



Forensic Crime Investigation System Using EBGM and PCA

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Abstract: Since criminals are getting more and more sophisticated in their act, it is quite unfortunate that Criminal and Civil Law together with the Law Enforcement Agencies are proven to be inefficient towards crime prevention and conviction of criminals in the law court. This research seeks to present a Forensic Crime Investigation System in a bid to curtain criminal activities and possibly bring crime perpetrator to justice. The system tracks and identifies the faces of individuals during surveillance, and should a crime occurs, it compares the images of the surveillance database against the standard database to uncover the identities of the faces found at the scene. This research use Gabor Based hybrid of Elastic Bunch Graph Matching (EBGM) and Principal Component Analysis (PCA) model for processing image forensics (facial recognition and identification). An Object Oriented Methodology was utilised to develop a software system using Java programming language. This system will be capable of generating real time recognition of faces during surveillance which will maintain and reveal the identities of people involved in or present at the crime scene. The system was test run using students' data, and within the campus of Federal University of Agriculture Makurdi, surveillance was conducted at different locations, forensic analyses were carried out on the images captured, and the identities of these images were uncovered.

Keywords: Image forensic, criminal investigation, EBGM, PCA

I. Introduction

Criminal investigation is an applied science that involves the study of facts, used to identify, locate and prove the guilt of a criminal [1]. It is an ancient science that may have roots as far back as circa 1700 BCE in the writings of the Code of Hammurabi. In the code it is suggested that both the accuser and accused had the right to present evidence they collected [2].

In the modern times, criminal investigations are often done by government Police forces although Private investigators are also commonly hired to complete or assist in criminal investigations. Criminal investigation can include searching, interviews, interrogations, collection and preservation. Modern day criminal investigations commonly employ many modern scientific techniques known collectively as forensic science.

This paper focuses on the use of image forensic particularly, facial recognition and identification to enhance criminal investigations. The image processing algorithms used is a hybrid of Elastic Bunch Graph Matching (EBGM) and Principal Component Analysis (PCA) models. Our concerned in this paper is to develop a software system using the hybridized algorithm that is capable of performing face recognition and identification on real time surveillance to aid image forensic investigation.

II. Related Works

The origins of forensic science are largely European. Forensic science draws from diverse disciplines, such as geology, physics, chemistry, biology, and mathematics, to study physical evidence related to crime [7].

Digital image forensic is the collection of scientific methods to systematically infer particulars of an unknown image generation process from a given (set of) digital image(s) [14].

Reference [8] uses a Probabilistic video analysis to solve the problem of visual tracking by using a time series space model parameterized by a tracking motion vector. His work and that of an earlier work on condensation algorithm by [6] revolutionized the field of computer vision and pave way for human face recognition.

Reference [18], systematically investigated the incorporation of temporal information in a video sequence for face recognition. In their research, they proposed the tracking-and-recognition approach, which attempts to resolve uncertainties in tracking and recognition simultaneously in a unified probabilistic framework. To fuse temporal information, the time series state space model is adopted to characterize the evolving kinematics and identity in the probe video. Three basic components of the model are:

- a motion equation governing the kinematic behavior of the tracking motion vector,
- an identity equation governing the temporal evolution of the identity variable and
- observation equation establishing a link between the motion vector and the identity variable.

Reference [10] introduced a simultaneous object tracking and verification based on posterior probability density estimation using sequential Monte Carlo method.

Reference [15] in their work uses color based algorithm to transform RGB (red, green and blue) to YCbCr (luminance, chrominance blue and red). This transformation method first detects the face region using skin-color from image.

Reference [16] in their research on *face detection with facial features and gender classification based on support vector machine*, emphasized that colour is a power cue of human face, and the distribution of skin clusters is in a small region of the chromatic color space. So, processing color is faster than processing other facial features.

In their proposed algorithm, skin color detection is firstly performed on the input color image to reduce the computational complexity. In the color detection process, each pixel is classified as either skin or non-skin based on its color components. The gamma corrected RGB value is determined using:

$$\text{GammaRGB} = (c1 * \text{inputRGBimage})^{c2} + c3$$

where $c1 = 1.0$, $c2 = 1.0$ and $c3 = 0.0$

The Y, Cb and Cr components are determined through the following formula using the constant C with the value 128

$$\begin{aligned} Y &= (0.299 * (\text{gammaRGB}[0,i,j] - C)) + C + (0.114 * (\text{gammaRGB}[2,i,j] - C)) \\ Cb &= (0.564 * (\text{gammaRGB}[2,i,j] - Y)) \\ Cr &= (0.713 * (\text{gammaRGB}[0,i,j] - Y)) \end{aligned}$$

Here, gammaRGB is the array with 0 representing the Red layer and the 2 represents the Blue layer. The range of Cb is between -50 and 2 while the range of Cr is between 10 and 100 determine the skin region.

The given YCbCr image is converted to one-layer gray scale image. This system takes the Green layer. The face boundary is estimated by determining the center point of the gray image face photo. The skin image is estimated based on the threshold gray level between 20 and 80. The outer boundary of the face is also determined.

The facial feature image is given as the input to the Support Vector Machine (SVM) that classifies the gender as whether a male or female by applying the estimated threshold value. The SVM values in one-Dimensional array are determined by:

$$\text{SVM}[\text{index}] = \frac{\begin{array}{l} \text{Sum of intensity values of 3 layers} \\ \text{(RGB) of the pixel in the feature image} \end{array}}{\text{No. of pixels so far processed} \times 255 \times 3}$$

Where, 255 is the maximum intensity value of the gray level intensity, and 3 is the total number of layers.

If the resultant SVM value is greater than the estimated threshold value 0.07, then the face in the given input image is a MALE, otherwise, the face in the given input image is a FEMALE.

Face recognition is such an integral part of our lives and performed with such ease that we rarely stop to consider the complexity of what is being done. It is the primary means by which people identify each other and so it is natural to attempt to 'teach' computers to do the same [17]. The main reasons for poor performance of such systems is that faces have a large variability and repeated presentations of the same person's face can vary because of their pose relative to the camera, the lighting conditions, and expressions. The face can also be obscured by hair, glasses, jewelry, etc., and its appearance modified by make-up. Because many face recognitions systems employ face-models, for example locating facial features, or using a 3D mesh with texture, an interesting output of face recognition technology is being able to model and reconstruct realistic faces.

The Principal Component Analysis (PCA) is one of the most successful techniques that have been used in image recognition and compression. PCA is a statistical method under the broad title of *factor analysis* [12]. The purpose of PCA is to reduce the large dimensionality of the data space (observed variables) to the smaller intrinsic dimensionality of feature space (independent variables), which are needed to describe the data economically. This is the case when there is a strong correlation between observed variables. PCA are suitable for prediction, redundancy removal, feature extraction, data compression, etc. Because PCA is a classical technique which work in the linear domain, applications having linear models are suitable, such as signal processing, image processing, system and control theory, communications, etc.

PCA as used in face recognition is a powerful algorithm based feature extraction technique, which applies the Karhunen-Loève transform to a set of training images and derives a number of projection axes that act as the basis vector for the PCA subspace. As a first step, the average image in I is computed and subtracted from the training images, creating a set of data samples $i_1, i_2, \dots, i_n \in I - \bar{I}$.

These data samples are then arrayed in a matrix X, with one column per sample image

$$\mathbf{X} = \begin{bmatrix} \vdots & & \vdots \\ i_1 & \cdots & i_n \\ \vdots & & \vdots \end{bmatrix}$$

$\mathbf{X}\mathbf{X}^T$ is then the sample covariance matrix for the training images [5].

A primary benefit of PCA arises from quantifying the importance of each dimension for describing the variability of a data set [19]. Therefore it is important to keep in mind that PCA best serves to represent data in simpler, reduced form.

Elastic Face Bunch Graph (EBGM) algorithm is a feature-based approach to the face identification problem [4]. In the context of EBGM, the facial features that are used are called fiducial points. Images are represented internally by the algorithm using spectral information of the regions around these features, which is obtained after convolving those portions of the image with a set of Gabor wavelets of varying size, orientation and phase. The results of the convolution for a specific position (called the Gabor Jet) are then collected for all fiducial points on a given image and aggregated (together with the feature coordinates) in that image's Face Graph.

EBGM make use of Gabor features, being the output of band pass filters, and these are closely related to derivatives which are less sensitive to lighting change. Also, this approach uses features only at a key node of the image rather than the whole image, which can reduce the noise taken from the background of the face images. Together with other important advantages, it is relatively insensitive to variations in face position, facial expression [9]. The matching procedure uses the FBG as a face template for finding the precise fiducial point, which solve the problem for automatically localization.

The representation of local features is based on the Gabor wavelet transform. Gabor wavelets are biologically motivated convolution kernels in the shape of plane waves restricted by a Gaussian envelope function [3]. The set of convolution coefficients for kernels of different orientations and frequencies at one image pixel is called a jet.

A jet describes a small patch of grey values in an image $I(\vec{x})$ around a given pixel $\vec{x} = (x; y)$. It is based on a wavelet transform, defined as a convolution

$$\mathcal{J}_j(\vec{x}) = \int I(\vec{x}') \psi_j(\vec{x} - \vec{x}') d^2 \vec{x}'$$

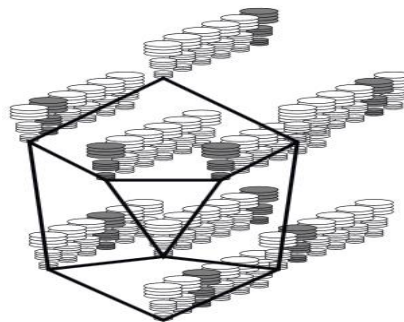
with a family of Gabor kernels

$$\psi_j(\vec{x}) = \frac{k_j^2}{\sigma^2} \exp\left(-\frac{k_j^2 x^2}{2\sigma^2}\right) \left[\exp(ik_j \vec{x}) - \exp\left(-\frac{\sigma^2}{2}\right) \right]$$

Gabor wavelets are chosen for their robustness as a data format and for their biological relevance. They provide robustness against varying brightness in the image. Robustness against varying contrast can be obtained by normalizing the jets. The limited localization in space and frequency yields a certain amount of robustness against translation, distortion, rotation, and scaling. Only the phase changes drastically with translation. This phase variation can be either ignored, or it can be used for estimating displacement. A disadvantage of the large kernels is their sensitivity to background variations. It has been shown, however, that if the object contour is known the influence of the background can be suppressed [13].

To find fiducial points in new faces, one needs a general representation rather than models of individual faces. This representation should cover a wide range of possible variations in the appearance of faces, such as differently shaped eyes, mouths, or noses, different types of beards, variations due to sex, age, race, etc. It is obvious that it would be too expensive to cover each feature combination by a separate graph. Instead a combine representative set of individual model graphs into a stack-like structure, called a face bunch graph (FBG); see Figure 1. Each model has the same grid structure and the nodes refer to identical fiducial points.

Figure1: Face Bunch Graph [11]



A set of jets referring to one fiducial point is called a bunch. An eye bunch, for instance, may include jets from closed, open, female, and male eyes, etc., to cover these local variations. During the location of fiducial points in a face not seen before, the procedure selects the best fitting jet, called the local expert, from the bunch dedicated to each fiducial point. Thus, the full combination of jets in the bunch graph is available, covering a much larger range of facial variation than represented in the constituting model graphs themselves.

III. Methods

This research uses the Object Oriented methodology in its design. We made use of Sky Biometric API and Luxand FaceSDK to implement Gabor Based Face Recognition Using EBGM and PCA model.

The over view of Gabor Based Face Recognition Using EBGM and PCA model as proposed by [12] follows:

- i. Recognizes novel faces by first localizing a set of landmark features.
- ii. Extract some features such as gender, age, etc.
- iii. Approximation of landmark features.
- iv. And then measuring similarity between these features

For the 1st and 2nd approach we use feature based algorithm known as **EBGM**. For the 3rd approach we use the statistical based algorithm called as **PCA**. The difficulty in the analytic approach of EBGM is the requirement of accurate landmark localization which can be achieved by the use of holistic approach method such as PCA.

The approach proceeds as:

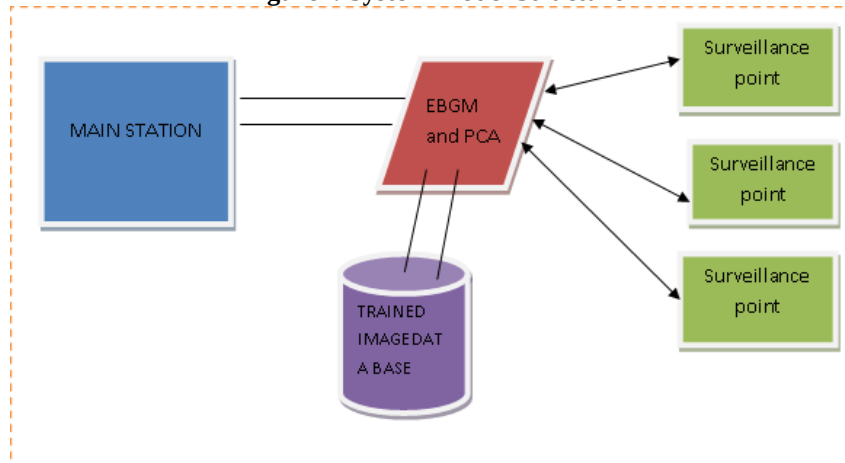
LOCALIZATION: Recognize novel faces by first localizing a set of landmark features.

EXTRACTION: Extract some of some feature – like gender, age, mood, etc.

APPROXIMATION: Approximation of landmark features using PCA.

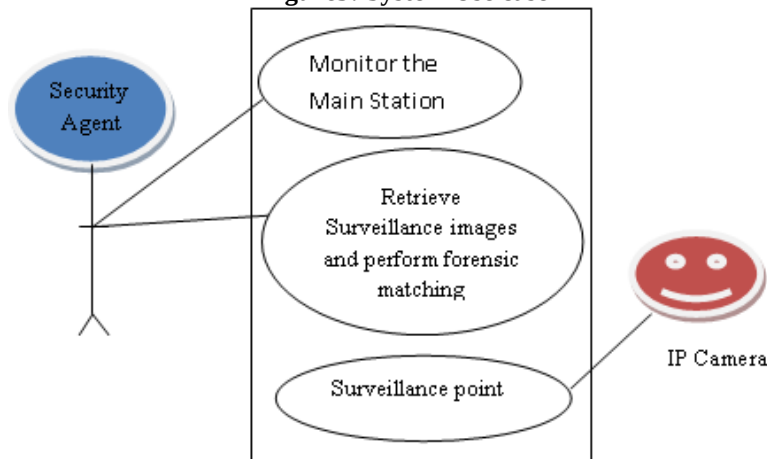
A. System Model Structure

Figure2: System Model Structure



From the model above it is clearly shown that; multiple surveillance points exist, inputs from each of the surveillance points goes to the forensic algorithm which in turn performs a facial identification and returns the identities of those faces captured

Figure3: System Use case



From figure 3, the system's use case structure is having two actors;

- Security Agent: these are human actors that monitor the main station where all the surveillance points are feeding in. They can also retrieve surveillance images from archives and perform forensic matching.
- IP Camera: these are inhuman actors that serve the purpose of our input sources.

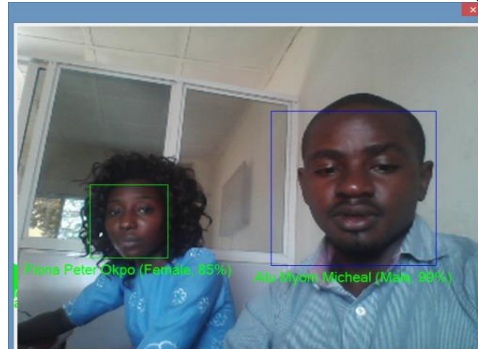
For the purpose of this research work, we will be using Java Programming Language for the system model implementation

IV. Results

The process of crime investigation (using image forensic) by the investigation agencies has been made easy by this application. The system is not just keeping watch; it is performing forensic matching at the same time. Images captured during surveillance are compared against the central database to uncover their identities

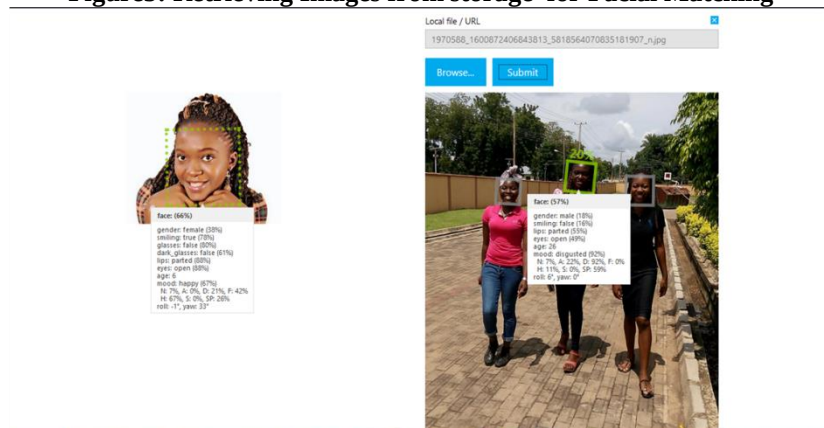
thereby making it easier for the security agency to monitor at the station and this information is also saved for archiving. Aside the real time forensic matches, images from the archives are also used for forensic processing as needed. The results from the system test run are presented and discussed.

Figure 4: Real Time Surveillance Face Identification (main station)



During real time surveillance, shown in figure 4 above, as the IP cameras are taking a close watch of the area they are sending input signals inform of images to the main station. At the main station forensic matching is being carried out. The system compares the images captured during surveillance against images already saved in the database and returns their identities. As the security agent monitors the main station they don't just see faces, they also get the identities of these faces.

Figure5: Retrieving Images from storage for Facial Matching



From figure5 above, an image from the surveillance camera was retrieved (i.e. the image that contain three ladies) and the system carried out a forensic matching against the student database and found a match with 20 percentage of resemblance.

V. Conclusion

There are surveillance cameras everywhere and every criminal or law breaker is quite aware of this. Most times after committing a crime they also destroy the surveillance storage. With IP cameras, the storage doesn't even have to be anywhere close to the camera so you can commit a crime but you will have no control of the surveillance storage. Besides just monitoring the surveillance main station one can also uncover the identities of faces captured on real time.

In most developing countries which Nigeria is part of, the general public have lost confidence in their leaders regarding crime investigations. This has even affected the altitude of the people towards police.

With real time surveillance and facial matching, the security agencies can easily uncover the identities of people as this will enhance investigation process.

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