficient tools but more research and further applications are necessary.

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