People Recognition for Loja ECU911 applying artificial vision techniques

Diego Cale, Verónica Chimbo, Henry Paz-Arias and J. J. Barriga-Andrade

***Abstract*—This article presents a technological proposal based on artificial vision which aims to search people in an intelligent way by using IP video cameras. Currently, manual searching process is time and resource demanding in contrast to automated searching one, which means that it could be replaced. In order to obtain optimal results, three different techniques of artificial vision were analyzed (Eigenfaces, Fisherfaces, Local Binary Patterns Histograms). The selection process considered factors like lighting changes, image quality and changes in the angle of focus of the camera. Besides, a literature review was conducted to evaluate several points of view regarding artificial vision techniques.**

***Index Terms*—OPENCV, QT CREATOR, EIGENFACES, FISHERFACES, LBPH, ICONIX, FRAME, artificial vision, people recognition.**

I. Introduction

Because of its nature to optimize process, resources and time, intelligent systems could be used for monitor and control in several areas such as security, health, criminology among others.

The system presents a solution for people searching by using IP video cameras; its main objective is to contribute with such type of solution that is in boom [1]. The artificial vision system is based on algorithms fusion for detecting and identifying faces in an intelligent way. In order to identify an specific person, a list of pictures is stored; once the person has been found several alerts will be triggered by using a web page that relies on Google Maps for geolocation. Several tests on ATMs, supermarkets, buses have been conducted in order to the system feasibility. In addition, other type of test was performed in the technological area of Loja ECU911 using cameras such as the Loja's Fair in September 2015 which provided feasible and favorable results according to expectations.

Currently, ECU911 is in charge of handling the video surveillance system to respond to emergency situations across the Ecuadorian territory. Its aim is to contribute permanently to the achievement and maintenance of public comprehensive security, and presents the following services: Video surveillance, emergency hot line, community engagement and institutional coordination, which are described in the following Table I.

Nowadays, people searching processes are done manually by ECU911 and other institutions in charge of monitoring, controlling and securing citizens, which is time and resource demanding since it is required to have people performing such tasks 24 hours a day, 365 days a year. Therefore, an artificial vision system is proposed, which would monitor in an autonomous way all days of the year, by providing real time alerts, supporting the video surveillance service of ECU911.

TABLE I
ECU911 Services.

Service	Description
Video Surveillance	It uses the most advanced technology to monitor activities that might produce risk.
Emergency hot line	Emergency service attending calls dialed to 911, 24 hours a day, 7 days of the week, 365 days of the year.
Community engagement	Talks and training for children, youth and communities focused on the proper use of ECU911 service and the importance of citizen cooperation in comprehensive security.
Institutional coordination	All emergency institutions working together permit to attend the same situation in a complete perspective, allowing and effective and comprehensive response. It reduces times and manages to mobilize specialized units for specific emergencies.

At present, ECU911 of Loja owns technological infrastructure that allow to control certain locations of the city, their cameras provide a great quality of image and range. Indeed, the the only automated process handled by ECU911 is the storage of such information, but in order to find something it is necessary to completely review the whole video, which is time consuming; the technical proposal aims to replace such process with one that is able to process data in real time.

This paper is structured in the following way: Section II compares several vision artificial techniques, section III shows features of the tools, section IV contemplates system implementation, section V presents a case study which describes the operation of the system and the results obtained, section VI is about conclusions arrived and section VII covers considerations in terms of informatic security.

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II. General Study of Artificial Vision Techniques

A. Importance of Artificial Vision

Artificial Intelligence computer system are currently used in several fields of investigation to make processes more autonomous and automatic, given the ability to make decisions by themselves according to [2]. Artificial vision is a field of Artificial Intelligence that aims to perform an abstraction of the real world to mathematically model processes of visual perception of living beings, generating computer programs through these simulation capabilities [3].

B. Artificial Vision Application

Several enterprises around the world are implementing this technology with good results.

- RCG Holdings Limited in Hong Kong is using it for security, monitoring and access control, they implemented an artificial vision system with a face recognition engine that adapts to several states of lighting and poses of a person according to [4].
- Ample Trails from India developed a real-time people recognition system to control access and record attendance with a success rate of 99 % as mentioned in [5].
- Toshiba with other computer companies, developed an artificial vision system adapted to computers for security and faster accessibility by replacing hibernation or standby states with the use of the face to enable access as compiled in [6].
- Also, Facebook DeepFace is able to recognize faces with a precision rate of 97.25 % which is very similar to the ability of a person as mentioned in [7].

C. Algorithms and methods

There are several algorithms for face detection within artificial vision which have considered lightning changes, image quality, several changes in the face such as beard, hair color or glasses which may affect its identification. Then, a review of the most used techniques and methods within artificial vision will be performed, which highlights the ones used for features extraction as it is one the most important phases in the process of people face detection and recognition. Such methods are divided in three groups which are: based on appearance, characteristic points of the face and hybrid ones.

Holistic methods based on appearance These methods use all face region as an input for the face recognition system. The image of the face is transformed to a space where statistical techniques are applied. However, using all face as the only feature, often presents limitations given by expression changes, pose or illumination. It implements the technique of Principal Component Analysis (PCA) which let to obtain vectors of lower dimensions without loss of important information as mentioned in [8].

Methods based on featured points of the face. These methods are based on extracting common features that make the face such as nose, eyes or mouth, to classify its geometric features and/or the appearance separately in the system.

Distance analysis to characteristic points. One the first recognition system its based on the technique of geometric points of the face. From the detection of different characteristic points, vectors that contain data of distances between them are created. The more points detected, the greater number of distances that could be calculated thus obtaining better results in the recognition as showed in Figure 1. [8].

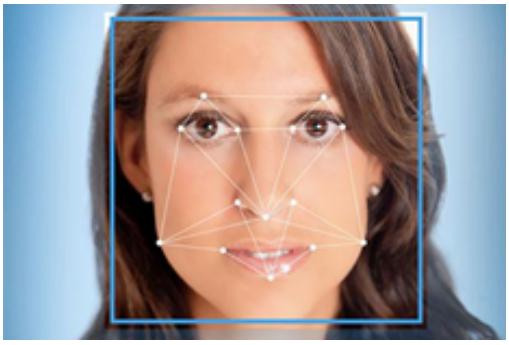

Figure. 1. Face Detection

Local Binary Patterns. Although LBP algorithm is simple it does provide robust information against lighting changes. It is based on taking neighbors about a central pixel which sets a threshold value as stated in [9]. The neighborhood is changed to binary depending on the value whether it is higher or lower than the threshold, and every found value is concatenated to build a unique binary number which later will be converted to a decimal value that will represent the new value of the pixel. The image is divide in regions where LBP is applied to obtain its histogram. These histograms are then concatenated to obtain a representation of the face.

EigenFaces. It that performs Principal Components Analysis (PCA) of the covariance matrix formed by the source images and the input image, which compares distances between the vector of the original image with the rest.

FisherFaces. Algorithm that uses FLDA to reduce dimension.

LocalBInaryProcess. Uses histogram of oriented gradients (HOG) to improve performance of detection.

The following process was used to compare the three algorithms (EigenFaces, FisherFaces and LocalBinaryProcess):

- **Image processing:** Size of images is normalized, plus contrast is equalized.
- **Facial detection:** Viola-Jones algorithm was implemented getting a 20ms time detection.
- **Image handling:** Once it is known that there is a face, it would be cut to stay with the information that really interests (the face).
- **Extraction and feature comparison:**
  - Use of FisherFaces with a response time of 10 ms.
  - Use of EigenFaces with a response time of 10 ms.
  - Use of LocalBinaryProces with a response time of 10 ms.
- **Properties:**
  - **EigenFaces:**
    - Eigenfaces number: 200.

  - Threshold: 10000.
  - **Advantages:** Small computation time and very good results in optimum condition.
  - **Disadvantages:** Bad results on adverse conditions (lighting, pose and orientation) and/or few training images.
- **FisherFaces:**
  - Threshold: 1500.
  - **Advantages:** Soften the problem of changes in posture or light and deformations of the face. It performs better than Eigenfaces when the number of poses is lower.
- **LocalBInaryProcess:**
  - Binary Patterns.
  - Images of 320x243 pixels.
  - 3500 images used to train.

In conclusion, the chosen algorithm was Local Binary Process because it is better suited to lighting conditions, the operator is an extension of the original LBP coding; hence, sometimes it is called LBP extended. If the points of the circle do not match image coordinates, the point has to be interpolated. Indeed, OpenCV [10] which is an open source library for computer vision and machine learning, implements a bi-linear interpolation as shown in equation 1:

$$f(x,y) \approx [1-xx] \begin{bmatrix} f(0,0) & f(0,1) \\ f(1,0) & f(1,1) \end{bmatrix} [\frac{1-y}{y}] \qquad (1)$$

By definition, LBP operator is more robust against changes in monotone gray scale. Finally, spacial information is included in the facial identification model.

D. Facial recognition process

Five phases have been considered (as shown in Figure 2) for the development of the artificial vision module and are listed as follows:

Figure. 2. Artificial Vision stages

1) **Acquisition**. Images were obtained with an IP camera, it is important to consider camera location, verify that the quality of images is not lower than 640x480 pixels of resolution, images should not be distorted. Indeed, the better quality of the image, the fastest is the process and the results are more effective.
2) **Detection**. This is the most critical part since it would impact the rest of the phases if an adequate detection and location has been performed. Detection comprises two parts:
   - **Detection of the region of the face**. The detection of the regions of interest in an image is done by Haar-Like features as shown in Figure 3, adapted by Viola and Jones from the use of Haar wavelets. This system considers rectangular regions in a window of detection, it add the intensities of the pixels in each region and calculates the difference between these amounts. The difference is used to classify subsections of the image. [11]
   - **Eye position detection**. To correctly align the image during pre-processing, it is mandatory to determine the coordinates of the eyes in it. Besides, there are several methods to detect eyes, the most direct is to use classifiers of Haar as in face detection, but trained with images of eyes according to [12].

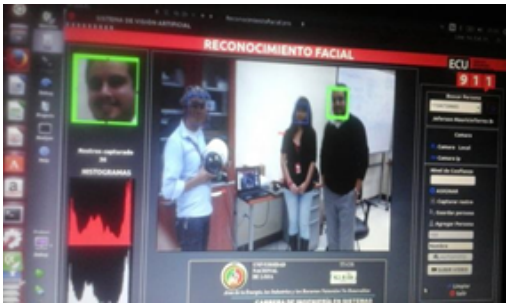

Figure. 3. Face recognition

3) **Pre-processing and normalization**. Pre-processing stage according to [13] is carried out from the information obtained during detection. This stage performs a series of geometric transformations over the image, leaving it ready for proper feature extraction. During pre-processing four phases are used to normalize and align the image as mentioned in [9].
   (a) **Image Acquisition**. The first step is obtain the initial image that will be processed.
   (b) **Rotation**. One of the utilities to calculate eyes coordinates, lies in determining the angle of rotation of face in an image and offset it. Having faces with no rotation would produce better results during the recognition process.
   (c) **Scaling**. To ensure that all images have the same size, the distance between the centers of the eyes is used to get a radio by which the image will be increased or reduced. Indeed, this is required since several recognition techniques demands input data with the same size (In this case the matrix of pixels).
   (d) **Cutout**. Once the image has been rotated and scaled, next is to cut it to obtain its region of interest. The coordinate of the right eye is used to establish the region of interest. There are several standardized images by which the region of interest can be extracted according to the system needs. Such formats are documented in the standard ISO/IEC 19794-5 according to [14] which defines an area similar to a passport photograph, based on such standard a region that exclusively comprises the area of the face is defined. [11]

   A summary of the process is shown in Figure 4
4) **Feature Extraction**. It is used to obtain information that is relevant in undertaking a comparison as shown

Figure. 4. Pre-processing and Normalization process

in Figure 5. Local Binary Pattern Histograms (LBPH) method (createLBPHFaceRecognizer()) was used in this stage.

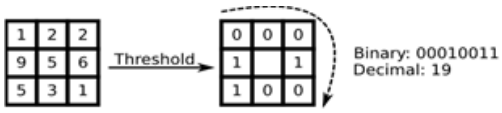

Figure. 5. Feature Extraction

5) **Comparing and Recognition**. There are several methods to obtain a score for making a decision. Such methods could be divided in distance and classifiers according to [15]:
   - **Distance**
     - Euclidean Distance:
       It is represented in equation 2, and is one of the most basic measures to calculate distances. This distance is defined as the direct distance between two points on a plane. The clearest example is the distance between two points on a plane of two dimensions with coordinates x and y. If there were two points P1 and P2 with coordinates

       $$x_1, y_1$$

       and

       $$x_2, y_2$$

       respectively, the euclidean distance between them would be:

       $$d_E(P1P2) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (2)$$

     - Chi-Square:
       Chi-Square distance takes such name because the formula used to calculate is almost similar to the goodness of fit test that is used to compare discrete probability distributions. For biometric recognition, it is used to measure the distance from histograms. Distance calculation for two histograms S and M is represented in the following equation 3:

       $$x^2(S, M) = \sum_i \frac{(S_i + M_i)^2}{S_i + M_i} \quad (3)$$

   - **Classifiers**
     - K-Nearest Neighbours:
       K-NN method is a non parametric object classification technique based on the samples that are closer to the space of features. The algorithm is based on finding k neighbors that are more near to the object, depending on the amount thereof; classify in the set having a greater number of nearby samples [16].
     - Support Vector Machines (SVM):
       SVMs are learning models for regression and classification. Its objective is to represent in a space a series of classes and try to find a hyperplane that divides them into zones in which when any input enters, it would be classified according to such zones [16].
       SVM classification is used to produce a model based on training data, which will be able to accurately predict the class of labels of test data. Figure 6 shows a visualization of the process of SVM classification,

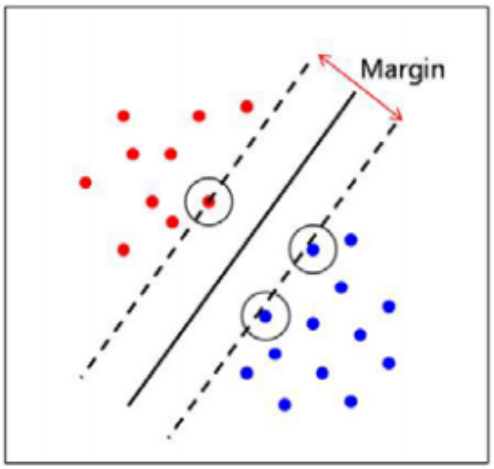

Figure. 6. SVM Classification support vector machines find the hyperplane that maximizes the margin between two different classes

       For this reason, the method chosen for this study is SVM because it allow to establish a margin between two data sets.
     - Gaussian Mixture Models:
       GMMs are density parametric probability functions represented as a sum of Gaussian components. Biometric classification is usually used in conjunction with EM (Expectation Maximization) to estimate its parameters. Notably OpenCV, still has no implementation of this technique.

III. Developed Software Tools

Nowadays, ECU911 does not have tools to support people search and identification process. Therefore, an intelligent system which uses cameras and gives new security citizen services is presented. The technology used is described below.

(a) **Desktop Application (DVFACE-DETECTOR)**. The purpose of this system is to handle people, it functionality is described below:
   - **People:** Allow to handle information of people to be searched.

- **Users:** In charge of register users and control access to the system.
- **Cameras:** Manage the cameras that are located in several places of Loja.
- **People Search:** Before searching a person, it is required to upload a list of pictures of the person.

(b) **Web Application (DVFACE-ALARM.)** Used to visualize camera location so that it would be easy to determine a person location. It has the following modules:

- **People:** Used to insert people information from a web environment.
- **Users:** Module used to register users and control access to desktop or web version.
- **Cameras:** Camera registration along with its geographic location.

IV. Implementation

The following describes the architecture of the system proposed.

1) The input data (Frames) arrives from ECU911 cameras.
2) Database is used to store the images obtained with the cameras and process data during detection.
3) The result is notified through the screen once the person has been found.

The following applications have been developed as part of the Artificial Vision System:

- **DVFACE-DETECTOR:** C++ was used together with QT-CREATOR framework because of the experience acquired and the fact that it is free with great amounts of documentation. GitHub was chosen as a repository since it allows to have the code available online to be accessed from everywhere, plus it is compatible with QT-CREATOR.

- **DVFACE-ALARM:** Javascript and EXTJS framework were used to build this web application on the client side. PHP was used on the server side to perform database queries. The tools mentioned before were chosen because of the experience. GitHub was also chosen as the code repository due to its benefits.

V. Case Study

The following describes the application of the system on a Case Study.

1) **Face Detection** Figure. 7 shows image processing in the people recognition module, the following shows all the images processed by OpenCV library.

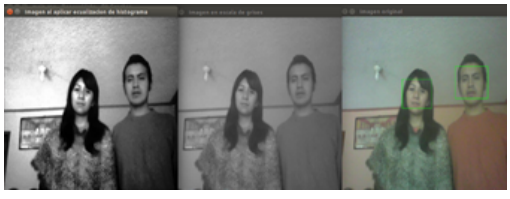

Figure. 7. Image Processing

2) **Face Processing** Figure 8 shows face detection which requires the activation of the camera used for face recognition.

Figure. 8. Face Processing

3) **Face Recognition** In order to search a person, it is required to have all of his data as well as the cameras that will provide the frames to analyze during image processing; then, two process are executed (training and face identification).

(a) **Training** A list of photos is required so that the model of the face of a searched person could be registered, it is recommended to have a set of photos of different lighting sources since it benefits expected results as shown in Figure. 9.

Figure. 9. Face Training

(b) **Face Identification** Once the model has been trained with a specific person to search and having the camera activated, will allow the system to identify such face and raise and alert with the name of the person that has been identified as shown in Figure. 10 Then, web application will display an alert stating that the person has been found. Figure 11 shows information of the found person as well as the initial picture used to search such person and the picture containing the most prominent features. Also, the user will have the ability to mark a person as found if all information is correct otherwise the process could

Figure. 10. Face Identification

be restarted if results were not as expected.

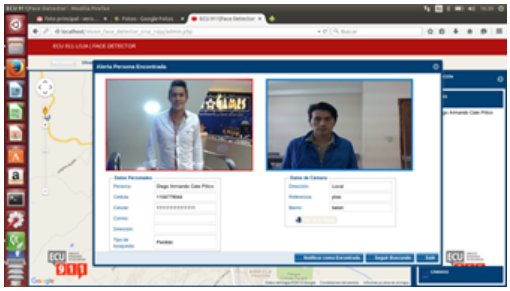

Figure. 11. Notification Process

VI. Conclusions

- FaceRecognizer class with HaarCascade Frontal Faces sorter for face detection and Local Binary Patterns Histograms (LBPH) for face identification, produced the intended results.
- Lighting changes should be monitored for the construction of artificial vision systems since it might affect the results.
- People recognition system is a technological proposal based on artificial vision for searching people in an intelligent way by using IP video cameras which replaces the current manual process that is time and resource demanding.

VII. Future Work

The following mechanisms are described in order to secure networks links and information that will be handled.

First of all, network links has to be secured in terms of using either dedicated channels or VPN so that ECU911 could securely connect to several sources of information (IP cameras) that are located across the city. Besides, it will help to secure providers as well since they will have to expose part of their critical infrastructure (particularly financial institutions). Indeed, a network security architecture has to be defined from scratch.

Second, secure protocols based on TLS must be in place throughout the application to encrypt information that will be traveling and stored in different places of the solution. Third, a hash verification signature needs to be added to prevent data tampering as it may be intercepted by malicious user aiming to corrupt or modify it. Indeed, such hash would help to verify that the searched people is the one selected by an employee of ECU911.

In addition, role based access control is required in the system to avoid unscrupulous users modifying or uploading undesired data. Moreover, audit trails has to be present across the system and database, although encryption is not a must to have it is required to apply it for sensitive information such as users, passwords and personal data. Also, a code review is required to guarantee that the application is free of vulnerabilities due to code obsolescence.

Finally, an Ethical Hacking has to be performed to find other vulnerabilities that might compromise the system, and to verify that the inclusion of new network links would not pose a threat to ECU911 and providers. Last but not least, high-availability needs to be reviewed depending on how critical is the service provided by ECU911.

In summary, several points of the solution has to be secured and examined to protect information integrity, availability and confidentiality.

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