Face recognition System for Smartphone based on LBP

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***Abstract*—This paper presents a face recognition algorithm based on Local Binary Pattern (LBP) to be implemented in a Smartphone with Android operating system where the input image is obtained using the camera of such Smartphone. The LBP algorithm is used for Face characterization, due to its low complexity and its robustness light of this method is chosen to be applied in a Smartphone, this is because the light sensor of smartphone could darken or lighten the captured image and affect a efficient recognition. To perform system testing on a Smartphone was used a standard database (AR Face database) to simulate the capture of images, the average of images was used for obtaining a template by person and using Euclidean distance for classification, showing that the LBP obtains good results using a simple classification algorithm with a Smartphone with limited processing power like a smartphone, further tests were performed with 1 to 9 training images, obtaining up to 90% of recognition.**

1. Introduction

Face recognition is one of the most widely used biometric technologies because the data acquisition approach is non-intrusive. Face recognition is performed by taking a picture and can be performed with or without the cooperation of the person under analysis. Thus, face recognition is a biometric technology that has obtained high acceptance among users [1], [2]. A face recognition system can be used for either identity verification or person identification. In the identity verification task, the system is asked to determine whether the person is who he/she claims to be, whereas during the person identification task, the system is asked to determine, among a set of persons whose facial characteristics are stored in a database, the person who most closely resembles the image under analysis [3], in n this work only part of facial identification is covered. .

Variable illumination, pose, facial expressions are important problems that must be considered in the development of face recognition systems because these factors significantly decreasing the accuracy of face recognition performance [4]. Among these factors, changes in lighting conditions are very important because they occur not only due to the differences on illumination conditions between indoor and outdoor environments but also with the light sensor of each Smartphone, which produces different amount of lighting depending on the device and sensor with which account. This topic has received significant attention. Due to this, different schemes have been proposed to reduce the variable illumination problems [4]. Some processes take the input image to reduce the illumination changes and improve the quality of the input face image; examples of these processes including illumination are histogram equalization [5], and contrast-limited adaptive histogram equalization (CLAHE) [6].

Also another approach to address the illumination conditions is the development of face recognition algorithms that are able to provide a good performance under such conditions and this depend the accuracy of the feature extraction method. Thus, several methods have been proposed to solve the problem. One example is the eigenphase approach, which uses the phase spectrum together with principal component analysis (PCA) and the support vector machine (SVM) [7], [8]. Feature extraction methods based on other frequency transforms, such as the discrete cosine transform [9], [10], discrete Gabor transform [11], [12], discrete wavelet transform [13], [14], and discrete Haar transform [15], have been proposed. These approaches, under controlled conditions, achieve recognition rates of over 90%. Several other approaches have been proposed to solve the problems related to changes in illumination conditions using genetic algorithms [16], image processing filters [17], and linear regression-based classification [18] in recent years.

The Local Binary Pattern (LBP) [19], [20] algorithm is one of the best texture descriptor methods. The acceptance and popularity level of this feature extraction method has propitiate its implementation even in facial expression recognition systems, achieving good results. Therefore, This texture descriptor method is chosen to be applied, because have a lot of benefits like a low complexity to develop on a Smartphone. The LBP algorithm has been implemented only in simulation environments, where it has responded satisfactorily, as is shown in [21], [22], but has not yet been implemented in a biometric system that works in an uncontrolled environment, to prove if it responds acceptably in situations that are not presented in a simulation environment.

There has been increasing interest in the development of face recognition schemes that are suitable for implementation in mobile devices, such as smartphones, which generally have low computational power. Because these systems must operate in environments with varying illumination, it is advantageous to maintain minimal computational complexity, i.e., one that does not require a preprocessing stage to improve the image quality. Hence, this paper proposes the implementation of the LBP algorithm for face recognition. After take the photo from Smartphone camera, detect and crop the face of the image, it is divided in sub-blocks of 3×3 pixels, which are characterized by the LBP coefficient corresponding to the central pixel of each sub-block. Finally, Euclidean distance is used to perform recognition. The proposed methods are evaluated with several illumination, relying on the AR face databases and a database made directly in the Smartphone using the camera.

LBP will be implemented as feature extractors as part of a facial recognition system for the Android operating system, in order to assess the effectiveness and efficiency of this algorithm.

The remaining of this paper is organized as follows: Section 2 presents the description of the proposed method. Section 3 presents and analysis of the experimental results. Finally, Section 4 provides the conclusions of this research.

2. Proposed Method

Biometric systems are a set of automated methods for recognizing people using physiological or personal behavior characteristics [1], [2]. A biometric system is, essentially, a pattern recognition system and, generally, can be divided into four main modules: a capture module, a feature extraction module, a comparison and classification and a database module. In capture module is taken the picture to analyze; in the feature extraction module, biometric data are processed, and a set of discriminatory features is extracted to represent the most important features of the person identity under analysis, in this work are used the LBP for feature extraction. In the decision module is used the Euclidean distance to determine the winner class, and finally in the database module it's stored all models of each person to identify.

2.1. Android OS

The importance of mobile devices called ”smart phones” has been increasing in recent years, thanks to technological development in this area. Then the percentage of use of smartphones by brand is show in the Figure 1,

Android is an operating system based on Linux kernel, and was developed by Android Inc., which was acquired by Google in 2005. Android was introduced in 2007 and is currently the most widely used mobile operating system in the world, as is reported by IDC and is shown in Figure 2.

Worldwide Smartphone Sales to End Users by Vendor in 2014 (Thousands of Units)

Company	2014 Units	2014 Market Share (%)	2013 Units	2013 Market Share (%)
Samsung	307,597	24.7	299,795	30.9
Apple	191,426	15.4	150,786	15.5
Lenovo*	81,416	6.5	57,424	5.9
Huawei	68,081	5.5	46,609	4.8
LG Electronics	57,661	4.6	46,432	4.8
Others	538,710	43.3	368,675	38.0
Total	**1,244,890**	**100.0**	**969,721**	**100.0**

Source: Gartner (March 2015)

*The results for Lenovo include sales of mobile phones by Lenovo and Motorola.

Figure 1. Worldwide Smartphones sales until 2015.

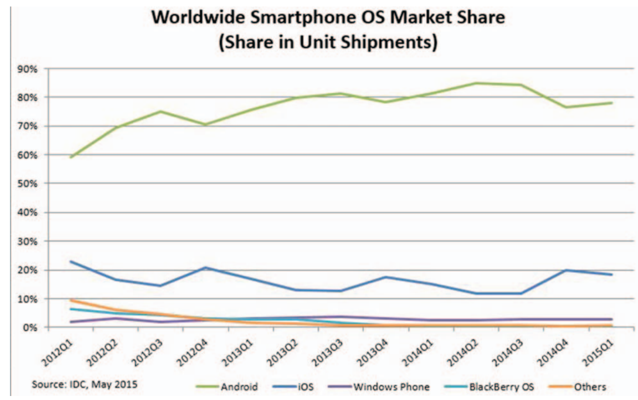

Figure 2. Worldwide Smartphones OS Market until 2015.

2.2. Local Binary Pattern (LBP)

The original Local Binary Pattern (LBP) method uses windows of 3x3 pixels of an image representing a neighborhood around the central pixel, as shown in Figure. 3(a), where the central pixel is used as a threshold to compare values of its 8 neighbors. The pixels whose values are less than the threshold must be labeled with 0 and those that are greater or equal than the threshold are labeled with 1, as shown in Figure. 3(b). Then, the labels of pixels are multiplied by 2^P, where$0 \leq P \leq 7$ represents the position of each pixel in the neighborhood, as shown in Figure. 3(c). Finally, the resulting values are added to obtain the label of the central pixel of that neighborhood, as shown in Figure. 3(d). This method produces 256 possible values for the label of the central pixel. This process is repeated for the entire image and produces a LBP matrix (LBP image). It's important to mention that the original method use the histogram of values obtained above, but in this proposal is used directly the values of LBP, and shown that the results are good enought.

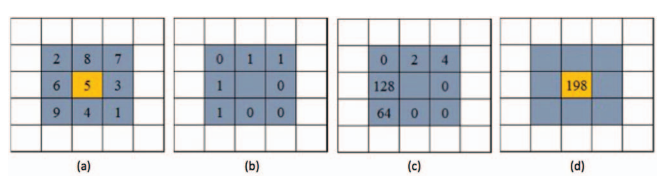

Figure 3. LBP Algorithm: (a) Values of neighbors around the central pixel. (b) Comparison of each neighbor with the central pixel. (c) Substitution of each value of the comparison by the corresponding 2^P value. (d) Adding and replacing of the central pixel with the resultant value.

2.3. General Scheme System

In order to apply the LBP algorithm, it will be used in a face recognition system; this system will be implemented on the Android operating system. In Figure. 4, the general scheme of face recognition system is shown and blocks will be explain below.

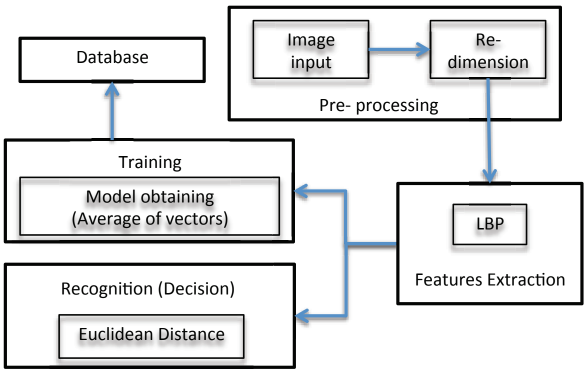

Figure 4. Block diagram of proposed face recognition system.

In this work 2 different tests were performed:

- The first test is performed in a real uncontrolled environment taking photographs with the Smartphone camera an example of these images are shown in Figure 5 and is performed a database with 10 different people, for training process were used only 3 images per person, then a test is made with 3 other images of each person.

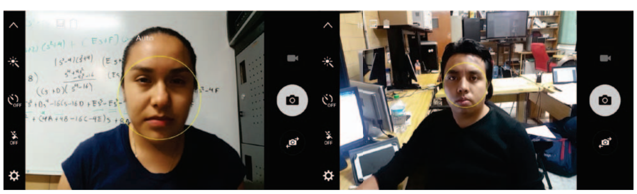

Figure 5. Example of image taken from smartphone camera.

- The second test is performed with the AR Face database and for practical purposes the database is stored in Smartphone memory simulating that photos have already been taken with Smartphone camera, in this test are obtained results using a different amount of training images an example of these images are shown in Figure 6 and test with all images on the database.

Figure 6. Example of images in AR Face database.

2.3.1. Input (face). Using the Smartphone camera face pictures are taken as shown in Figure. 7 and Figure. 8. The system will detect the face of the person and will eliminate all leftover image parts. Finally the cropped face image will be the one used in the following steps.

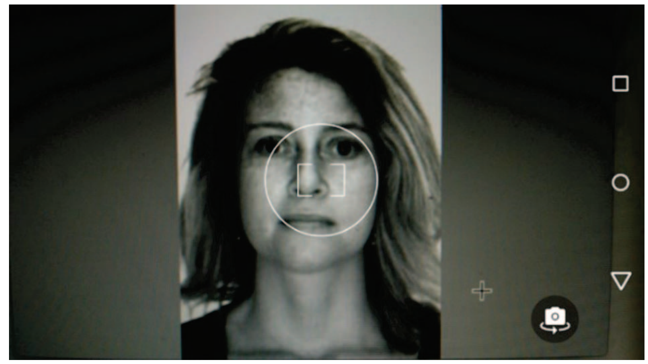

Figure 7. Opening the Smartphone camera to take the sample.

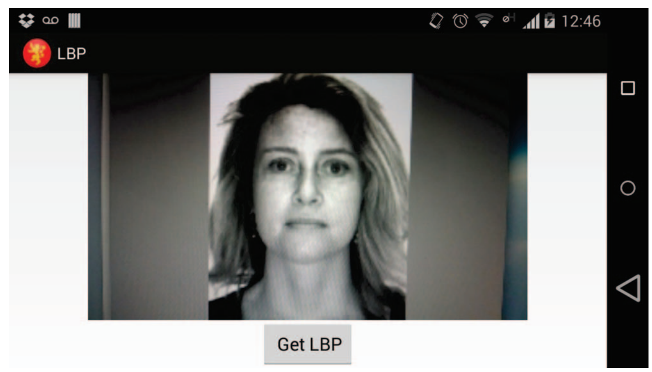

Figure 8. Taking the test sample.

2.3.2. Re-dimension. The images are redimensioned in order to maintain a standard size in every shot no matter much the distance, this is because not always the photo was taken at exactly the same distance from the person. Also all pictures already redimensioned are passed to grayscale to subsequently apply the LBP algorithm.

2.3.3. Feature Extraction. For feature extraction the LBP algorithm will be implemented like explained above, to obtain the feature vector of the sample. Figure. 8 shows that the movil application have a button with ”Get LBP” which apply the LBP algorithm to capture image, the result of this block in the application on the Smartphone is shown in Figure. 9. After apply the LBP to the image, this is converted to row vector concatenating each row one after another. Finally the average of different number of images of the same person is used like model to classification stage.

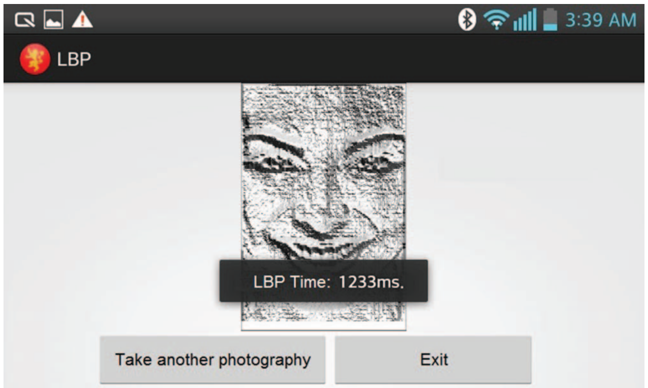

Figure 9. Sample after application of the LBP, the execution time of the algorithm is shown.

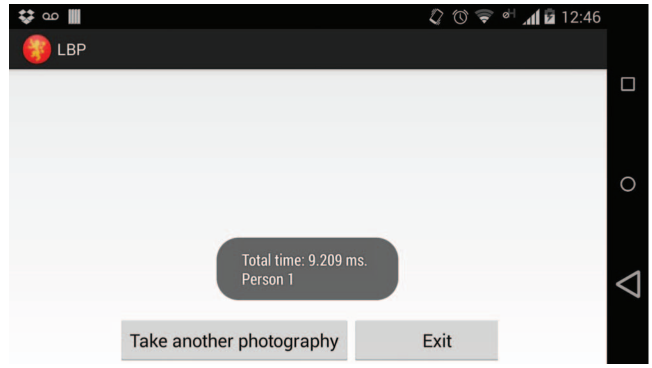

Figure 10. The system identifies the person that has been entered. The ID and the execution time of the algorithm are shown.

2.3.4. Classification. This block of the system is divided in two parts:

Training: It will take place when individuals are entered to the database. The feature vectors of each person will be marked with the ID of the person to which they belong, and then, will be stored in the database. For this, tests with different number of training images were made, were used from 1 to 9 training images taking into account that while more images are used to train the system, the recognition rate will be higher as we will see in the part of results. To obtain the model of each person, the average between these is computed by:

$$I_T(x,y) = (\sum_{i=0}^{n} I_i(x,y))/n \qquad i = 0,1,\dots,n;$$
$$x = 1,2,\dots,N; \qquad y = 1,2,\dots,M$$

where n is the number of image to obtain the average, N is the height of redimensioned image and M is the width of redimensioned image resized.

Identification: The identification part is done when you want to identify a person, this task is done by taking the photograph from the Smartphone camera, then the image is cropped, is redimensioned and applies the LBP algorithm, later the Euclidian distance (equation 2) is used to compare with the model of each person and so make a decision and allocation of identity.

$$dst = \sqrt{(x_s - y_t)(x_s - y_t)^T} \qquad (1)$$

where x_s is the estimated feature vector of the image under analysis and y_t is the centre of the t-th class.

It should be noted that the whole process is carried out internally in the Smartphone, the sample images shown above are to illustrate how the process is done, but in real application only the image taken with the Smartphone camera and an outcome with the ID assigned and the time it take to perform the process as shown in Figure. 10.

3. Experimental Results

3.1. Test 1: make a 10 people database

For the training phase a database of 10 people was taken, using the Smartphone camera in the input module. The system was trained with three photographs of each person, which were classified using the average of this three image like model. It was stored into the database as the feature vector of the person concerned. For the recognition phase three photographs of each person were taken. Table 1 shows the successes, errors, effectiveness rate and the average execution time obtained.

TABLE 1. RESULTS OBTAINED WITH THE LBP ALGORITHM IN THE TEST 1, WITH A DATABASE OF 10 PEOPLE AND A TRAINING OF 3 IMAGES PER PERSON.

Algorithm	Successes	Failures	Effectiveness	Execution time
LBP	28	2	93.33%	9.2 ms.

3.2. Test 2

For the training phase a standard AR Face database of 120 people where 65 are males and 55 females and 14 images per person were used, it's important to say that in this work only taken the images without oclussion from database, and this were storing on memory of Smartphone, to avoid the take of each picture through the Smartphone camera. The system was trained with diferent number of photographs of each person, which were classified using the average sample. It was stored into the database as the feature vector of the person concerned.

For the recognition phase, a total of 5040 pictures were analyzed. For increasing the number of illumination conditions, the AR database was expanded only for testing, including 2 additional images per each one contained in the original AR database. This allows us to increase three times the number of face images in the AR database, obtaining a larger number of face images with different illumination conditions, simulating the posible function of the light sensor of the camera increasing or decreasing the illumination on images. To this end, the 14 face images, of each person were used to generate 28 additional images of each person with different illumination conditions by means of the intensity transformation given by:

$$I(x,y) = |255(I_{orig}(x,y)/255)^{\gamma(x)}| \qquad (2)$$

where $\gamma(x)$ is defined according to desired effect on the resulting image. However, to generate face images with spatially varying illumination $\gamma(x)$ was selected as follows:

$$\gamma(x) = -\frac{2(C-1)x}{M} + C, \qquad 0 \leq x \leq M/2 \qquad (3)$$

to produce face images where the illumination increases from left to right, and

$$\gamma(x) = \frac{2(C-1)x}{M} - (C-2), \qquad M/2 \leq x \leq M \qquad (4)$$

to produce images where the illumination decreases from left to right.

Table 2 shows the results obtained with up to 9 training images. It can be seen that the effectiveness of the LBP algorithm implemented on Smartphone is acceptable considering that the database contains images with variations in lighting and some facial expressions. Also whereas a basic classifier is used as the Euclidean distance that has low computational cost and the model of each person is obtained from a non-supervised method, as is the average between images, the results are considered satisfactory. The results obtained in the work of Yang and Cheng [23] where the AR database and chi-square distance used are similar to those obtained in the proposed system, Yang and Cheng present a study on hLBPI, this is comparable method with used in this work, which obtains recognition rates between 64 and 92 % which allows us to say that the results obtained in the Smartphone application of the proposed system and conducting tests in a real uncontrolled environment are good enough like in [23] using a simulated and controlled environment for testing; In addition, you can also compare the results with those of hLBPH, eLBPH, Eigenface, Laplacianface and Fisherface which according to [23] obtained in most cases lower results than those presented in this article.

Also is remarkable that the time of execution for all images is considerably short, considering that the application is on a Smartphone with a low computational power.

These results can be compared with other methods such as those developed in [24], where a database of 10 people in total was used, and 20 images of each person were used for training and 40 for testing, showing that results using opti-SRC method, proposed in [24] on average is 90%, where the time of processing is 239 ms, which is considerably higher than reported in this work, which is 9.2 ms.

TABLE 2. RESULTS OBTAINED WITH THE LBP ALGORITHM WITH DIFFERENT NUMBER OF TRAINING IMAGE.

1 image	**2 image**	**3 image**	**4 image**	**5 image**
38.7	45.2	68.1	72.3	77.0
6 image	**7 image**	**8 image**	**9 image**	
78.0	82.9	89.6	90.8	

4. Conclusions

The application on a Smartphone of a method such as LBP for facial feature extraction shows it have a good performance, in addition to the computational cost is low, when tests were done with a standard database with 120 people is obtained a recognition rate of up to 90% using models with 9 training images per person. It notes that the implementation of a method of facial recognition on a Smartphone has many applications, besides that, having a database within the Smartphone does not limit its use only with an Internet connection allowing the user to make an identification in real time. One possible application may be for police department in the pursuit of suspects. Another advantage of this application is that the runtime for identification is very short which makes the application even more attractive. The use of Android operating system is because it is the most currently used in the market. When test 1 was developed shows that when a small real database (only 10 persons) is used, the identification rate is until 93%, obviously when the database increases the number of training individuals the identification rate it diminished and the confusion in the application increases because of the possible similarity between individuals. Another advantage of this application is that the procedure use the Smartphone microprocessor and you not need use internet to send the image to a server to apply the algorithms, and you can do real time test and does not matter the sensibility of the Smartphone light sensor or if you are in a place with a lot of light or in a place something dark, this is thanks to LBP which has the property of being invariant to illumination.

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