APPLICATION OF AN AUTOMATIC CLUSTERING AND SEGMENTATION TOOL ON METABASITIC ROCK UNITS IN THE SOUTHERN RED SEA HILLS, NE SUDAN

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ABSTRACT

This paper refers about a method for class extraction from multispectral imagery under geological aspects. In the case under consideration metamorphic rock units have been tested for their possible discrimination by an automatic class building and segmentation process as proposed by SCHULZ & WENDE (1993). The procedure uses the assumption of spectral homogeneity to test a Landsat TM dataset, which will be adopted by statistical criteria like variance and correlation coefficient for the class finding algorithm. Depending only on the thresholds defined before the application and not on interactively described classes, it is possible to set the user-defined statistical reliability of the classes. Furthermore it allows an exclusion of pixels with no certain dependencies of classes without masking. The area under research shows changing relief with flat sandy parts and rough terrain formed of metamorphic rocks under arid conditions. The roughness of the terrain is the limiting factor for this method, especially by the influence shadow. This happens in terms of high frequency textures which disable the clustering process due to their inhomogeneity, so it has to be combined with a texture classifier or a smoothing process.

ZUSAMMENFASSUNG

In diesem Artikel wird die Anwendung eines Klassenbildungsverfahrens unter geologischen Gesichtspunkten vorgestellt. Bei dem präsentierten Beispiel handelt es sich um metamorphe, basische Gesteine, die in Hinblick auf ihre mögliche spektrale Trennbarkeit durch einen von SCHULZE & WENDE (1993) vorgeschlagenen automatischen Klassenbildungsprozeß untersucht werden. Anschließend erfolgt die Klassifizierung der Bildpixel durch Vergleich mit einer Lookup-Tabelle der Klassen. Das Verfahren nutzt die Annahme der spektralen Homogenität, angewendet auf einen Landsat TM-Datensatz, die durch statistische Kriterien wie Varianz und Korrelationskoeffizienten für die Klassen angepaßt wird. Dies ermöglicht eine automatische Klassenextraktion entsprechend den gewählten statistischen Vertrauensbereichen. Weiterhin wird durch das Verfahren ermöglicht, Mischpixel unbestimmter Zugehörigkeit zu eliminieren. Das Testgebiet liegt klimatisch in einer semiariden bis ariden Zone, das Gelände zeigt ein wechselndes Relief mit flachen, sandigen und steilen, zerklüfteten Partien. Als limitierentender Faktor für dieses Vefahren erweist sich das steile, rauhe Relief, da das auftretende Rückstrahlungsverhalten innerhalb einer geologischen Einheit, insbesondere durch Abschattungen, starken Schwankungen unterliegt. Hieraus resultiert eine spektrale Inhomogenität, die in Verbindung mit den homogenen sandigen Bereichen nicht als eine klassifizierbare Einheit erkannt wird. Daraus folgert für die weitere Entwicklung die Einbindung eines texturkorrigierenden Verfahrens.

1. INTRODUCTION

For image classification or region segmentation there are several procedures available which use different approaches. Image classification techniques can be grouped into three different classes. *Local* techniques are based on the local properties of the pixels and their neighbourhood. *Global* techniques segment an image on the basis of information obtained globally (e.g. histogram based segmentation), and third *split*, *merge* and *growing* techniques use both the notions of homogeneity and geometrical proximity (PITAS 1993) .

All these techniques usually deal with the problem of class definition stimulated by visual interpretation or, in case of an unsupervised classification, define a number of classes which will be found after a certain number of pixels have been processed (e.g. cluster analyses). They do not account for the effect of the image content that may leave part of the image unprocessed, at the later stages. This is one of the aimed improvements of the implicated algorithms.

Originally the application under concern has been choosen for the evaluation of a terrain and atmospheric influences suppressing image processing scheme.

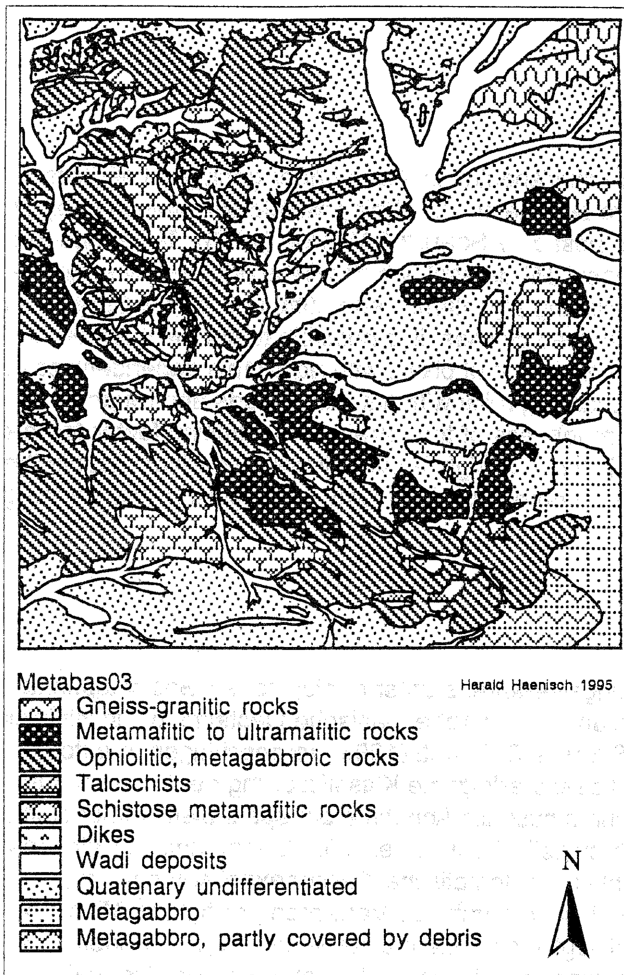

fig.1: Geological sketchmap of the area under consideration.

This method is under development at the Free University of Berlin. The basic ideas have been proposed by SCHULZ et al. (SCHULZ 1990, 1992 and SCHULZ & WENDE 1993) as part of the program "Objektbezogene Informationsgewinnung aus Fernerkundungsdaten zum Aufbau eines digitalen Landschaftsmodells" - IFAG, Frankfurt/Main. The authors application has been set to work at the Institute for Geoinformatics of the Free University of Berlin. But during the implimentation it appeared that there could be a possibility for use as rock discrimination scheme under geological aspects, a theme difficult to handle, if one wants to see varieties of rock units and not only to distinguish between rocks in general and unconsolidated sediments.

2. DATA AND RESOURCES

The dataset to be classified is a subset of the Landsat TM image 171 - 47 (25. Dec. 1988). The test site is part of the southern Red Sea Hills of Sudan aproximatly 150 km SW of Port Sudan.

The rocks which can be observed there are at most intensely, alterated amphibole to greenschist facies metabasitic units with some additional deeply weathered syn- to late-tectonic migmatites and granites. The meta-basitic rocks are talc schists, chlorite-serpentinite schists, chlorite schists, metabasalts and metagabbros to meta-ultramafitites (fig.1).
The hilly country side is disected by wadi water runoffs. It shows in addition to the overall variety of rocks a high frequent change in lithology with irregular repetition and thickness. This was another motivating ground to apply an automatic classification scheme. The situation has been formed by tectonic processes beginning with late Proterozoic rifting and accretion developments in northeastern Africa during the Pan-African tectono-thermal phase (HAENISCH et. al. 1996, this volume).

Implementation of the algorithm has been realised in 'C' on a Sun SparcStation 10 with 96 MB mainmemory. In order to get a simple format the dataset has been transformed with Erdas Imagine 8.2 in a generic binary format with band interleaf by line mode (BIL), a format almost equal to the Erdas 7.4 LAN-File representation without the 128 byte header. The data conversion was carried out with im-/export-modul of Erdas Imagine 8.2.

To have an easy access to problems imerging during the development, the realisation has been constituted of three parts. *Calcta* is the program part to find the training areas, *calcclas* develops the classes as described below, and *calcres* attaches the pixels to the given classes.

3. CONCEPT

In this particular approach the classification of multispectral image data is devided into three main functions 'search for the smallest homogeneous set of training areas', 'reduction of the set of smallest homogeneous training areas to classes', and 'attaching the image pixel values to the related classes' (fig.2).

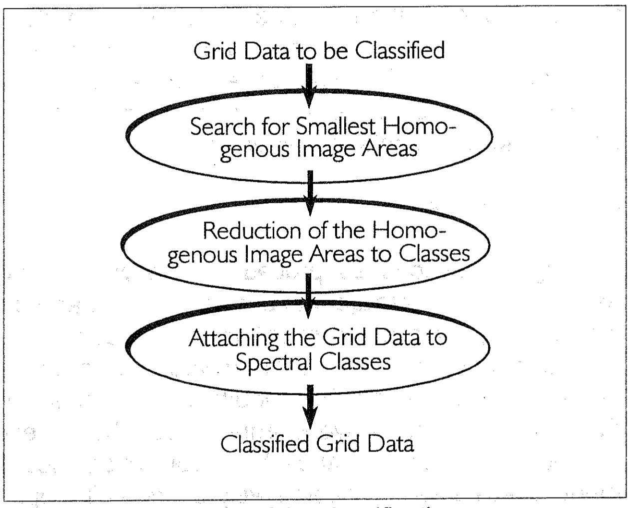

fig. 2: Flowchart of the classification process.

The class creation depends on the search for training areas with homogeneous sites in the grid data and on the attachment of the determined training areas to final classes. An area is considered as homogenous, if the grey values of each band show normal distribution according to the z-transformation, and the bands are correlated with each other to a certain degree, depending on the choosen values of reliability. This is achieved, if first the previously set variance threshold is not violated. Second, if the pixel neighbourhood is considered to be at a 68%-level within the single standard deviation. Third, the pixel neighbourhood lies at least with a 95%-level within the second standard deviation, and fourth the prove of a previously set correlation coefficient with a confidence level of 99% is achieved. The correlation test can only be applied if the influence of the other random variables has been eliminated as in the three steps before (WOLF 1968, p.519). The number of pixels in the neighbourhood can be varied by the size of the moving search window. Possible arrays are 3X3, 5X5, 7X7 etc..

The attaching of training areas to clusters and finally classes (up to several thousand, depending on the image content) is based on the 'modified Mahalanobis-Distance t^2' (SCHULZ & WENDE 1993, see formula 1) or Hotelling-T^2-Test (BORTZ 1989). This deviation measure consists of a quantitative and a qualitative part as represented by the vectors of means u and v, and on the other hand of the correlation matrixes A and B of two training sets which have to be compared.

$$t^2 = (u-v)^T * (A+B)^{-1} *(u-v) \qquad (1)$$

The decision to combine two training areas to a cluster is oriented on the previously defined threshold of t^2, or the smallest allowed distance of two classes to each other, which can not be exceeded by the computed t^2-values.

The t^2-test establishs a reduction of the discovered training sites by comparing each site with all the others, a necessary step to reduce the possibly large number of similar TA's. In a three channel image, each Channel is represented by 8-bit data, and 16.7 million combinations possible. This computation will be repeated until the number of clusters can not be further reduced and the final classes are fixed. For each of the given classes results a mean vector and a correlation matrix clearly characterizing each class will be obtained. The result allows the further pixel attachment to the classes. A similar method has been described by MCCAFFREY & FRANKLIN (1993) and is centered around the F-test and limited to four channels to evaluate.

In order to get a classified result of an image it is possible to apply a variety of methods with a given set of classes. In this paper only one procedure will be presented. It is a distance measure applied to all pixel vectors to be compared with the class vectors in the lookup table from the calcclas-algorithm. A pixel vector will be attached to one class if a previously given threshold of maximum deviation is not exceeded and the class is the nearest. The deviations will be determined by comparing the vectors of grey values with the mean vectors of the computed classes. Until now the classification scheme does not allow more then 256 classes due to the 8-bit image-representation. The center scheme of this proposal is the class generating algorithm.

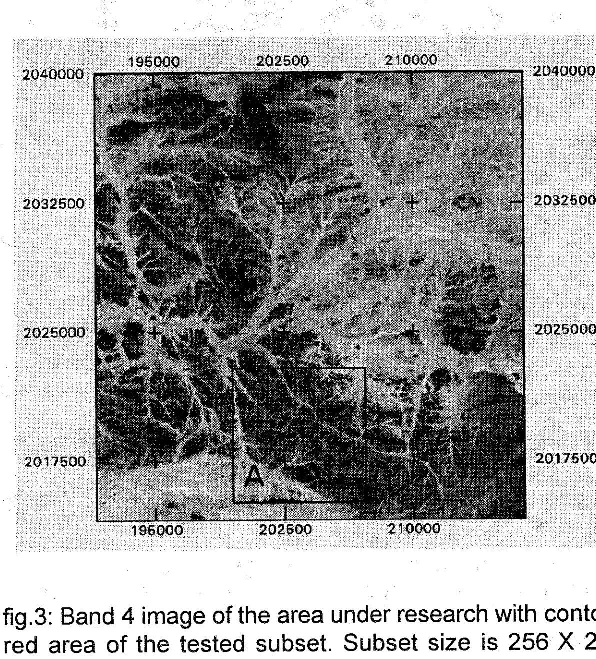

fig.3: Band 4 image of the area under research with contoured area of the tested subset. Subset size is 256 X 256 Pixel.
The coordinates represent the UTM-Grid for Zone 37 and Speroid Clarke 1880.

4. RESULTS

4.1 Primary Results

The time consumption of the program triplet varies with the array size and the homogeneity of tested images. The fastest process is the extraction of training sites for further computation. Here time needed to proceed is a function of the array size of the moving window. Secondly it depends on the number of control steps for each centerpixel and its neighbours carried out. Relief textures smaller then the moving window disables the TA-finding algorithm.

The most processor time consuming step is the class-building algorithm. The number of operations performed for the comparision of the computed training areas (TA's) and clusters increases by

$$(n \cdot 2)-1 \qquad (2)$$

where 'n' is the number of TA's and clusters to be compared. The number of iterations to proceed depends on the homogeneity of the imagery, and therefore the necessity to rearrange the class statistics.

The process of attaching the grid data to the spectral classes is dominated by the number of classes and the size of the pixel array to be assigned to the classes. Obviously the time needed would be exaggerated enormously if a large distance from the classes is allowed and the feature-space of interest around each class vector intersects with another.

fig.4: A sample of a classified image (upper left of fig.3) as computed from the tested subset 'A' and applied on the wider vicinity. The values are:
- correlation coefficient = 0.9
- standard deviation = 2
- clusterdistance = 2
- feature space distance for pixels = 3

4.2 An Example

If using the descricbed procedure one will quickly realise that a heterogeneous composed image in terms of high and low frequent spectral areas is not easy to handle when the 'short waved' part is under research. In our example smooth sandy areas will dominate the result. A work-around would be the elimination of terrain influence by a correction model (under preparation) or alternatively a smoothing operation which would obviously effect the resolution and spectral response (fig.3).

The following tables 1 and 2 show the combination lists which were obtained from the subarea 'A' in figure 3. The band combination used is 7-4-1. The subset has a size of 256^2 pixel, 65.536 Pixel per Layer.

The distinction of metamorphic rocks under the conditions of the proposed algorithm is in parts interesting especially if certain spectral features of potential occurences can be discriminated. This implies an already good knowledge of the geology at least in points, but nevertheless it allows to see similar fine distinguished features in the surrounding area, as can be seen in figure 4.

Size of search window	Correlation coefficient	Standard deviation	Number of TA's
3X3	0.95	2.0	1
3X3	0.95	2.5	14
3X3	0.95	3.0	71
3X3	0.90	2.0	19
3X3	0.90	2.5	105
3X3	0.90	3.0	406
3X3	0.85	2.0	65
3X3	0.85	2.5	302
3X3	0.85	3.0	913

Table 1: Results produced by different correlation coeffiecients and standard deviations with calcta-routine.

Cluster distance	Number of classes	Iterations
1	1	1
1	14	1
1	69	2
1	18	2
1	102	2
1	359	3
1	61	3
1	272	3
1	733	4

Table 2: Results produced by unique cluster-distance for the computed number of TA's from table 1.

5. DISCUSSION

One of the most striking observations is the texture dependency of the class finder. At a given reliability level the Landsat TM image data of the area under research will predominantly produce classes for the sandy and 'fresh' eroded material. Because of the low frequent changes in the spectral properties which are not disturbed to such an extent by the relief like the hardrocks, the primary aim in this research.

The computation time is also an important factor worth to consider if this algorithm is to be applied. One should be aware of the requirements for the system, especially when used to compute large pixel arrays.

6. CONCLUSION

The classification of rockunits in an arid area with rapid change in relief and lithology can not be maintained by the applied procedure alone. There has to be an accompanying image processing scheme to suppress the influence of texture and to prevent a rather frustrating result in the way of non-classified hard-rock units. An unsatisfying imagination for almost every geologist is mapping in such a rough terrain structure.

The program is sensitive to the coefficients of variance and correlation and can be optimized by several passes through the image data. Still a little bit of interpretation work has to be conducted to select the best class-site determination with reference to the classification problem at hand. On the other hand it is important to realise that the imaging conditions, to which one has to be aware are very unfavourable because sand often covers the rockunits in thin layers and the influence of long term regional polymetamorphism gives problems difficult to be solved especially if Fe-ore minerals are finely distributed. But nevertheless the algorithm seems to be a very reasonable tool for the classification of soils with smooth transitions into each other and low texture frequencies or on data which have been relief corrected with less impact on texture patterns.

The primary advantage of this scheme is the possibility to use unlimited number of spectral bands to get classes and the possibility to influence variance, standard deviation and the degree of correlation of the spectral 'pixel vector' in its neighborhood.

For further developments it is possible to obtain the C-source code of the program.

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