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Neural versus Statistical Approaches for Pattern Recognition in Space Imagery

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Abstract – We investigate multispectral space image classification using the new neural model called Concurrent Self-Organizing Maps (CSOM), representing a winner-takes-all collection of small modular self-organizing neural networks. For comparison, we evaluate the performances of Bayes classifier. The implemented neural/statistical classifiers are evaluted using a LANDSAT TM image with 7 bands composed by a set of 7-dimensional pixels, out of which a subset contains labeled pixels, corresponding to seven thematic categories . The best experimental result leads to the recognition rate of 95.29 %.

Keywords: neural pattern recognition, multispectral space imagery, concurrent self-organizing maps

I. INTRODUCTION

The Self-Organizing Map (SOM) (also called Kohonen network) is an artificial unsupervised network characterized by the fact that its neighbouring neurons develop adaptively into specific detectors of different vector patterns. The neurons become specifically tuned to various classes of patterns through a competitive, unsupervised or self-organizing learning. The spatial location of a neuron in the network (given by its co-ordinates) corresponds to a particular input vector pattern. Starting from the idea to consider the SOM as a cell characterizing a specific class only, we present and evaluate for space imagery the new neural recognition model called Concurrent Self-Organizing Maps **(CSOM)** (described by Neagoe in [1] for face recognition). It has been successfully applied by Neagoe and Ropot in [2,3,7]) for image recognition and speaker recognition and by Cataron and Neagoe in [6]), also for speaker recognition. **CSOM** represents a collection of small SOMs using a global competition strategy. In Romanian, the model has been called **MONACO** (**M**odule **N**euronale **A**uto-organizabile **Co**ncurente). The research of evaluating CSOM (MONACO) model (for recognition of random vectors, images, speech and speakers) has been partially supported last two years by the Romanian Academy under the Grants Nr. 171/2003 and Nr. 152/2004.

Processing of satellite imagery has wide applications for generation of various kinds of maps: maps of vegetation, maps of mineral resources of the Earth, land-use maps (civil or military buildings, agricultural fields, woods, rivers, lakes, and highways), and so on. The standard approach to satellite image classification uses statistical methods. A relative new and promising category of techniques for satellite image classification is based on neural models. We further evaluate the new neural CSOM model for recognition of multispectral satellite images by comparison with SOM and the well known Bayes statistical classifier (assuming normal classes).

II. CONCURRENT SELF-ORGANIZING MAPS (CSOM) FOR PATTERN CLASSIFICATION

Concurrent Self-Organizing Maps (CSOM) are a collection of small SOMs, which use a global *winner-takes-all* strategy. Each unit network (SOM) is used to correctly classify the patterns of one class only and the number of networks equals the number of classes. The CSOM *training* technique is a supervised one, but for any individual net the SOM specific training algorithm is used. We built "n" training patterns sets and we used the SOM training algorithm independently for each of the "n" SOMs. The CSOM model *for training* is shown in Fig. 1.

For the recognition, the test pattern has been applied in parallel to every previously trained SOM. The map providing the least quantization error is decided to be the winner and its index is the class index that the pattern belongs to (see Fig. 2).

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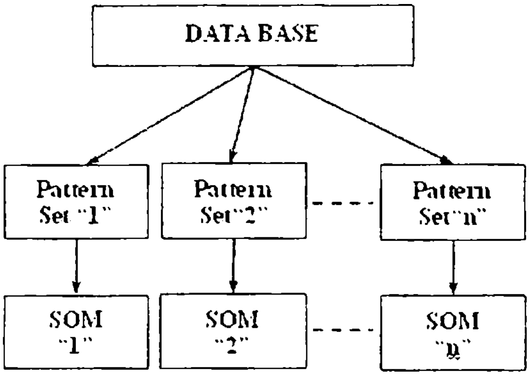

Fig 1 The CSOM model (training phase)

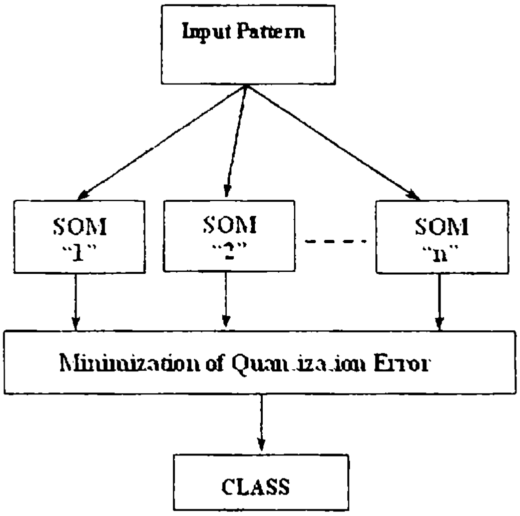

Fig. 2. The CSOM model (classification phase).

III. CSOM FOR CLASSIFICATION OF MULTISPECTRAL SATELLITE IMAGERY

Processing of satellite imagery has wide applications for generation of various kinds of maps: maps of vegetation, maps of mineral resources of the Earth, land-use maps (civil or military buildings, agricultural fields, woods, rivers, lakes, and highways), and so on. The standard approach to satellite image classification uses *statistical methods*. A relative new and promising category of techniques for satellite image classification is based on *neural models*. The concluding remarks obtained as a result of the research on applying neural networks for classification of satellite imagery are the following:

- neural classifiers do not require initial hypotheses on the data distribution and are able to learn non-linear and discontinuous input data;
- neural networks can adapt easily to input data containing texture information;
- the neural classifiers are generally more accurate than the statistical ones;
- architecture of neural networks is very flexible, so it can be easily adapted for improving the performances of a particular application

3.1. *Satellite Image Database*

For training and testing the software of the proposed CSOM classification model as well as the classical SOM and the Bayes classifier (for comparison), we have used a LANDSAT TM image with 7 bands (Figs.3.a-g), having a number of 368,125 pixels (7-dimensional), out of which 6,331 pixels were classified by an expert into **seven thematic categories** (classes): A- *urban area; B-barren fields, C-bushes, D- agricultural fields, E-meadows, F-woods, G- water* (Fig. 4).

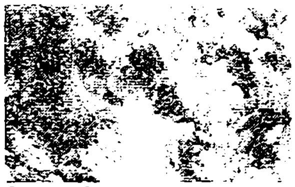

Fig. 3.a. Spectral band 1

Fig. 3.b. Spectral band 2

Fig. 3.c Spectral band 3

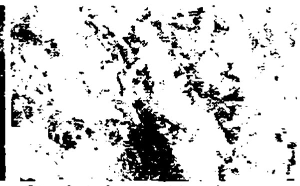

Fig. 3.d. Spectral band 4

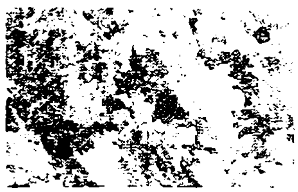

Fig. 3.e Spectral band 5

Fig. 3.f. Spectral band 6

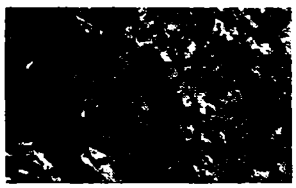

Fig. 3.g Spectral band 7

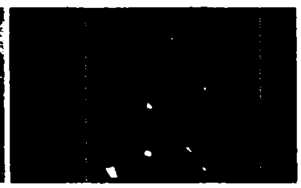

Fig. 4. Calibration image

3.2. *Experimental Results of CSOM Satellite Image Classification*

Each multispectral pixel (7 bands) is characterized by a corresponding 7-dimensional vector containing the pixel projections in each band. These vectors are applied to the input of the neural/statistical classifier. For clasification, we have experimented the following neural versus statistical techniques:

- the new CSOM model
- the classical SOM classifier
- the Bayes classifier (by assuming the seven classes have normal repartitions).

The results of simulation are given in Tables 1-6. Two classified multispectral images are given in Figs. 5 and 6 and the corresponding histograms are shown in Figs. 7 and 8. The recognition rates for the training lot and also for the test lot are shown in Figs. 9-10.

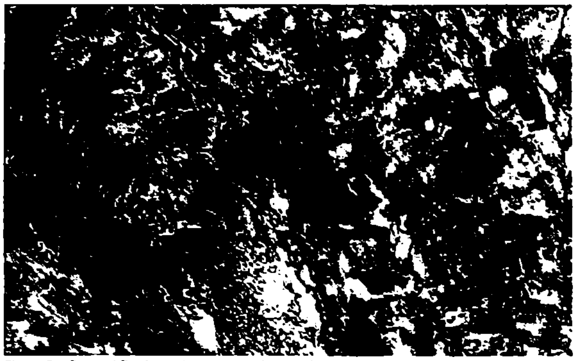

Fig. 5 Classified multispectral pixels (7 categories) using a circular CSOM architecture with 7 x 112 neurons (recognition rate 95.29%)

Fig. 6 Classified multispectral pixels (7 categories) using a circular SOM architecture with 784 neurons (recognition error 4.31 %)

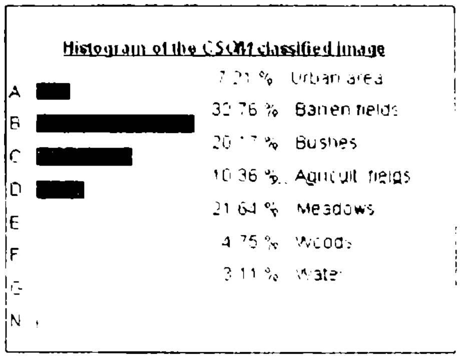

Fig. 7. Histogram of the classified multispectral LANDSAT TM image given in Fig. 13 (using CSOM)

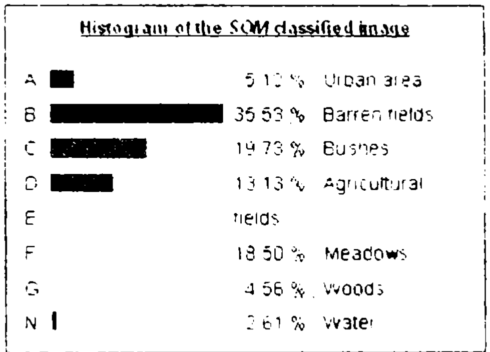

Fig. 8 Histogram of the classified multispectral LANDSAT TM image given in Fig. 14 (using SOM)

Table 1. Experimental results of multispectral satellite image classification with CSOM, SOM and Bayes classifiers (7 thematic classes; input vector space has the dimension 7)

Nr	Type of classifier	Total number of neurons	Number of networks	Recognition score for the training lot (%)	Recognition score for the test lot (%)
1	**Circular CSOMs (7 x 112)**	784	7	98.71	**95.29**
2	Circular SOM	784	1	96.49	94.31
3	**Linear CSOMs (7 x 112)**	784	7	98.64	**95.10**
4	Linear SOM	784	1	97.06	94.12
5	**Rectangular CSOMs [7 x (14 x 8)]**	784	7	97.98	**95.07**
6	Rectangular SOM (28 x 28)	784	1	96.53	92.80
7	Bayes classifier			95.83	94.22

Table 2. Comparison of the best pixel classification scores obtained by SOM and CSOM for the training lot as a function of the number of neurons

Number of neurons		**49**	**98**	**196**	**392**	**784**	**Bayes**
Recognition rate [%]	*SOM*	91.60	93.53	95.10	95.86	97.06	95.83
	CSOM	93.27	95.01	96.62	97.76	98.71	

Table 3. Comparison of the best pixel classification scores obtained by SOM and CSOM for the test lot as a function of the number of neurons

Number of neurons		49	98	196	392	784	Bayes
Recognition rate [%]	*SOM*	92.04	93.87	93.62	94.34	94.31	95.17
	CSOM	92.86	94.79	93.71	94.85	95.29	

Table 4. Confusion matrix for the circular SOM with 784 neurons (test lot)

Assigned Class	Real class							
	A	B	C	D	E	F	G	Total [%]
A'	**80.00**	0.08	1.97	0.00	0.00	0.21	0.62	1.96
B'	8.57	**99.41**	0.66	0.00	0.00	0.00	0.00	37.54
C'	5.71	0.17	**73.68**	0.33	0.48	4.95	3.73	4.80
D'	0.00	0.00	1.97	**96.45**	0.00	9.28	0.00	29.00
E'	0.00	0.00	0.66	0.00	**98.55**	0.00	0.00	6.48
F'	0.00	0.00	14.47	2.77	0.00	**84.74**	1.86	14.57
G'	5.71	0.08	4.61	0.00	0.00	0.41	**93.79**	5.21
Unclassified	0.00	0.25	1.97	0.44	0.97	0.41	0.00	**0.44**
Total [%]	2.21	37.54	4.80	28.50	6.54	15.32	5.09	100.00

Table 5. Confusion matrix for the circular CSOMs with (7 x 112) neurons (test lot)

Assigned Class	Real class							
	A	B	C	D	E	F	G	Total [%]
A'	**90.00**	0.25	0.00	0.22	0.00	0.21	0.00	2.18
B'	2.86	**99.58**	0.00	0.00	0.00	0.00	0.00	37.44
C'	4.29	0.17	**84.87**	0.44	1.45	6.80	2.48	5.62
D'	0.00	0.00	1.32	**95.79**	0.00	6.39	0.00	28.34
E'	0.00	0.00	0.00	0.00	**98.55**	0.00	0.00	6.45
F'	0.00	0.00	5.26	3.55	0.00	**85.77**	0.00	14.41
G'	2.86	0.00	8.55	0.00	0.00	0.82	**97.52**	5.56
Unclassified	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Total [%]	2.21	37.54	4.80	28.50	6.54	15.32	5.09	100.00

Table 6. Training time required by the best SOM and CSOM as a function of the number of neurons (for multispectral pixel classification)

Number of neurons		49	98	196	392	784
Training time [sec]	*SOM*	276	545	1140	2040	4872
	CSOM	56	93	171	423	1020

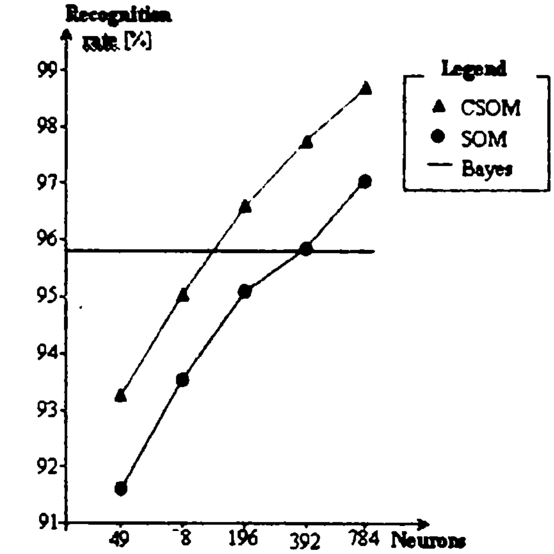

Fig. 9. Best pixel recognition rates on the training lot as a function of the total number of neurons

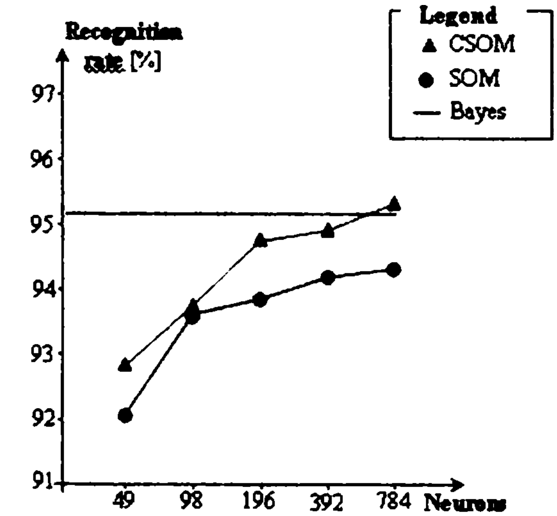

Fig. 10. Best pixel recognition rates on the test lot as a function of the total number of neurons

IV. CONCLUDING REMARKS

1. The new **CSOM** model uses a collection of small SOMs, each network having the task to correctly classify the patterns of one class only. The decision is based on a global *winner-takes-all* strategy.
2. We can evaluate the very good recognition score of multispectral satellite image classification for all the experimented classifiers, both neural ones (the new CSOM and the well-known SOM) and also statistical (Bayes). *However, the CSOM model leads to slightly better results for all the considered variants by comparison to SOM and Bayes.*
3. The best results (a pixel *classification rate of 95.29% for the test lot)* are obtained using a CSOM model containing 7 circular SOMs with 112 neurons each of them. Taking in.o ..ccoun. .... ..rc..i..c.ur.. variants 'or t' e components o' CSOM, for this application the best variant is circular, followed by linear and then by .e..angula..
4. The CSOM model requires a significantly less training time by comparison to the single SOM and Bayes.

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