Techniques and Methods used in Face Recognition

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Abstract— Face recognition is the process of identifying the faces of humans by their unique characteristics. It is a least intrusive technology, as it works with the most authenticating factor, human face. This paper consists of methods and techniques that emphasizes on recognizing a person by comparing the characteristics of his face known or to the already stored images in the database. The techniques and methods discussed in this paper are Principal component Analysis (PCA), Elastic bunch Graph Matching (EGM) algorithm, Linear Discriminant Analysis (LDA), Independent Component Analysis (ICA), Eigen spaces, Knowledge-based, Feature invariant, Template matching, Appearance-based approaches and Microsoft cognitive services. Microsoft Cognitive Services expands on Microsoft's evolving portfolio of machine learning APIs and enables developers to easily add intelligent features – such as emotion and video detection; facial, speech and vision recognition; and speech and language understanding – into their applications.

Key words: Face recognition, PCA, Microsoft Cognitive Services, FERET database, Machine Learning, and OpenCV Platform

I. INTRODUCTION

Face detection can be defined as detection of human faces in the image, and then returning the location of each human face in the image.[1] It has various applications in computer vision communication and regular access control system, some of which are video conferencing, human-computer interaction, content based image retrieval, automatic authorization etc. [1] However, this technique faces various problems due to variations of image look, such as pose variation (front, non-front), occlusion, image orientation, illuminating situation and facial appearance [2]. Face detection lies in between of all facial analysis, e.g., face localization, facial feature detection, face recognition, face verification and facial expression recognition. It is a fundamental technique for other applications such as content-based image retrieval, video conferencing, and intelligent human computer interaction. [3]

A. Image Processing

Image processing techniques in face recognition can be used to enhance raw images. It has various stages and those are:

- Image scanning
- Storing
- Enhancing
- Interpretation

There are two methods of image processing:

- Analog Image Processing
- Digital Image Processing

Analog Image Processing: Analog Image Processing refers to the adjustment of image through electrical means.

Digital Image Processing: In this method, digital computer algorithms are used to process the image. The image will be converted to digital form using a scanner – digitizer and then process it. [4]

It is a technique in which the input is an image and output of the image processing will either be an image or a set of constraints or characteristics associated to the image. Expert optical and analog image processing also are forthcoming. [4]

B. Face Detection

Face Detection is a computer technology used to identify human faces in digital images and is used in a wide variety of applications. It is a psychological process which detects humans and locates faces in a visual scene. Face detection is considered as a particular case of object-class detection, where object-class detection is a task of finding the locations and sizes of objects in an image that belong to a particular given class. [4]

The main aim of this technique is the detection of frontal human faces, which is equivalent to image detection, in which the image of an individual is matched minutely. [4] Images detected, are matched with the images stored in the database and if there is any difference in the facial features of image, it will cancel or invalidate the image matching process. [4]

C. Face Recognition

Face recognition is a technique which is used to automatically identify or verify a person from a digital image. This technique is incorporated in computer applications which compares selected facial feature from the image and a facial database or a training set which collectively forms a face recognition system. [5] It is used to authenticate a person in an effective way and facilitates us to identify or detect the changes in the facial patterns of a specific person to a certain extent.[6] The recognition system can accept local variations in the facial expressions of a specific person.

The system is trained for consequent recognition of new images by extracting the distinguishing features from the storage images. Those distinguishing features are known as "Eigen faces". Face recognition is classically used for identification or verification. In verification, an individual is already registered in the reference database. [7]

II. MICROSOFT COGNITIVE SERVICES

Microsoft Cognitive Services are a set of APIs, SDKs and services available to developers to make their applications more intelligent, engaging and discoverable. These services expands on Microsoft's evolving portfolio of machine

learning APIs and enables developers to easily add intelligent features – such as emotion and video detection; facial, speech and vision recognition; and speech and language understanding – into their applications. [8] The vision is for more personal computing experiences and enhanced productivity aided by systems that increasingly can see, hear, speak, understand and even begin to reason.

This suite provides us with intelligent APIs that are cross-platform and provide intelligent data such as facial recognition in images. There are three visions which made the face recognition system:

1) Computer Vision API
2) Face API
3) Emotion API

A. *Computer Vision API*

The cloud-based computer vision API provides developers with access to advanced algorithms for processing images and returning information. By uploading an image or specifying an image URL, Microsoft computer vision algorithms can analyze visual content in different ways based on inputs and users choices. [8]

B. *Face API*

Detect human faces and compare similar ones, also organize people into groups based on visual similarity.
Face API usually performs the following steps:

1) Face Detection
2) Face Verification
3) Face Identification
4) Similar Face Searching
5) Face Grouping

C. *Emotion API*

Analyze faces to detect a range of feelings and personalize your app's response. Recognize emotions in images. The emotions detected are anger, happiness, neutral, sadness, collectively. [8]

III. EXISTING SYSTEM

Face recognition has been a sought after problem of biometrics and also has a variety of applications in modern life. The problems in field of face recognition attracts researchers working in biometrics, pattern recognition field and computer vision. The problem of this technique has gained even more importance after the recent increase in the terrorism related incidents. [9] Use of such technique for authentication also reduces the need of remembering passwords. It can provide a much greater security, if face recognition is used in combination with other security measures for access control. The cost of the license for an efficient commercial face recognition system ranges from 30,000 $ to 150,000 $ which shows the significant value of the problem. [9] Though it is considered to be a very crucial authentication system. But even after two decades of continuous research and evolution of many face recognition algorithms, a truly robust and efficient system that can produce good results in real time and normal conditions is still not available. The Face Recognition Vendor Test (FRVT) that has been conducted by the National Institute of Standards and Technology (NIST), USA, has shown that the commercial face recognition systems do not perform well under the normal daily conditions. [10] Some of the latest face recognition algorithm involved machine learning tools which performed well but sadly the training period and processing time is large enough to limit its use in practical applications. Hence there is a continuous strife to propose an effective face recognition system with high accuracy and acceptable processing time. [11]

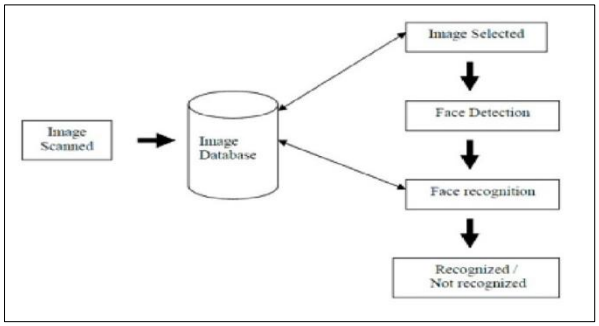

Fig. 1: Existing System

- R Brunelli and Poggio in their work, performed face recognition by matching templates of three facial regions (eyes, nose and mouth), independently. Since the system did not include a geometrical model of the face, thus during classification, configuration of the components was unconstrained. [20]
- D.J Beymer followed a similar approach but with an additional alignment stage in his work. [21]
- L. Wiskott and N Kruger implemented a geometrical model of a face, by a 2D elastic graph. The recognition was based on wavelet coefficients that were computed on the nodes of the elastic graph. [22]
- Haye and Nefian performed a window shift over the face image and the DCT coefficients computed within the window were fed into a 2D Hidden Markov Model. [23]

A. *Several Algorithms Used for Detection*

1) *Independent Component Analysis(ICA)*

A large number of face recognition algorithms use face representations calculated by unsupervised statistical methods. Typically these methods work by finding a set of basis images and then represent these faces as a linear combination of those images. Principal component analysis (PCA) is a popular example of such methods. The basis images calculated by PCA, depends on pair wise relationships between pixels in the image database. In face recognition, important information is contained in the high-order relationships among pixels. Better basis images are calculated by those methods which are sensitive to high-order statistics. Independent component analysis (ICA), generalization of PCA, is one such method [12]. ICA is performed on face images in the FERET database under two different architectures, one architecture treats the images as random variables and the pixels as outcomes, and another treats the pixels as random variables and the images as outcomes. The first architecture found basis images for the faces. The second architecture produces a factorial face code. [12]

2) *Principal Component Analysis(PCA)*

Principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation and converts a set of observations of possibly correlated variables into a set of

values that is linearly uncorrelated variables, called principal components. [13] The number of distinct principal components is equal to the smaller of the number of original variables or the number of observations minus one. This transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it is orthogonal to the preceding components. The resulting vectors are an uncorrelated orthogonal basis set. PCA is sensitive to the relative scaling of the original variables. [14]

PCA is the simplest of the true eigenvector-based analyses. If a multivariate dataset and is visualised as a set of coordinates in a high-dimensional data space say, 1 axis per variable, then PCA can supply the user with a lower-dimensional picture when a projection of this object is viewed from its most informative viewpoint. This is done by using only the first few principal components so that the dimensionality of the transformed data is reduced [14]. It is closely related to factor analysis. Factor analysis typically incorporates more domain specific assumptions about the underlying structure and solves eigenvectors of a slightly different matrix. [15]

3) Eigen Spaces

Eigen space-based face recognition is one of the most successful methodologies for the computational recognition of faces in digital images. Starting with the Eigen face Algorithm, different Eigen space-based approaches have been proposed for the recognition. [16] These methodologies differs mostly in, the kind of projection method used (standard, differential, or kernel Eigen space) in the projection algorithm employed, in the use of simple or differential images before or after projection, and in the similarity matching criterion or classification method employed. [16]

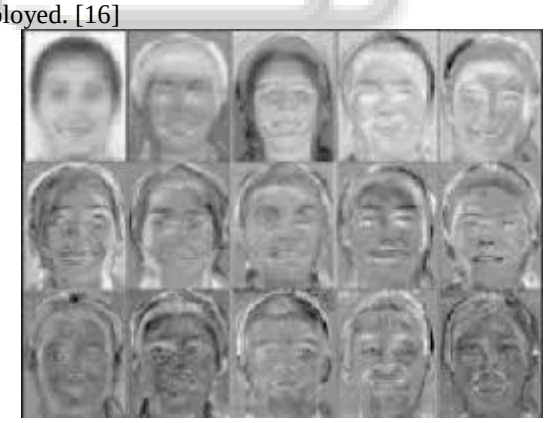

Fig. 3: Eigen-spaces

4) Elastic bunch Graph Matching

Elastic bunch Graph Matching (EGM) algorithm is inspired biologically for recognizing the object in the field of computer vision. This algorithm draws its biological inspiration from two sources: (i) Visual features that are used in this algorithm are based on Gabor wavelets, which have been proved to be a good model of early visual processing in the brain (ii) This matching algorithm itself is an algorithmic version of dynamic link matching (DLM), which is a model of invariant object recognition in the brain.

Visual objects are represented as labeled graphs, where nodes represent local textures and the edges represent distances between the node locations on an image based on the Gabor Wavelets [12]. Overall, an image of an object using this algorithm is represented as a collection of local textures in a certain spatial arrangement. [12]

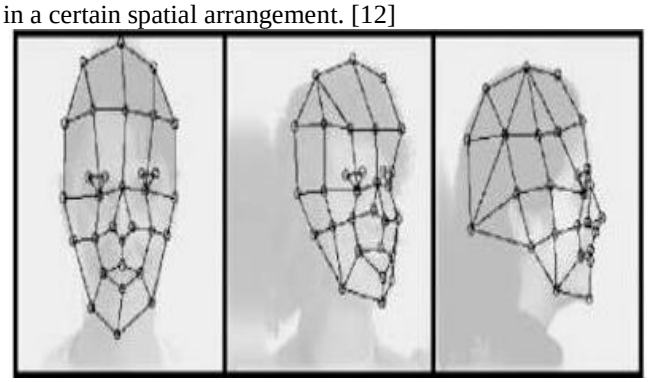

Fig. 4: Elastic bunch Graph Matching

5) Linear Discriminant Analysis (LDA)

This method is a generalization of methods used in statistics, pattern recognition and machine learning to find a linear combination of features that characterizes two or more classes of objects and the resulting combination may be used as a linear classifier or for dimensionally reduction before later classification [12]. LDA is closely related to principal component analysis (PCA) and factor analysis; in that they both look for linear combinations of variables which best explain the data. LDA works when the measurements made on independent variable of each observation are continuous quantities.

Fig. 5: Linear Discriminant Analysis

B. Several Face Detection Techniques

Several face detection techniques are categorized as:

1) Knowledge-based
2) Feature invariant
3) Template matching
4) Appearance-based approaches

1) Knowledge-based approaches

These approaches depend on a set of rules, based on human knowledge, to detect faces. For example, a face often includes two eyes, a nose and a mouth within certain distances and positions relative to each other. Feature invariant approaches locate faces by extracting structural features of the face. Generally, a statistical classifier is trained and, then, used to differentiate between facial and non-facial regions. Template matching approaches use predefined or parameterized face

templates to locate and detect faces, by computing the correlation values between the template and the input image. Appearance-based approaches depend on a set of delegate training face images to find out face models. Generally, appearance-based methods have shown superior performance compared to others. Up till now, Viola-Jones face detector has the most impact in face detection research during the past decade. It is broadly used in genuine applications such as digital cameras, and digital photo managing software. [17]

2) Feature Based Face Detection

There are different approaches for fully automatic detection of facial features. These new techniques may use to basic concepts and features of the facial geometry by locating the mouth position, nose position and eyes position by using various significant algorithms. These detection regions for features such as eye, nose and mouth are estimated and hence there is an enhancement in the detection accuracy significantly. [18]

In this, H-plane of the HSV color space is used for detecting eye pupil from the eye detected region. At first, the detection of the face occur using Viola and Jone's Boosting algorithm and a set of Haar-like cascade features. The eye look for area is minimized by assuming the eyes expected position to be at the upper part of the face. Haar-like cascade features are used for the eye detection. It locates the rectangular regions containing eyes. For the eyes ROI, an algorithm is developed to locate the eye pupil by taking Hue information of the eye image. [18]

The hue image is threshold and contour is detected in the threshold image. Centroid of the contour is detected as the eye pupil. Next is the detection of nose using Haar-like features. Having known the eyes centre and the position of the nose, an approach is proposed based on the facial geometry for mouth location estimation. An algorithm is developed to locate the lips corners points, which are considered as good features for tracking lips movement. Finally, nostrils are detected from the nose ROI by taking threshold of the gray nose image and obtaining the contours in the threshold image. [19]

A robust algorithm is proposed for automatic and accurate detection of different facial features. An improvement over detection of eyes, mouth and nose are done by estimating the probable region for each features. Geometrical interpretations of location of facial features, used in the algorithms are described with pictorial descriptions. The observations have clearly stated that the use of facial geometry features such as eyes, nose and mouth have greatly improved the accuracy in detection as compared to that of using algorithm of whole face image.

The proposed lip detection algorithm is found to be accurately detecting the lips corners for both neutral face images and smiling face images. The eye pupil detection method using H-plane of the HSV color planes image is found to be robustly detecting the pupil in spite of obstacles like wearing spectacles, bad illumination of eye area, variation is sizes of eyes. Algorithm developed using corner detection method, for detecting both inner and outer eye corners are found to be giving accurate results even in faces wearing spectacles. The proposed method for nostrils detection is also found to be accurately detecting in all kind of frontal images tested. [8]

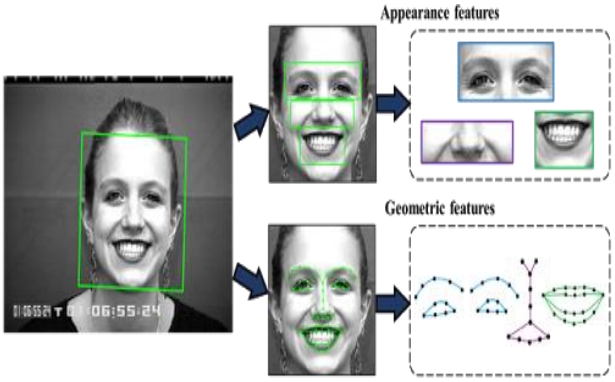

Fig. 6: Feature based face detection

3) Geometric Based Face Detection

This is a PCA based modeling of geometric structure of the face for automatic face detection. This method improves the face detection rate limiting the search space. For images and videos, one of the best face detection techniques is Skin Color Modeling (SCM). But for even better template matching performance in terms of detection rate and time, feature selection is very important. [19]

This is an efficient feature extraction and selection method based on geometric structure of the facial image boundary and interior. Principle Component Analysis (PCA) and canny edge detection are used to model the geometric structure of face. The fusion of these two models provides higher face detection accuracy and improves time complexity. Both models provide filtering of image in terms of pixel values to get the face location that are very fast and efficient for large image databases.[19] The proposed system uses skin color model which reduces the search space. Orientation invariant threshold based on geometric model and improves system further. Feature extraction and selection based on novel combination of geometric filter with SCM filter is introduced for reliable template matching.

The proposed system is composed of two major components: [9]

1. Skin regions are segmented using skin color model.
2. Segmented regions are filtered using geometric model of Face.

They can focus on four color spaces which are normally used in the image processing field:

RGB: Colors are precise in terms of the three main colors: red (R), green (G), and blue (B).

HSV: The three attributes that are apparent about colors can be represented individually in the terms of hue (H), saturation (S), and intensity value (V). The conversion between HSV and RGB is nonlinear.

The major goal in this segmentation process is to remove the background of the image from skin regions using skin color model. At first, input image is changed into chromatic color space. A grayscale image of skin possibility is constructed using Gaussian model. Skin pixels have some set of stable values for each R, G and B component. A normalized image has three principles and they are normalized-red, normalized-green and normalized-blue. Later two images are constructed by extracting these normalized components using Segmentation process. By applying dissimilar threshold for normalized input image, each of these images is changed into black and white image.

The geometric modeling has three key steps:

1) Detected skin regions are projecting using PCA.
2) Projected skin regions are reconstructed using smaller number of Principal Components (PCs).
3) Edges are detected from reconstructed skin regions.

Each region is resized into same resolution as detected skin regions are in different sizes. A predefined mask is applied on each skin regions after resizing. Threshold value is rotation invariant because we are taking the cumulative sum of the projected geometric structure. [19]

Another advantage of the proposed method is that it is very fast in computation because of the filtering. If the filter values of skin segments are within the range of a face or non-face, system can take decision so time complexity to identify the face becomes O(1). Fusion of PCA based geometric modeling and SCM method provides higher face detection accuracy and improves time complexity. The proposed method makes it very fast and efficient for large image databases by improving the face detection rate and limiting the search space.

Fig. 7: Geometric based face detection

4) High-Level Language based Face Detection

It is a user oriented language model for face detection. These are still hard to use because they need explicit knowledge on details of algorithmic techniques.

A high-level language model was projected for face detection with which users may develop systems effortlessly. This model classifies the big trouble and problems of face detection considering the important and necessary conditions involved in it. The developers may use the various recognized conditions to express various problems by representing the expressions in terms of language model. The proposed associated interpreter interprets the conditions to find and classify the best algorithms to solve the represented problem with corresponding conditions after conditions have developed by users.

To expand systems easily and even without specific knowledge of face detection theories and algorithms, this technique was purposefully built with a high level language model for face detection for users. Because of this, the problem of selecting algorithms and deciding complicated parameters for algorithms are isolated from development of face-detection applications.

The problem is defined and expressed with the language model suggested and an interpreter to select appropriate algorithms for the associated sub-space of the problem by the developers. At first, important conditions to classify the huge problem of face detection are considered. The conditions identified here are then expressed in terms of a language model so that developers have been used them to express various requirements of a given problem. The conditions which are expressed by developers plays an important role as the interpreter interprets the conditions to find and organize the optimal algorithms to solve the represented problem. This model is a part of the Open Vision Language (OpenVL). It is a vision language that allows programmers to describe their vision problem in terms of what it is they want to do, instead of how they want it be done. A proof-of concept is implemented and some example problems are tested and analyzed. They present two different detection problems to validate and demonstrate the easiness of use of our proof-of concept language model proposed in this paper. Three different face detection algorithms have been implemented for the selection of proper algorithms in this paper:

1) AdaBoost based algorithm
2) Neural Network based algorithm
3) Color based algorithm

The first case is to detect an upright, frontal and large face for face identification. Face detection is often used as a pre-processing for identifying persons by providing the exact future improvement. Some intelligent approaches for selecting algorithms are necessary to be considered for more optimal selection process.

IV. CONCLUSION

Authentication & Identification has become major issue in today's digital world. Face detection plays a significant role in authentication & identification. Thus, human faces can be captured and emotions like anger, happy, neutral and hairy or bald, left and right eye percentage can be detected collectively using the computer vision API of Microsoft Cognitive Suite. The images of the individual person are captured and compared to the images already present in the database. There are several existing approaches available to do so.

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