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Unsupervised Spatial Feature and Change Detection in RS Imaging

Conclusive Report

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SUMMARY

This is a conclusive report. Pending possible further funding it was decided to continue further R&D development of the system within the limited means of the University of Amsterdam with the UNSUP software as is. Target is to experiment with the UNSUP software in its present state (see previous report) with data sets in various user contexts, in order to determine the most promising lines for completing this promising state-of-the art module of unsupervised classification of multispectral remote sensing images. We investigated other related European studies to which we had access. It suggested a focus on the interface of RS (rasterized) to GIS (vectorized) processing and analysis, *i.e.*

- best practice method for mapping unsupervised class features in RS imagery to *land cover* classes for an area;
- effective mapping of signature based *land cover* classes to best fitting (local) geo-administrative *land use* classification for that area;
- associated methods of change detection on short/long term intervals;
- associated methods of disaster residuals or pollution detection.

We shall exploit the competitive edge of UNSUP by applied experiments with UNSUP together with other users in the US or Europe. The emphasis of this research will be on the applied methodology in the context of prevailing GIS processing environments (interfaces to GIS packages, S-Plus environment, ArcInfo). This might best pave the way for final funding to achieve the system for general use.

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Unsupervised Spatial Feature and Change Detection in RS Imaging
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(1) Scientific work during report period

Publications. The following publications appeared concerning the results of our research for this project and the prototype system of unsupervised classification. (UNSUP).

Kemenade, C. H. M. van, La Poutré, J. A. and Mokken, R. J. (1999a). Density-based unsupervised classification for remote sensing. In: Kanellopoulos, I., Wilkinson, G. G. and Moons (Ed's). *Machine vision and advanced image processing in remote sensing. Proceedings of Concerted Action MAVIRIC (Machine vision in remotely sensed image comprehension).* Berlin: Springer-Verlag. (ISBN 3-540-65571-9).

Kemenade, C. H. M. van, La Poutré, J. A. and Mokken, R. J. (1999b). Density-based unsupervised classification for multi-spectral imagery. In: Stein, A., Van der Meer, F., and Gorte, B. (Ed's). *Spatial Statistics for Remote Sensing. (REMOTE SENSING AND DIGITAL IMAGE PROCESSING: Volume 1).* Dordrecht: Kluwer Academic Publishers, 165-84 (ISBN 0-7923-5978-X).

After the stop order for insufficient funds, valid as of October 1st, 1999, any efforts of further software development had to be stopped. It was decided to continue further R&D development of the system within the limited means of the University of Amsterdam with the UNSUP software as is. Target is to experiment with the UNSUP software in its present state (see previous report) with data sets in various user contexts, in order to determine the most promising lines for completing this promising state-of-the art module of unsupervised classification of multispectral remote sensing images.
We proposed our relations at CRREL, Hanover (NH) to perform such analyses with knowledgeable RS datasets under their guidance as expert users. Target:

1. one or two joint articles in major RS journals explaining the new methods and their advantages;
2. improved requirements and specification of the UNSUP system for actual operational implementation.

We did not get any answers to this proposal and invitation for joint cooperation.

In the mean time we started to investigate other related European studies to which we had access. Our findings suggested a focus on the interface of RS (rasterized) to GIS (vectorized) processing and analysis, *i.e.*

- a best practice method for mapping unsupervised class features in RS imagery to *land cover* classes for an area;
- an effective mapping of signature based *land cover* classes to best fitting (local) geo-administrative *land use* classification for that area;
- associated methods of change detection on short/long term intervals;
- associated methods of disaster residuals or pollution detection.

In particular it seems important to improve singular and crucial points in the process chain from (raster based) RS-image => spectral clusters => land cover signature classes => (GIS vector based) best local land use classes => harmonization within (international) standard classifications => change detection.

Our findings also led to the conclusion that in most GIS environments operational possibilities and research opportunities are limited to a few available commercial proprietary standard packages like ERDAS/IMAGINE , CPI , ARC/Info, etc. This may seem a safe practice, but it implies that one has to rely on and make do with the usually very limited analytic possibilities in those packages. The methodological

content of dominant commercial packages like ERDAS/IMAGINE and the like, dating back to mainframe days, is usually some 10-20 years behind current state-of-the-art scientific methodology, because they can use their market dominance to prevent risky innovation, thus protecting their investments.
Just a few examples.

1. For instance, the ISODATA/ISOCLUS unsupervised clustering algorithm is based on legacy methods of the mid-seventies (see for instance the reference in the ERDAS/IMAGINE manual, where 1975 is mentioned as the latest item!). Today much better and faster cluster methods and algorithms are available, such as CART and *kd*-tree algorithms, as have been used in our UNSUP system.

2. For supervised (trained) classification still mainly the classic method of ML multinormal classification is used. This method is optimal only for multinormal distributions, an assumption almost always falsified by the skewed and wayward distributions in spatial imagery and cartography. During the last decade a multitude of nonparametric methods for both supervised and unsupervised classification are available, based on multivariate density estimation and nearest neighbour search in high-dimensional space. These have been implemented with profit in the UNSUP system.

3. In classification practice selection of land use based masks appears necessary in order to reduce the processing load by the stratified selection, as defined by the masks. The idea of masking is inspired by the necessity to reduce the mass and computational burden of pixels to be analysed, as well as some stratification to ensure detection of small sized but important object or classes in the image. This is due to the fact that legacy cluster analysis of the full image of a random sampling from it tends to reproduce the large sized dominant classes and miss the possibly important small sized classes in an image.
More efficient methods of unsupervised class detection manage to circumvent this by the use of *biased sampling* of the pixels of an image targeted at getting a *learning sample* of pixels carrying the characteristic feature and class information of a particular image, which is then used in nonparametric unsupervised classification. This is followed by a nonparametric supervised allocation of the full image to these classes using nearest neighbour and projection pursuit methods. This highly effective approach, combining speed of classification with discriminating power has been implemented in the UNSUP system.

4. Almost universally legacy methods of (un)supervised classification methods are based on classical cluster analysis, necessitating the a priori postulation of a target number of classes, which then has to be adjusted a posteriori in order to get a 'good' separation of classes.
However, in feature detection and classification the *number of classes* should not be an input parameter, but an outcome of the classification analysis, which should be driven by the basic discrimination parameter: *class separation*. According to this requirement user defined degree of class separation is the basic driving parameter in the UNSUP system, with the number and set of classes as its outcome. Hence the characteristic class feature structure and class detail of any particular RS image, as found by UNSUP is mainly a function of the required degree of separation, as set by the user according to his (her) particular purposes.

4. *Raster GIS analysis vs. vector GIS analysis.* From a methodological/statistical point of view raster based analysis of RS images at the GIS level is superior to vector GIS analysis. Powerful state-of-the art spatial/statistical analyses can be performed quite near the original data information and error levels, without the additional error components introduced by raster-vector transformation and subsequent vector data manipulation.

However, until recently raster image analysis required very demanding storage and processing capabilities, pre-empting the application of efficient modern data analysis techniques, whereas the very substantial storage savings involved in vector GIS affords more opportunities. As a consequence, most standard GIS packages have biasedly evolved toward mainly vector based GIS data manipulation, thus carrying forward the legacy of mainframe/mini days when storage (DASD) counted heavily. Since the mid-nineties these storage/memory limitations are rapidly losing their impact. Hence it is time to develop and incorporate the better raster based analysis possibilities into the regular GIS analysis environments.

(2) **Research plans for the remainder of the period.**

As a consequence of the funding stop research plans as stated in the previous report have to be postponed to the future. As stated above it is decided to use the limited funds of the University of Amsterdam to exploit the competitive edge of UNSUP by applied experiments with UNSUP together with other users in the US or Europe. The emphasis of this research will be on the applied methodology in the context of prevailing GIS processing environments (interfaces to GIS packages, S-Plus environment, ArcInfo). This might best pave the way for final funding to achieve the system for general use.

Immediate implementation and integration of the current version of UNSUP with standing operational GIS systems should require special funding for that special purpose. That can best be done with the UNSUP system as resulting from the above mentioned experiments.

Annex to							
Sixth Interim Report December 1999 till January 2000							
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