Unsupervised Spatial Feature and Change Detection in RS Imaging

Fifth Interim Report

Principal Investigator
Prof.dr R.J. Mokken

1 November 1999

United States Army
European Research Office of the U.S. Army

USARDSG-UK, Edison House
223 Old Marylebone Road
London, NW1 5 TH
England

Contract number: N 68171-98 C 9012

Approved for Public Release; Distribution unlimited

CCSOM/Applied Logic Laboratory
PSCW - University of Amsterdam
Sarphatistraat 143
1018 GD AMSTERDAM
The Netherlands
tel. #.31.20.525 28 52
fax #.31.20.525 28 00
e-mail ccsoff@wins.uva.nl

R&D # 8444-EN-01
Broad Area Announcement Proposal
submitted to the
Remote Sensing / GIS Center USACRREL
72 Lyme Road
Hanover, New Hampshire 03755 USA

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)

2. REPORT DATE
November 1 1999

3. REPORT TYPE AND DATES COVERED
Fifth Interim Report (July-October 1999)

4. TITLE AND SUBTITLE
Unsupervised Spatial Feature and Change Detection in RS and Imaging

5. FUNDING NUMBERS
N68171-98-C-9012

6. AUTHOR(S)
Prof.dr. R.J. Mokken

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
ALL/CCSOM, PSCW, Universiteit van Amsterdam
Sarphatistraat 143
1018 GD AMSTERDAM, The Netherlands

8. PERFORMING ORGANIZATION REPORT NUMBER
BAA-RM IV-5

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

SUMMARY

Most of our work since the last interim report was spent on studying necessary adaptations of the software to various operational requirements, assisted by data runs to suggest their use, and studying and assessing recent statistical and neural theoretical developments for possible application. Main activities continued:

- requirements analysis for development of prototype into a system for operational use;
- re-designing the basic methodology implemented by the system, involving a clear separation of the main methodological elements;
- differentiating project pursuit classification and pixel blending within classes;
- conserving inspection mode to facilitate selecting (sub) classes and regions in a
- classified image for further analysis;
- continue study of spectral de-mixing, within (sub) classes, using RBF neural network technology.

14. SUBJECT ITEMS
Remote Sensing, Statistics, GIS, Neural Networks, Classification Methods, Optimization.

15. NUMBER OF PAGES
5

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified		

Unsupervised Spatial Feature and Change Detection in RS Imaging
Contract no. N68171-98-C-9012
Fifth Interim Report

(1) Scientific work during report period

Over the summer we received signs from our partners in Hanover (NH) that our previous prototype had aroused much interest and appreciation during demo's and tests in the field. Preparations seem to have been made to integrate or incorporate it in the operational environment of some USACE institutions. Some implementation difficulties were reported to us. These encouraging experiences supported our conviction that this system of unsupervised classification should serve as a highly efficient and discriminating detection tool in such areas as water control, oil spillage, environmental monitoring, land usage, and change detection, where multispectral remote sensing data are used. Its combination of an innovative, highly effective method of adaptive, targeted pixel sampling, together with the latest efficient statistical techniques and high speed algorithms, should make it a fast and cutting edge instrument of feature detection in multispectral RS-images, compared with current legacy methods.
However, although this prototype might well be used as a supplementary explorative aid to field operations, it should be considered unfit for immediate integration in operational processing environments. For good operational use some additional features and data management possibilities should be added, which necessitate a further re-engineering of the system beyond the capabilities of the present prototype.

Consequently, as already anticipated in the fourth interim report, we shifted our research efforts over this period from the original objectives toward a redesign, which would incorporate these necessary features already in this initial stage of the project. (In the original proposal this stage was located more at the end of the project, so as to enable the incorporation of the new methods which are the main target of the proposal).
The following items were studied and prepared.

1. More modular redesign of the system, involving a clear separation of the main methodological component:

- a) adaptive pixel *learning sample* selection options:
    - homogeneous, without stratification;
    - homogeneous, with stratification;
    - biased random, with stratification;
    - local/global density selection.
- b) multivariate density based *unsupervised class detection*, involving class separation tuning for optimal detection;
- c) the various *image classification* modes:
    - 1-NN (nearest neighbor) mode;
    - 1st PC (principal component) projection pursuit mode;
- d) the various *blending* modes:
    - no blending;
    - blending along 1st PC (principal component) axis;

Especially the introduction of all combinations in the simultaneous application of mode c) and d), which was not possible in the earlier prototype, will be necessary in subsequent applications. For instance, different line segments along the 1st PC should be used for projection pursuit classification on the density classes and the blending of pixels within classes. To ensure robust and reliable classification, a relative small segment length should be used for image classification. A (much) longer segment should be used to represent blending of pixels within a class, and subsequent (de)mixing analysis. We have experimented with these parameters on an available data set.

2. The highly innovative pixel-by-pixel classified image inspection mode should give the full classified/blended image, together with, as in the prototype, per pointed pixel its class parameters and its original spectral and new (class blend) values. In the earlier prototype this possibility is volatile, as it is not saved when exiting a classification run.
For operational use it will be necessary to save selected classify/blended images in database format at will, in order to re-inspect or re-analyze the image at a later stage:

- given a user accepted image classification, a closer pixel-by-pixel investigation can be done separately, at later moments;
- the underlying classified database is amenable to further analysis, using other analysis modules;
- the image classified/blended database (after addition of geo-coordinates) can be used in the context of GIS spatial statistical techniques, such as Kriging, etc.

3. Moreover, in the prototype the classified GIF image and Inspect image mode are determined by initial screen size. An operational version should enable full scrolling over the entire *.bsq image size, chosen independent of screen size.

Some additional operational features are essential for further analysis of regions and areas in terms of the detected classes in the image.

4. For instance, given a classified image:
- select the pixels in a specified class for further analysis.
- select a contoured region (*e.g.* a known polluted or oil spit spot) within the classified image to focus further analysis on this selection (*i.e.* generalize this by means of spectral or class vector matching across the image).
We have continued investigating these options, as they are necessary for the continuation of our project according to our proposal.

5. We have continued investigating spectral de-mixing, within (sub)classes, to be used within selections as mentioned ad 4. Spectral demixing is essential for targeted oil detection, snow area analysis or water pollution area detection, in order to find pollution components in terms of mixture components. We have started to look at this using RBF neural network technology.

6. We have almost completed an *ad hoc*, menu based, users interface, which could facilitate considerably the use of the software in the further development of our methodological research along the lines of the proposal.

Unfortunately, since the fourth interim report (April 1, 1999) we received two stop work orders for insufficient future funding, the last one valid as of October first. Consequently, since then there was no capacity for active software development and implementation. So, most of our work over the summer up to now was spent on studying necessary adaptations of the software to various operational requirements, assisted by data runs to suggest their use, and studying and assessing recent statistical and neural theoretical developments for possible application.

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

During this period we received the disturbing news that further funding of this project beyond this reporting period (i.e. as of 1 October 1999) is not sure. It should be regretted if the continuation of this cooperative research project on behalf of the USACE labs and divisions in general, and in particular of its CRREL-RS/GISC staff, with whom we had such good and mutually stimulating contacts over the years would come to an abrupt end. The consequence of this would be that the results, as mentioned above, as well as below, can not be further developed and completed, or made available to USACE and its clients. This indeed would be a waste of R & D capital investment over the last four years.
However, assuming restored funding and continuation of this project, we envisage completing the rebuild and reengineering design projects mentioned above and continuing the lines as mentioned in the original proposal.

1. innovative optimization;

2. spectral de-mixing;

3. unsupervised change detection.

4. methods for evaluating classification error and accuracy.

We shall then proceed according to the following plan.

A). Study innovative improvements in algorithmic performance and classification accuracy.

This focuses on methodological and algorithmic (precision, convergence and speed) enhancement of the basic features of this set of unsupervised classification procedures. Accuracy evaluation and measurement is here associated with the errors of misclassification, known in standard *supervised* classification methods such as in parametric discriminate analysis and trained artificial neural networks. As these methods are based on, and presuppose the matching of image pixels to *previously known* class or ground coverage parameters, the concepts of misclassification and errors of misclassification can be immediately defined and modeled in, for instance, the well-known *confusion* matrices.
However, in non-parametric, unsupervised classification these concepts do not have an immediate meaning because, by definition, no such prior knowledge exists as the whole procedure aims to detect, define and generate *a posteriori* the system of

classes as contained in the spectral information of a particular image and its subsequent mapping to the pixels of that image.
Hence there is no direct analogue here to the familiar confusion matrix. We propose to study possibilities to develop analogous measures and concepts in the context of the two levels that matter in our system of unsupervised classification:

(1) the *reliability* of the detected class system (how stable are its detected classes under pixel sampling and picture window);

(2) the *accuracy* of the pixel class mapping (are similar pixels mapped to the same class?).

A different problem is how classes and pixel mappings in an image correspond with available, usually occasional ground knowledge. This concerns the *validity* of the obtained set of classes and its image mapping. This we shall study and assess the examination of classification results for images with substantive patches of quality ground knowledge with two major purposes:

- *calibration* and *tuning*: do the known patches correspond to discernible classes, and which levels of classification parameters serve to get the best correspondence? (at what levels can clouds or vegetation be separated from water);
- *generalization potential*: does the coverage in a known patch correspond with that of other patches with the same class?

In order to enable this type of study it was decided that CRELL RS-GISC (Dr. LaPotin) will send us some images with lots of pin-pointed ground knowledge (*e.g.* oil-spill data, urban/rural, coastline areas, snow cover, flood data?), which are *sufficiently annotated* for us here to identify known patches of ground cover and use them for further quality assessment, validation and calibration.

B). Study spectral de-mixing; within classes at the (sub-)pixel or level.

In conventional classification methods, such as the ISODATA module in the ERDAS/IMAGINE system, pixels are allocated to a class just in terms of a particular class label. In our system, in addition to that, classes are characterized in terms of a univariate distribution along a linear segment, as determined by the first principal component of their singular value decomposition. Pixels can thus be represented as particular distribution values within that class (the *blending* option). This makes it possible to attack mixed pixel blending as a mixture problem.
For instance, it was pointed out to us during the last meeting at CRREL RS/GISC that certain patches in the mountain area were labeled as belonging to the same class as water in the Painted Rock reservoir. Obviously, in actual applications one usually could seek to separate these classes by choosing a higher, more discriminating density value for class merging. This, however, would change the whole classification pattern and structure across the full image. Instead of that, in our case one could restrict oneself just to the investigation of the distribution within that class looking for multimodality or other mixing components. Using statistical demixing techniques one could thus decompose ('de-mix') that single class into sub-classes corresponding to

'shadow' and regular water. This approach might also be feasible for the analysis of snow cover.
Anticipated further work in this field is the development of non-parametric models more general then the linear singular value decomposition within classes. We will investigate whether recent neural network theory based on radial basis functions (RBFs), and the use of spiking neurons can show the same promises here as were propagated elsewhere. Together with the use of evolutionary computation methods to search for models for demixing of clusters consisting of multiple classes, and the usage of Bayesian methods to exploit the spatial the spatial structure during pixel classification. Spatial structure is exploited by computing prior probabilities over a spatial neighborhood, and use these to compute posterior pixel classification probabilities.

For all these studies we need images with varied reliable designated 'true' known ground knowledge patches. During our 5-7 October meeting at CRREL RS/GISC it was agreed with dr. LaPotin that we shall obtain at least three images to serve that purpose (oil spill, urban/rural, coastline areas, snow cover?).

C). Unsupervised change detection

In later stages of this project, assuming sufficiently confidence inspiring results from this research, we can try to make a start with the application of these methods and techniques of unsupervised classification to the corresponding multi-image problem of detecting change areas comparing two or more similar coordinated and registered images, such as, for instance, provided by time-sequential overpasses by LANDSAT TM RS imagery. Results in this respect might assist GIS-users in the area of emergency management.

(3) Significant administrative actions during the report period

During the reported period there has been no change in personnel involved in the project.

(4) Other important information

None

(5) Statement showing the amount of unused funds

See attachment.

Annex to

Fifth Interim Report March till November 1999
Unsupervised Spatial Feature and Change Detection in RS and Imaging

contract no. N 68171 98 C 9012
contractor Prof.dr R.J. Mokken
ALL/CCSOM, PSCW, University of Amsterdam

1. Statement showing amount of unused funds at the end of the covered period

2nd Incrementally Funded Period November '99-March 00	total	$ 33,921
3rd Incrementally Funded Period April 00 - March 01	total	$ 48,867
total unused funds at end of covered period		**$ 82,663**

2. List of important property acquired with contract funds during this period

none

R&D # 8444-EN-01