A DSP Implementation of an AOM and its Application to Defects Detection in Textile Material

Ibarra-Picó, F.; Garcia-Crespi, F.; Cuenca-Asensi, S.A.; Morales-Benavente, J.L.; Lorenzo-Quintanilla J.J.

Departamento de Tecnología Informática y Computación
Campus de San Vicente
Universidad de Alicante
E03080 - Alicante, Spain
Phone: +34-965909387
Fax: +34-965903681
Email: ibarra@dtic.ua.es

Abstract. This paper explains a method of defects detection in textile material using a DSP. This **Supervised Learning** method will allow the detection of defects in anyone of the phases of production. An algorithm of pattern classification based on minimum distance is used to carry out this method. Scalar distance in an **AOM network** is used to provide a measure of the angle which form the 2 compared vectors too. Finally, some experiments have been carried out.

1 INTRODUCTION

The objective of any industry is the fabrication of its products as quicker as possible and with the smallest cost. To reach these objectives we should automate the production process **[4]**, but at the same time we should also control not only the process but also the final product in order to make sure that the final result is a valid product for the market.**[1]**.

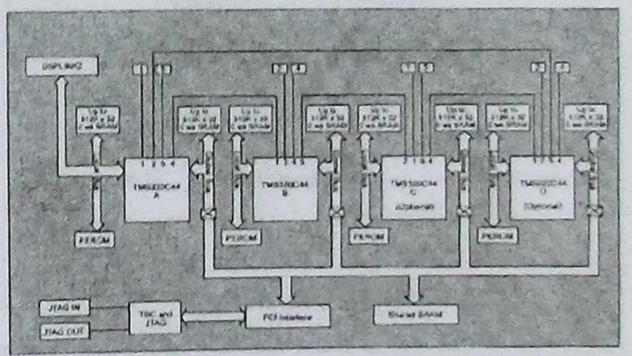
To be able to compare a sample taken in a certain instant with other previously classified we should apply computing mechanisms that measure the approach from the sample to those that we know. Previous to the classification of any measure we should know a series of well classified samples which will indicate us the degree of approach to the taken measure.

These classification algorithms will be based on characteristic vectors of images, with which was created the database with the classified patterns, (starting from now "pattern vectors"). These are the vectors that will be compared with the vectors of characteristic of the current image (starting from now "test vectors"). Therefore, and by means of the classification algorithm, we will be able to know to which pattern vector approaches more each test vector, and, consequently, if we know that the pattern vector contains defects, we could, in the same way, say that the test vector contains the same or similar defects.

2 DEVELOPMENT SYSTEM

To carrying out the experiments of defects detection in textile stuff based on AOM distance, we have worked with a card of digital signal processing (DSP). It is a Texas Instruments's card named PCI/C44S **[2]** with two processors C44 (that works at 50MHz) which works in parallel to carry out the high speed classification of the captured images **[5]**.

The diagram of blocks of the PCI/C44S card is the following one:



3 AOM CLASSIFIER

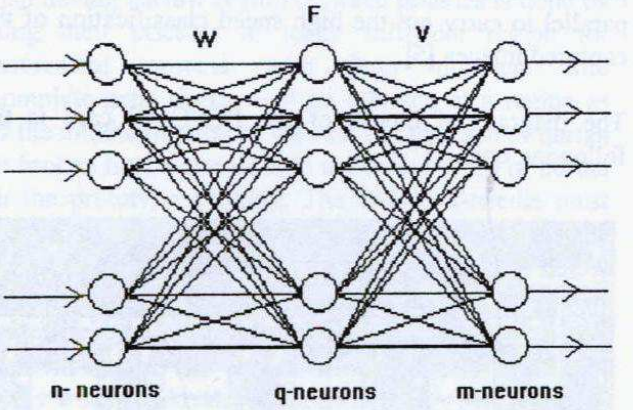
To compare what they look like each other two vectors whose values are normalised, this algorithm obtains a AOM distance among them, as the value of the scalar product of the vectors. That is to say, the degree of similarity among the vectors will come given by the angle that they form between them. The distance obtained is always a value between 0 and 1, since this value is the cosine of the angle that the two vectors form. As the values of the vectors has been previously normalised, the modules of the vectors are rejected simplifying vastly the calculations to carry out.

Let a set of **q** patterns pairs $(\mathbf{a_i}, \mathbf{b_i})$ for $\mathbf{i=1}$, .., **q** belonging to the vector spaces $\mathbf{R^n}$ and $\mathbf{R^m}$, where the patterns $\mathbf{a_i}$ are normalised in same way so $|\mathbf{a_i}| = \mathbf{k}$ where $\mathbf{k} \in \mathbf{R}$ and $\mathrm{i} = \mathbf{1..q}$. We will build two learning matrices in the following way:

$$A = \begin{bmatrix} a_{11} & a_{21} & \cdots & a_{q1} \\ a_{12} & a_{22} & \cdots & a_{q2} \\ \ldots\ldots & & & \\ a_{1n} & a_{2n} & \cdots & a_{qn} \end{bmatrix} \quad B = \begin{bmatrix} b_{11} & b_{21} & \cdots & b_{q1} \\ b_{12} & b_{22} & \cdots & b_{q2} \\ \ldots\ldots & & & \\ b_{1m} & b_{2m} & \cdots & b_{qm} \end{bmatrix}$$

where **n** dimension patterns are the columns of matrix **A** while **m** dimension patterns are the columns of matrix **B**.

The memory is built as a neural network (see figure below) with two synaptic matrices (containing hebbian correlations) **W** and **V**, which are computed $\mathbf{W = AQ^t}$ and $\mathbf{V = QB^t}$. Where **Q** is an intermediate orthogonal matrix (Walsh, Householder, and so on) of dimensions **qxq**. The $\mathbf{q_i}$ vectors of matrix **Q** are an orthogonal base of the vector space $\mathbf{R^q}$.



If **Q** is a Householder matrix (built as $\mathbf{Q = I - 2uu^t}$ where $\mathbf{u^t = [2/q\ 2/q\ ...\ 2/q]}$) then the intermediate filter (**F**) in the hidden layer is

$$F(x_i) = \begin{cases} 1 - 2/q & x_i \geq 0 \\ -2/q & x_i < 0 \end{cases}$$

where only the winner neurone $\mathbf{x_i}$ which is associated to the $\mathbf{a_i}$ pattern rises to $\mathbf{1 - 2/q}$.

As a result, the neural network has an entrance level with **n** neurones, a hidden level with **q** neurones and an exit level with **m** neurones. Each processing element of a layer is connected with all the processing elements of the following layer. The AOM network can expand by backtracking with $\mathbf{W^t}$ and $\mathbf{V^t}$, what allows its bi-directional use.

4 EXPERIMENTS

Considering the appropriate experiments to carry out in order to measure the power of the programs and the card with which it works, it will be formed 3 series of experiments, two of which will be commented later on.

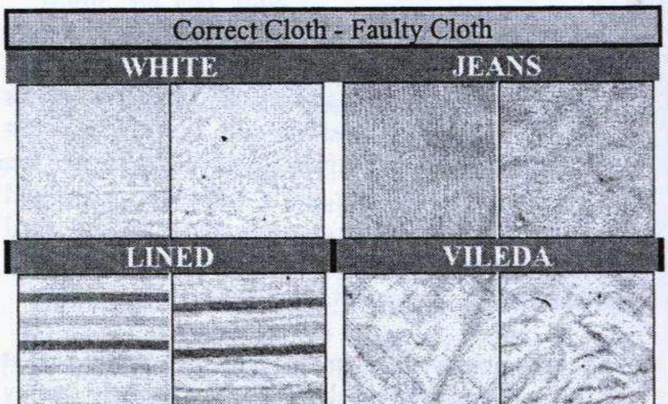
With regard to the AOM classifier, and in order to reduce not only the necessary operations but also the processing time, we have eliminated the hidden layer of the AOM network so that the calculation of the AOM distance is reduced to:

$$V_A = (a_1, a_2, a_3, \ldots, a_n) \qquad \text{AOM distance} = \sum a_i \cdot b_i$$
$$V_B = (b_1, b_2, b_3, \ldots, b_n) \qquad \forall i \in 1,2,\ldots n$$

To finish, we are going to show the parameters that have been used in the AOM classifier:

Parameters of AOM classifier	
Number of patterns	4 x 10
Distance method	Scalar Product
Filter f1	Scalar Product
Filter f2	Normalisation

4.1 Preparation Of Experiments



For the experiments carried out in this project, a battery of 40 images it has been created by scanning 4 different types of cloths (white cloth, jeans cloth, lined cloth, and "vileda" cloth). All the images have a size of 512x512 pixels, 256 grey levels and a 100 dpi resolution.

When creating the series of experiments, and because the group of samples is reduced (10 images for each cloth), we have considered the method **Leaving One Out**

This method consists on the use of a sample as test, and the other ones as training repeating the experiments, leaving every time a different sample, that's why its name.

The error rate will be the proportion between the number of fault experiments and the number of total experiments.

Image size	n x n
Window size	m x m
Number of Images	K
Number of Classifications x Image	$(n/m)^2$

$$T_e = \frac{\sum_i^k \frac{n^o\,errors}{(n/m)^2}}{k}$$

4.2 Series Of Experiments

Next, the results of each one of the carried out series of experiments are shown. For all the carried out series, we have measured the time of execution and the error rate.

4.2.1 Series 1

In the first series, it has been carried out experiments on the four different types of cloths and applied the following parameters for the MC calculation:

Windows size:	64 x 64					
Planes:	5					
Limits:	-1	32	64	96	128	255
Pieces:		2x2	3x3	4x4		

The previous parameters have been chosen to comparing them with the results of the following series that it will have less number of piece sizes. The obtained error rate has been:

Image	Cloth Type			
	Jeans	White	Lined	Vileda
0	0	0	1	0
1	4	1	9	0
2	6	0	8	0
3	6	0	6	0
4	3	0	16	0
5	7	1	12	1
6	2	0	20	1
7	0	0	14	2
8	1	0	19	1
9	0	3	16	2
Total Errors	29	5	121	7
Error Rate	4.53%	0.78%	18.91%	1.09%
Execution Time	4.801s	4.833s	4.725s	4.831s

We have obtained disparate results depending on the cloth type we are analysing, having the highest error rate for the most complex cloth type, that is to say, the lined cloth.

As far as the execution times is concerned, they are practically equal because they won't depend on the complexity of the cloth to analyse but on the MC parameters that will be considered.

4.2.2 Series 2

For the second series, we have changed the MC parameters with regard to the first series and we have considered different piece sizes to process for each image, since we wanted to observe the influence that this change would suppose in the error rate as well as in the execution times.

Windows size:	64 x 64					
Planes:	5					
Limits:	-1	32	64	96	128	255
Pieces:		2x2				

We have only considered a 2x2 piece size for each window of each image and we have obtained the following results:

Image	Cloth Type			
	Jeans	White	Lined	Vileda
0	0	0	0	0
1	2	1	10	0
2	3	0	17	0
3	6	0	9	0
4	4	0	17	0
5	5	0	17	0
6	2	0	15	1
7	0	0	19	2
8	1	0	19	1
9	1	3	17	3
Total Errors	24	4	140	7
Error Rate	3.75%	0.63%	21.88%	1.09%
Execution Time	2.859s	2.850s	2.826s	2.853s

If we compare the error rate of this series with those of the first series, we can see that the results are pretty equal. The only difference is that these results have increased because we have lost certain information in the MC calculation.

Now, we are going to study the behaviour of the execution times of the programs with these parameters. As we can observe the times have decreased notably due to the decrease of the complexity in the MC calculation.

4.2.3 Series 3

For the series 3 we have wanted to verify the importance that suppose either the number of planes and the limits selection. These limits have been selected in a homogeneous way, that is to say all the planes have the same size (they embrace the same number of grey tones). It has been decreased the number of planes with regard to the previous series from 5 to 4 planes.

Windows size:	64 x 64					
Planes:	4					
Limits:	-1	64	128	192	255	
Pieces:		2x2	3x3	4x4		

The error rate and the execution times obtained are the following:

	Cloth Type			
Image	Jeans	White	Lined	Vileda
0	0	0	0	0
1	9	10	11	14
2	9	3	19	11
3	9	9	9	9
4	12	8	18	12
5	23	1	22	11
6	15	2	20	13
7	14	1	26	12
8	15	3	25	13
9	21	2	18	15
Total Errors	127	39	168	110
Error Rate	19.84%	6.09%	26.25%	17.19%
Execution Time	3.557s	4.408s	4.108s	4.218s

When decreasing the number of planes to analyse, the error rate has suffered a notable increment in all the analysed types of cloths. Therefore the number of planes and the disposition of the same ones supposes one of the main factors to reach acceptable results.

The times of execution have also suffered a slight variation, decreasing in relation to the first series because the number of planes is lower. However, as we can see, the results follow the same rules that the previous series.

4.3 Final Results

To summarize, we will expose the results obtained in the three exposed series of experiments. To obtain the answer time necessary to evaluate a window, we have to divide the total execution time of the complete image by the number of processed windows. In our case, the number of windows is always the same and it is equal to 64 (an 512 x 512 image can be divided in 64 windows of 64 x 64).

	Success Rate	Total Execution Time	Answer Time
Series 1	93.67%	4.797 s	0.075 s
Series 2	93.16%	2.847 s	0.044 s
Series 3	82.66%	4.072 s	0.064 s

5 CONCLUSIONS

Once commented the experiments, we can extract some conclusions that guide us in later tests. In general, in anyone of the cases we can appreciate that the method doesn't require an excessive processing time; producing rates of success around 94%. These results are quite encouraging if we keep in mind that it has been analysed some complex cloth types (such as lined cloth).

To finish, and since the results obtained both in error rate and in execution times have been quite good, the application of this method can be very advantageous, moreover knowing that the development enviroment used is relatively simple.

6 REFERENCES

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