FACE RECOGNITION IN BIOMETRIC VENDING MACHINES

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Abstract: Many Biometric security systems are used to grant restricted access to certain resources. This paper presents a biometric system for automatic vending machines. It ensures that products submitted to legal restrictions are only sold to authorized purchasers. Making use of an identity card, the system checks if the purchaser verifies all the restrictions to authorize the product sale. No special cards or codes are needed, since the system only scans the ID card of the user and verifies that the purchaser is the ownership of the card taking a photograph. The simplicity of the system and the high recognition rates obtained make the biometric system an interesting element to be included in automatic vending machines in order to sell restricted products in certain areas.

1 INTRODUCTION

One of the main problems of vending machines is to grant that certain products, whose sale is restricted to adults, are only performed to authorized purchasers. Products as tobacco or alcoholic drinks cannot be offered in certain places to all the customers. If the vending machine is not placed in a restricted area, where only adults can access, some security facilities are required. In order to grant that only authorized purchasers can buy a certain product (a beer, for example) on a vending machine placed in a public access area, a biometric authentication system is proposed in this work. According to Automatic Merchandiser magazine, the vending industry's revenues in 2001 were 24.34 billion compared with 17.4 billion in 1992. Relevance of this kind of sales is really important, and is growing considerably.

Several kinds of products cannot be sold using automatic vending machines due to legal restrictions. Tobacco, alcoholic drinks or tickets to spectacles restricted to adults, are some of this kinds of products. Biometric measures include terms as fingerprint, genetic fingerprint, facial, iris and voice recognition and many others. Considering individual physiological characteristics of users, and making use of identification cards, it is possible to ensure that only authorized users can access certain resources. In our case, we want to ensure authorized sales over vending machines.

Biometric techniques can be used to certify that only adults buy these products. So, we propose the use of biometric procedures to determine if a consumer is or not an adult, and if he does, the sale is authorized. In our case, we propose the use of face recognition techniques (Yang et al., 2002) to ensure that the ID card of the consumer corresponds with the card owner, and that the consumer is an adult. The use of passwords, intelligent cards, codes or keys are not an alternative for this problem because minors cannot buy restricted products even if the ID card is modified. Every citizen is obligated by the government to have and carry an identity card. This document ID has always a photograph of the document's owner, and the date of birth is also registered. So, having an ID card, we can extract the birth date and calculate the age of the consumer. If this age is upper than the minimum age established to authorize a sale, the machine must verify if the ID card corresponds to the user that wants to perform the sale. If it does, sale is authorized and the user can insert the coins needed to buy the product. At this point, the machine sales the product, and records the sale data.

The rest of the paper is organized as follows: section 2 is devoted to present the system architecture proposed in this work; section 3 introduces the face components detection layer, and section 4 the facial authentication layer; experimental results are pre-

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sented in section 5; and finally, conclusions and references end the paper.

2 SYSTEM ARCHITECTURE

In order to authorize a sale, a recognition of the purchaser is needed. Figure 1 illustrates the process followed by the system before a sale.

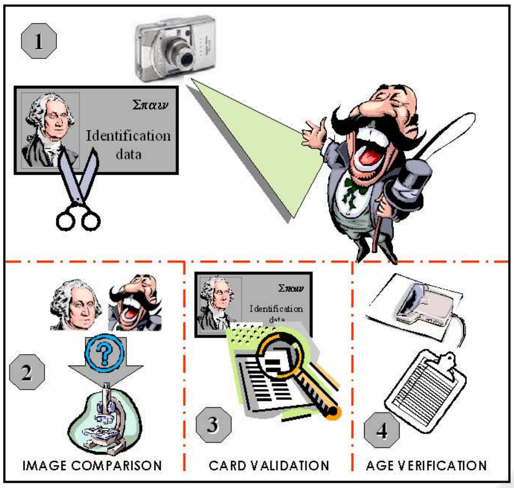

Figure 1: Process followed by the system before a sale.

First of all, the vending machine takes a photo of the purchaser and scans his personal card ID (see figure 2 (1)). Then, the system performs the location of the face, both in the card ID and in the photograph. After that, a preprocessing step including the image alignment and scale is performed, and then, the faces are normalized. Finally, the normalized images are adequately encoded and compared (figure 2 (2)), performing the final recognition.

If the recognition is successfully performed, the system can ensure that the consumer is the real owner of the card ID, any case else, the sale is rejected. Once verified the ownership of the document, the system verifies that the card ID has not been manipulated, and is an authentic document making use of the different security check-points that every card ID has. Then, the system locates the area where is placed the birth date of the purchaser (figure 2 (3)). Using an OCR layer, the system extracts the information and verifies that the purchaser has at least the minimum age required to authorize the sale. If these tree requisites (card ID ownership, card ID validation and purchaser's age) are verified, the sale is authorized. Any case else, the sale is rejected.

The application here proposed only requires a certain age of the potential purchasers to authorize a sale, but some other criteria can be taken into account.

Every citizen has an ID card provided by its government, so no additional cards are needed. Then, sales are not restricted to a limited number of clients having special cards or codes.

The identity of a customer is verified using its physiological characteristics. But biometric data is often noisy because of the environmental noise or the variability over time of the users. This problem can be solved combining several biometric techniques as it is introduced in section 4.

Figure 2 summarizes the system architecture.

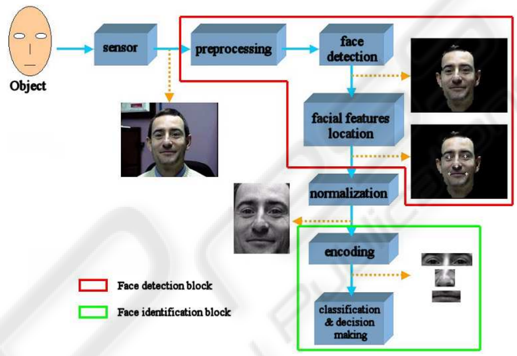

Figure 2: System architecture.

3 FACE COMPONENTS DETECTION

Considering reality, customers may not stand in front of camera properly. However, the purchaser is interested in performing the sale, we can assume he is going to place himself in a good angle in order to grant the biometric recognition, and then, the sale.

Face detection starts locating the eyes in the picture, since they can be detected with a high precision level. Once obtained their location, image can be normalized in order to extract more biometric characteristics (Brunelli and Poggio, 1993) and to match them with the pattern obtained from the image placed in the ID card (Brunelli and Poggio, 1993; Lam and Yan, 1998).

As it was introduced in (Brunelli and Poggio, 1993), eyes are placed in the center zone of the image, between the upper limit of the face, and the downer limit of the chin, and the separation between eyes are approximately the size of an eye.

Making use of a grey level distribution image we have implemented an algorithm that that works with the border distribution of the image end detects all the zones where abrupt intensity changes take place due to the high amount of borders existent. Border projection allows to detect the approximate zone where eyes are located, since eyes are usually the most structured part of the face.

Figure 3: Vertical and horizontal border detection.

Eyes detection algorithm is implemented following a multilayer design. Figure 3 illustrates the border detection process. First of all, an horizontal line placed in the longitudinal eyes edge is obtained. Once located this edge, face limits are detected (see figure 4) and the vertical edge of the nose is obtained (see figure 5). Then, two zones, where eyes could be sited, are defined. With the aid of two windows (see figure 6), less intensity pixels of the zones are located in order to obtain the pupils (see figure 7). At this point, eyes location can be clearly detected (see figure 8). Once eyes detected, the image is normalized having both eyes horizontally aligned. Then, other face components (nose, eyebrows and mouth) are much more easily detected, since the searching zone is considerably reduced.

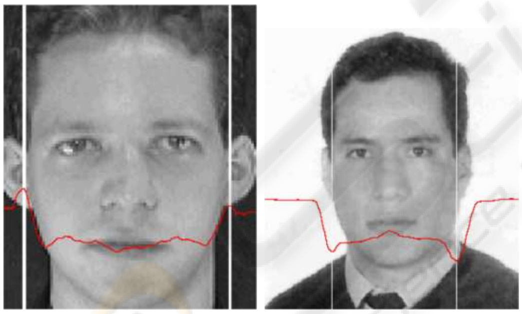

Figure 4: Face limits detection.

The process followed to detect exactly the eyes location is the extraction of the related eye's windows, their equalization, the image conversion to black and white format, its filtering, and its respectively closure and expansion (morphological operations) execution.

Then nose, mouth and eyebrows are detected. Using the horizontal projection of the vertical gradient (Brunelli and Poggio, 1993), the vertical position of the nose base can be obtained. Horizontal position can be obtained as the average point between the two reference points obtained in the eyes detection layer. Figures 9, 10, 11 illustrate the process followed in the detection process.

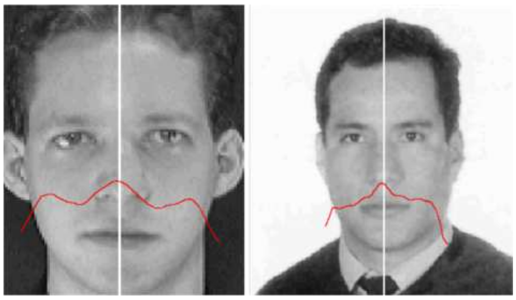

Figure 5: Nose edge detection.

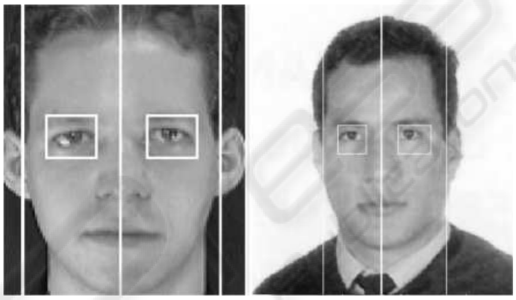

Figure 6: Windows where searching eyes.

4 FACIAL AUTHENTICATION

In order to certify that the user is the owner of the ID card introduced in the vending machine, both images (the one scanned from the ID card and photograph) are matched.

Once detected the most relevant facial components (eyes, mouth, nose and eyebrows) in both images, is time to compare them. Then, different techniques can be used. Correlation techniques (Brunelli and Poggio, 1993) perform well when images are correctly normalized, since they are sensible to size, rotation and position variations. So, an important effort is performed to normalize the images (see figure 12). Four different normalizations are considered: image without any preprocessing ($I(x, y)$), where $I(x, y)$ is the image matrix for coordinates x and y; image normalized using the average intensity for each pixel zone ($< I_D(x, y) >$); image gradient magnitude ($G(I(x, y))$); and Laplacian normalization ($L(I(x, y))$).

Correlation between both images is performed comparing each component window itself. The mouse window obtained by the camera is compared with the mouse window obtained by the scanner, and so one with the rest of components. Each window correlation is maximized itself, granting that each component window supplies the high possible amount of information. Taking into account that all the windows do not supply the same information, and knowing that this information can be erroneous in certain

Figure 7: Horizontal line connecting the pupils (white) and upper face limit (black).

Figure 8: Eyes location.

cases (glasses, mustache...), a multiple-classification subsystem is proposed. Each component has its own weight that is provided by a neural network as it is illustrated in figure 13. We have randomly selected a similar number (100) of purchasers and impostors to obtain the samples used in the training process. For the validation process we have used 100 samples corresponding (different of the previous ones) to purchasers, and 400 samples corresponding to impostors. (different of the previous ones)test. Inputs of the neural network are the correlation coefficients of the different windows (nose, eyes, mouth and face). The internal layer has four neurones and the output layer has two neurones. All the neurones have a sigmoidal logarithmic activation function.

Table 1 summarizes the results obtained for different training experiments performed by the neural network over 6 different sample sets (containing 2500 images each one of them). The neural network has four neurones in the intermediate layer, and two neurones in the output layer. Each one of the four input neurones corresponds to the four face component windows (mouth, nose, eyes and eyebrows) previously obtained. One of the output neurones indicates the certainty degree ($\mu_c \in [0,1]$) corresponding to an impostor (both images don't match), and the second neuron indicates the certainty degree ($\mu_u \in [0,1]$) corresponding to a real purchaser (both images match). The system considers a user be an authorized client whenever the difference between both degrees μ_c and μ_d are upper than a certain threshold. Selecting this threshold we can select different values for the False Acceptation Rate (FAR) an for the False Rejection Rate (FRR).

Table 1: FAR and FRR obtained by the neural network (training set).

Recognition rate (%)	FAR (%)	FRR (%)
98.446	10.5614	4.1026
98.7013	8.5964	7.6923
96.6234	2.7595	14.359
99.2208	7.929	6.6667
99.2208	9.0731	3.5897
100	7.161	8.2051

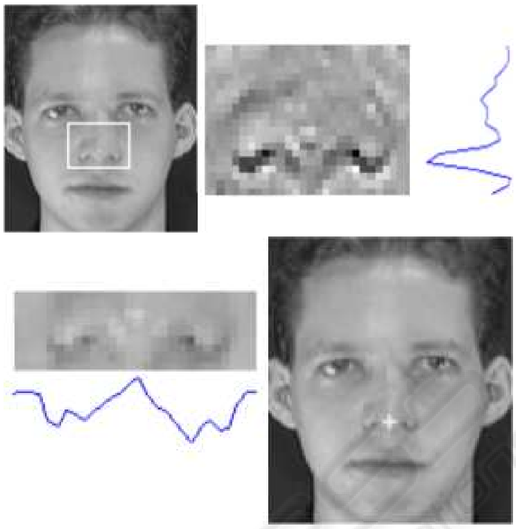

Figure 9: Nose detection: horizontal projection of the vertical gradient (up) and vertical projection of the horizontal gradient (down).

The neural network minimizes the quadratic average error of the outputs. So, when training with a high number of impostor samples, the network minimizes the FAR rate and the FRR presents high values. Then, it is possible to select different parameters according to the rate to maximize. In our case, is better to lost a sale than vending a product to a non authorized purchaser.

The standard correlation index $C(I,J)$ reduces the influence of the ambient illumination and its value varies from -1 to 1, where 1 implies that both images are identical, and -1 implies that both images are completely different.

$$C(I,J) = \frac{\sum_{x=1}^{m}\sum_{y=1}^{n}[I(x,y)-\bar{I}]\cdot[J(x,y)-\bar{J}]}{\sqrt{\sum_{x=1}^{m}\sum_{y=1}^{n}[I(x,y)-\bar{I}]^2\cdot\sum_{x=1}^{m}\sum_{y=1}^{n}[J(x,y)-\bar{J}]^2}}$$

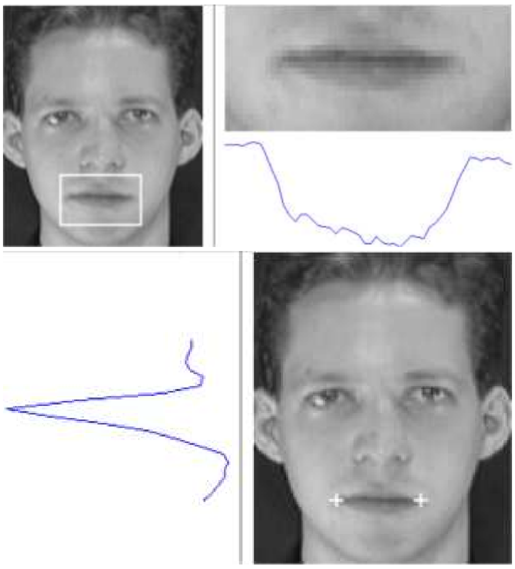

Figure 10: Mouth detection: horizontal projection of the vertical gradient (up) and vertical projection of the horizontal gradient (down).

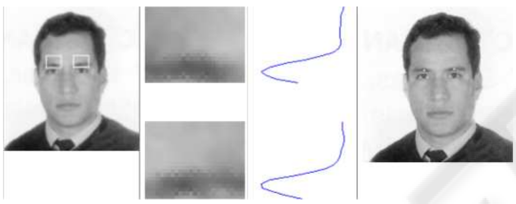

Figure 11: Eyebrows detection (left and right respectively).

$$C(I,J) = \frac{\overline{I \cdot J} - \bar{I} \cdot \bar{J}}{\sigma(I(x,y)) \cdot \sigma(J(x,y))}$$

If images are normalized having null average and a unity variance, there exists a relationship between the euclidean distance and the standard correlation index (Romano et al., 1996).

$$d_{euclidean(L_2)}(I,J) = \sum_{x=1}^{m} \sum_{y=1}^{n} |(I(x,y) - J(x,y)|$$

Being $I'(x,y) = \frac{I(x,y) - \bar{I}}{\sigma_I}$ and $J'(x,y) = \frac{J(x,y) - \bar{J}}{\sigma_J}$, the correlation index is obtained (Brunelli and Messelodi, 1995):

$$C(I',J') = 1 - \frac{\sum_{x=1}^{m} \sum_{y=1}^{n} |I'(x,y) - J'(x,y)|}{\sum_{x=1}^{m} \sum_{y=1}^{n} |I'(x,y)| + |J'(x,y)|}$$

In order to include all de information available, a new correlation index C is defined. This index includes a weighted combination of all the windows defined for the face elements.

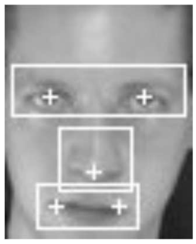

Figure 12: Normalized image taking into account facial component windows.

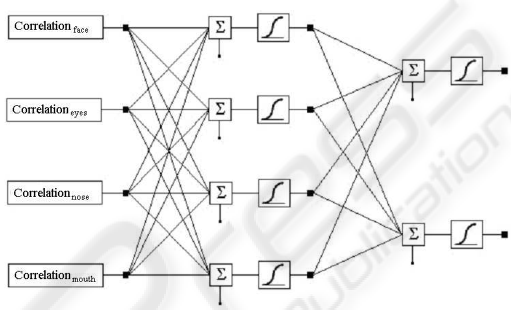

Figure 13: Neural network (forward back propagation) to obtain the correlation indexes.

$$C = k_{face} \cdot c_{face} + k_{eyes} \cdot c_{eyes} + k_{nose} \cdot c_{nose} + k_{mouth} \cdot c_{mouth}$$

Experimental results show that better results are obtained for the following values: $k_{face} = 4$, $k_{eyes} = 4$, $k_{nose} = 2$, $k_{mouth} = 1$.

5 EXPERIMENTAL RESULTS

Experiments performed in order to validate the system proposed shows that system obtains good performance in terms of calculus time and recognition rate. To study recognition raters, some indexes must be defined: False Rejection Rate (FRR), False Acceptance Rate (FAR) and Receiver Operating Characteristic (ROC). Figures 14 and 15 show the ROC rates obtained.

Experiments have been performed over a 19,460 samples, being 390 of them authorized clients, and 19,070 impostors. The correct sales rate obtained is 96.9 %, and the time employed to compute each sale is 6.2 seconds (0.4 seconds for size and position normalization, 3 for intensity normalization and windows extraction, 0.7 for windows correlation maximization, 0.1 for correlation indexes calculus, and 2 seconds to the rest of operations) over a 450MHz Intel Pentium III using MS Windows 98 and Matlab 5.2. Images used have 280x280 pixels.

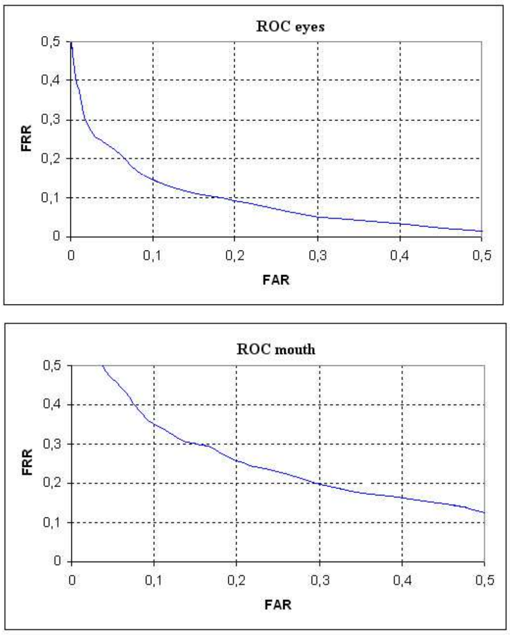

Figure 14: ROC obtained for different facial component windows.

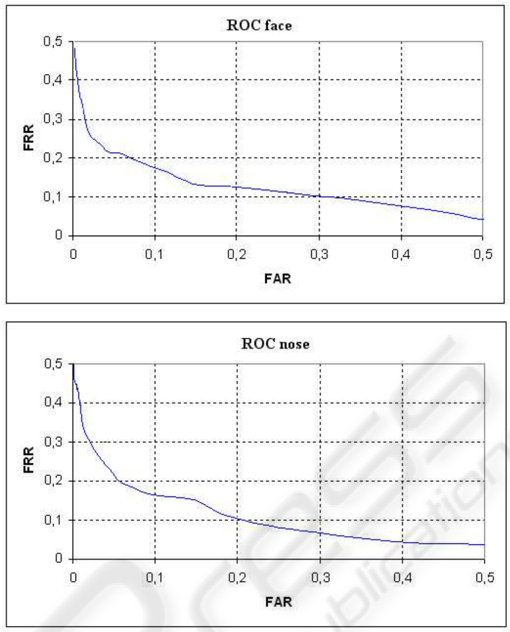

Figure 15: ROC obtained for different facial component windows.

Finally, an OCR layer is needed in order to detect if the sale is authorized or not. If the vending machine sells alcoholic drinks, the system must verify that the purchaser is an adult, so the system locates the client's birth date in its ID card. Once located, the image zone containing this date is processed by an OCR subsystem that obtains the date in a format that can be processed by the final decision module of the vending machine. This module allows or denies the sale according to the age of the purchaser.

6 CONCLUSIONS

Making use of biometric techniques, automatic vending machines can sell products nowadays restricted to adult zones or private places.

Adding a small digital camera and a scanner to the current vending machines, it is possible to build the proposed biometric security system that allows to sell restricted products everywhere ensuring that sales are performed only if purchasers are authorized.

Low computational and hardware costs make interesting to use this system.

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