A Method to Classify Digital Clocks Employing Image Segmentation and Associative Memories

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Abstract. This paper shows results obtained in the classification task of digital clocks in a real experiment for the recognition of digits extracted from a sequence of images taken from an intelligent digital camera (VCM40), mounted on a pneumatic machine. The purpose of the experiment is to obtain a smaller number of rejected pieces.

The digital clocks have an own sequence themselves, who depends of the type of clock that is being proven. For that reason, for each digital clock, the system has to classify them at the same time to check them and obtain a result of their sequence to verify that its working good or not.

Then, the problem to solve is simply to try to identify what kind of clock is mounted on the pneumatic machine, proving the sequence of each clock and to proceed to reject it or not. The neural network is employed to realize the classification task of the digits showed during the states of the sequence and to be compared with a conventional method used in the industry.

The results obtained were satisfactory because of the number of rejected pieces was adequately selected. The new method in comparison with the method used in the last process implemented, demonstrate that the Neural Networks application is very interesting for this industrial process. While the last method rejected 10% of which 4% was perfectly, the new method only have an error rate of 5%.

1 Introduction

Immersion of a visual machine to agile the industrial processes is a consequence of the utility of the computer science in our days. The faculty of the computer to see, to

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hear and to move it is a reality in our days. Also, robotics industry is growing day to day and its contributions too. In this paper we are going to describe a process to classify a set of digital clocks manufactured by ELTEC Company. The process to check the different types of digital clock depends of the ELTEC requirements. In this analysis we used the digital clock named TOD-2 M.

At the same time, this paper shows the interactive image recognition in an industrial process that counts with a set of sequences predetermined conforms by 9 stages. The image recognition process was made in various stages of them (6 in total). The objective is that the sequence must be adequately finished detecting any problems while is making. When a problem has been found is registered in a database, so the system has a register of the all problems found during the process.

Immersion of the vision computer in an industrial process, give us the following advantages:

a) The number of pieces analyzed is greater than if a human supervisor making the same task.
b) The interested people have a register adequate of the problems founded in the electronic board analysis. With this, they must try to obtain the cause that origin the problem and then to try to solve it.
c) To implement different types of digital signal processing techniques to the industrial applications.

As we mentioned above and in [1], we try to apply the vision computer in a real world application and obtain the best response of the equipment.

The classification of segmented image regions for object recognition has been addressed in several works. Neural Networks are used in [2] not only to classify known objects but to detect new image object. In [3], object of interest are first localized, the feature is extracted from the region of the interest and finally a Neural Network is applied to classify objects. Support Vector Machines are used in [4] to classify a segmented image region in two categories.

2 Characteristics and Generalities

Table 1 resumes the characteristics of the TOD-2 M, clock used during this experiment and figures 1 shows digital clock TOD-2 M.

TIMER	• It shows the time of the timer if this one previously has been programmed • If then it is marking and showing the time programmed in the timer (TIMER), the way of programming of the same one activates and it reestablishes it to zero minutes (00) • If one is in the way of programming of the timer, reestablishes the time to 00 and it remains within the same way.
▲	• When pressing momentarily this button, the time is increased by one minute. • If this button stays pressed by more than 1 second, the time is decremented in intervals of 10 minutes • When the indicator of minutes reaches a count of 60, the hours will be increased automatically and the minutes will be reestablished to 00 • When is being the time of the timer, it allows to make changes to the value of the same one in real time.
▼	• When pressing momentarily this button, the time decrement by a minute. • If this button stays pressed by more than 1 second, the time is decremented in intervals of 10 minutes • When the indicator of minutes reaches a count underneath 60, the hours will be to decrement automatically and the minutes will be reestablished to 59 • When is being the time of the timer, it allows to make changes to the value of the same one in real time
CLOCK	• It activates the programming of the clock or returns to show the present hour if the TIMER is activated • It accepts the new hour programmed when it is in the mode of programming of the clock • It can be used like the key of beginning for any mode of programming.

Table 1 Operation each button inside the digital clock TOD-2 M.

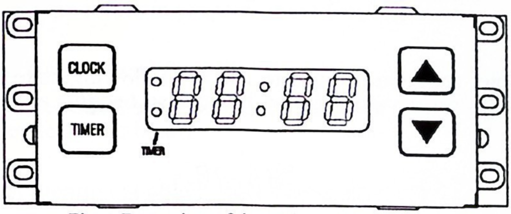

Fig. 1 Front view of the digital clock TOD-2 M

A simplified block diagram of the system is shown in figure 2.

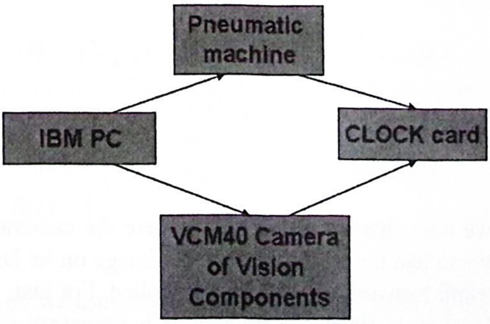

Fig. 2 Block diagram of the purpose system.

The VCM40 is manufactured by Vision Camera from Germany. It is an intelligent camera and it has three electronic boards into it. One of them has the DSP that controls all process concerning to the digital image processing task; it uses a specific program to interact with external equipment and it also counts with an operating system owned. The operating system has a set of instructions relatively small (it has only 40 instructions to interact with the user). An interface of communications is used to send the commands to the camera. The software included has the PROCOMM program that has the same utility of Windows HyperTerminal program.

Also, the user can interact with the camera using a C program compiled with the g21 compiler. This compiler was made for Analog Devices to interact with its commercial products. The experiments were executed on Windows 98 because of the compiler does not support the NTFS architecture.

The limitation of this camera is that only can take 14 pictures because DRAM is limited. Then, the problem is to try to adapt the number of images that we must take with the purpose to have good performance of the different digital clocks that are proved.

We prefer to solve this problem, using the sequence and use cases diagrams to relate the real problem with its solution. As we said, the camera only can be programmed using C language, for that, we do not use all types of diagrams that UML uses to represent the software engineering solutions. For that, we decided use only two of them.

At the same time, we have decided to use the following state sequence to represents the states of the TOD-2 M digital clock, as figure 3 shows.

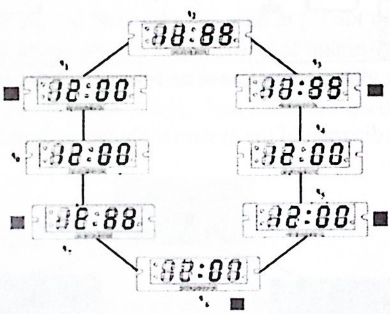

Fig. 3 State sequences for digital clock TOD-2 M.

As we can see, we have marked the moment where the camera took a picture. In that moment, the camera had the faculty to save the image on its DRAM, when it had been realized the Neural Network algorithm was applied. For that, the system has the possibility to decide when to finish the process. It is necessary to have this control because of it saves time to the operator and he can replace and verify the corresponding board.

3 Image Acquisition, processing and Segmentation

As we have been talking, the image acquisition process was realized using a VCM40 camera; the pneumatic machine counts with a little door above the place where the electronic board is inserted. This door can be closed, and then we can obtain a black area where the picture can be tacked. Figure 4 shows the structure of the pneumatic machine and the VCM40 camera position into it.

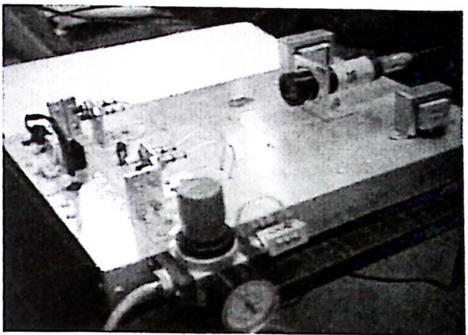

Fig. 4 Pneumatic machine and intelligent camera before to start proves.

When the electronic board that contains the displays is collocated in its position, the process begins and the following aspects must be considered:

a) The process finished satisfactorily
b) The process is stopped because of any trouble was identified in any components of the electronic board.

The second aspect mentioned above can be because:

a) The segments that are in the digits of the electronic board are light off.
b) The intensity of someone segments of the display is not the same like others.
c) The sound emitted for the clock is not operating adequately.

In the experiment we used a threshold to determine what kind of image was obtained from the camera. It was calculated of experimental form, the expression utilized is:

$$\hbar(t) = \begin{cases} 0 & if \quad \hbar(t) < \alpha \quad for \quad t > 0 \\ 1 & if \quad \hbar(t) > \alpha \quad for \quad t > 0 \end{cases} \tag{1}$$

For edge detection we used Sobel operators. As we know, they are used to find the edge detection in the domain of two-dimensional image, using the gradient and Laplacian expressions that are defined as [5]:

$$\nabla f = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \tag{2}$$

The magnitude of the gradient is given by:

$$\nabla f = |\nabla f| = \left[G_x^2 + G_y^2\right]^{1/2} \tag{3}$$

And the direction of the gradient vector is then:

$$\alpha(x,y) = \tan^{-1}\left(\frac{G_x}{G_y}\right) \tag{4}$$

In order to apply these operators, the function *f(x,y)* must be a closed form expression which we can differentiate analytically. Clearly, we can be able to approximate the partial derivatives and over an array of constant data representing the intensities of an image. Referring at this trouble, the most obvious and straightforward way to accomplish this is simply as follow:

$$\begin{aligned} G_x &= Z_5 - Z_8 \\ G_y &= Z_5 - Z_6 \end{aligned} \tag{5}$$

The Sobel operators may be useful due their smoothing effect. The discrete operators corresponding to the partial derivatives are given by:

$$\begin{aligned} G_x &= Z_7 + 2Z_8 + Z_9 - (Z_1 + 2Z_2 + Z_3) \\ G_y &= Z_3 + 2Z_6 + Z_9 - (Z_1 + 2Z_4 + Z_7) \end{aligned} \tag{6}$$

And the corresponding masks as:

$$\begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} \& \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix} \tag{7}$$

Figure 5 shows any image before and after to apply the Sobel mask to one of our image obtained. Also, we can see the forms of the image during the stages of the preprocessing and segmentation.

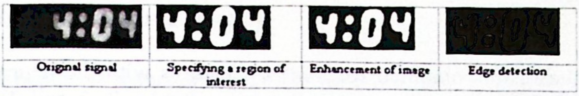

Fig. 5 The pre-processing stage on the image obtained from the intelligent camera.

4 Neural Network and Experimental Methodology

Neural Networks (NNs) are used for a wide variety of image classification tasks [6]. An object is represented by a number of features that form a d-dimensional feature vector x within an input space $X \subseteq R^d$. A classifier therefore realizes a mapping from input space X to a finite set of classes $C = \{1,......,l\}$. A neural network is trained to perform a classification task from a set of training examples $S = \{(x^\mu, t^\mu), \mu = 1,...,M\}$ using a supervised learning algorithm. The training set S consists of M feature vectors $x^\mu \in R^d$ each labeled with a class membership $t^\mu \in C$. The network typically has as many outputs as classes and the target labels are translated into *l*-dimensional target vectors following a local unary representation. During the training phase the network parameters are adapted to approximate this mapping as accurately as possible (unless some techniques, such as early stopping, are applied to avoid over-fitting). In the classification phase an unlabeled feature vector $x \in R^d$ is represented to the trained network and the network outputs provide an estimation of a-posteriori class probabilities for the input x, from which a classification decision is made, usually an assignment to the class with maximum *a-posteriori* probability [7][8].

In this work, we used an auto-associative neural network based in Hopfield idea. The network consisted of a weight matrix with 4000 neurons for the image recognition because of the images obtained had 50x80 pixels. The purpose to have this neural network is to recognize the eight important elements (numbers: ***0, 1, 2, 5,*** and letters **E, *n, d,*** and the ***points***), showed in the different stages during prove of clocks. The task is then, to recognize in the same picture after to taken it, the digits and the points illuminated in the electronic board all right with the process of prove mentioned before. For that, inside of the flash RAM we have positioned the weight matrix obtained during training phase that represents the eight elements corresponding. To obtain these reference patterns we use a probabilistic method because of the position of the digits in the picture taken were different (but not so much). With 20 electronic boards we obtained the average position.

5 Results

We show the results obtained for a set of features with the neural network mentioned above and the averaging method purpose (tables 2, 3 and 4). We prove the experiments using 500 electronic boards and its elements inside. Each board has four digits and three points to recognize, the task was that during a complete process of verification and approbation of each them, 5 pictures were taken. Then, we have a total of 3000 elements analyzed:

Stage/pattern	0	1	2	5	E	n	d	Points
1	2	1	1					2
2		2		2				2
3	2	1	1					2
4	1	1						3
5					1	1	1	
Total	5	5	2	2	1	1	1	9

Table 2 Number elements analyzed and its corresponding stages.

Then, with 500 electronic boards we have the following results for each pattern:

Stage/pattern	0	1	2	5	E	n	d	Points	
1	1000	500	500					1000	
2		1000		1000				1000	
3	1000	500	500					1000	
4	500	500						1500	
5					500	500	500		
Total	2500	2500	1000	1000	500	500	500	4500	13000

Table 3 Total of elements analyzed.

The results obtained for each pattern according the stage were the following:

Stage/pattern	0	1	2	5	E	n	d	Points	
1	980	491	496					994	
2		983		991				994	
3	980	491	496					994	
4	488	495						1438	
5					494	490	486		
Total	2448	2460	992	991	494	490	486	4450	12881

Table 4 Results obtained after to apply the Neural Network to the industrial process.

Then, with the results obtained we reached a recognition rate of:

$$\%recognition = \frac{12781}{13000} x100 = 98.5461$$

The high performance of the neural network demonstrated in the percent recognition avoid to have so much electronic boards in the market, because of the number of rejected pieces in this experiment were 121 elements (the worst in the analysis effected), another experiments were realized with other set of 500 electronic boards and the best only rejected 25 electronic boards. The troubles were because the dip switch was damaged or the electronic board was not welded adequately.

6 Conclusions and future works

In the present paper we demonstrate an application of the neural networks in an industrial process that counts with a set of stages predetermined. Also, we introduced a method to control the limitations that we had at using this type of classifiers in these applications. The primordial aspects used were:

- Image acquisition. Using the VCM40 (an intelligent camera manufactured by Vision Components),
- Pre-processing of image. Applying Sobel masks to edge detection,
- Segmentation. Using an empirical threshold; obtained from the pictures.
- Training and recognition. Using a neural network; for that.

The value of the threshold was determined of empirical form, it was obtained after that we analyzed 20 electronic boards that was used also for the training phase. The results that we obtained showed us that the application of the neural networks in an industrial process with more stages is possible. So verification and tested of digital clocks too. The results obtained optimize and automate a process that was realized using other technique (manually); results demonstrate that.

In order to increase the classification performances in this application, there are several actions that can be attempted. First, we must try realizing the recognition phase using another neural network and comparing the results obtained with that we reported here. So, this is a project in process; because the results reported are the first experiments after that the pneumatic machine and the digital clocks were assembled. For that, only we had presented these results. Second, a new neural network structure can be proposed to avoid using to set of electronic boards choosing the average position of them. Neural networks like LAM, BAM, ALFA, BETA, etc., can be used.

Finally, the algorithm and the approach implemented here will be applied to another kinds of digital clocks manufactured by ELTEC, where the complexity is different because of not only neural network must classify the set of digits, but that neural network must recognize what digital clock type is presents and the subcategory that it pertains.

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