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BIOMETRICS & ARTIFICIAL INTELLIGENCE

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BIOMETRICS & ARTIFICIAL INTELLIGENCE

I. History

For more than 20 years face recognition was considered among the hardest problems in artificial intelligence and particularly in computer vision. However, researchers have discovered regularities in various human physiological characteristics, like skin color and facial geometry. Teuvo Kohonen, proving that a simple neural network could perform face recognition for aligned and normalized face images, presented one of the best-known early examples of face recognition techniques in 1980s. Later developments brought fast, cheap and unobtrusive products in the market (Rajkhowa).

II. What is Biometrics?

Biometrics is a modern technological field that focuses on identifying an individual through his or her unique traits. Biometrics is best defined as measurable physiological and/or behavioral characteristics that can be utilized to verify the identity of an individual. They include fingerprints, retinal and iris scanning, hand geometry, voice patterns, facial recognition, facial thermogram, and ear geometry. Biometrics spans various fields such as artificial intelligence and biology as well as various hardware-related fields. They are of interest in any area where it is important to verify the true identity of an individual. Initially, these techniques were employed primarily in specialist, high security applications; however we are now seeing their use and proposed use in a much broader range of public facing situations.

III. What is the need for Biometrics?

Biometrics can be used for a variety of reasons. It will banish the use of cards and PIN. In any situation where we would like to verify an individual's identity in respect to a transaction may be a candidate for biometrics. One may want to use an ATM machine, or any other banking transaction, retail sale, or automated border control. But one must take care that biometrics cannot be applied in every situation. There are certain cases in which biometrics may not be the most secure method or verification and identification.

Since biometrics is a vast field, it will be out of the scope of this research paper and not much justice would be done to explain each of the techniques in details. For the purpose of presenting a detailed and thorough research paper, I have decided to narrow down the techniques to just one: Face Recognition.

IV. Why Face?

Even though it is a true fact that fingerprint, voice, hand geometry are unique for each individual, I think that the human face is the most recognizable part of the human body. Not only can a computer distinguish between two different faces, even a human is able to distinguish between two human faces with a naked eye. On the other hand, if one has to distinguish between two people by looking at their hand geometry, the computer will be able to do so immediately, but the human eye will not able to recognize the close differences. Someone might bring up an argument that a face can be surgically created or altered using plastic surgery. But one has to make note that the basic geometry of the face still remains the same. The distance between the ends of the eyes, the distance between

the forehead and the tip of the nose, the distance between one end of the lip to the other, all remain the same even if there is surgery done. The same is not true for other biometrics.

V. How is Biometrics (Face Recognition in particular) related to AI?

Face recognition technology uses a neural network approach to identify faces. Even though there are several face recognition technologies, each has a different algorithm to identify a face, almost all of them use neural network. A neural network is used to train the algorithms on human faces to determine the correct significance of each local feature. But it is not necessarily true that neural networks are used during the usual scene. Some techniques also use fuzzy logic, which is used to sharpen the images and help find the nearest match. This paper further discusses the various techniques in more details

VI. Some Terms

Face Enrollment – associating a face in a given image with a given image with a given label (subject's name).

Face Identification – given a face-image and a gallery of class labeled faces, finding the correct face.

Face Verification – verifying that a given label is associated with the face in the given image.

False Acceptance Rate (FAR) – the percentage of incorrect successful verifications.

False Rejection Rate (FRR) – the percentage of incorrect failed verifications.

Equal Error Rate (EER) – the value at which FAR equals FRR.

VII. Face Recognition

The face is the most recognizable part of the human body. It is unique for every person. There are exceptions in case of identical twins, but the computer can easily distinguish between them using one of the techniques. An image of the face is easy to acquire. It does not require any high-tech hardware. It only requires a camera (video or digital) that is connected to a computer. An image can also be taken from a video without the knowledge of the subject.

VIII. Primary Face Recognition Technologies

There are four primary methods that are used for facial recognition to identify and verify subjects. These techniques include eigenfaces, feature analysis, neural network, and automatic face processing. Since these techniques use different algorithms, some types of facial recognition technology are more suitable that others for applications such as surveillance, forensics, and network access. Besides these four techniques there are several other techniques such as Graph Mapping, Fisher Face, etc…

VIII. I. Eigenface

This technique is patented by MIT. It utilizes two dimensional, global grayscale images representing distinctive characteristics of a facial image describing what is common to groups of individuals and where they differ the most. "Eigenface", in other words, is known as "one's own face". Distinctive characteristics of the entire face are highlighted for use in future authentication. Just as mixing primary colors can create any color, combining features of approximately 100-125 eigenfaces can reconstruct the vast majority of faces. Once the subject is enrolled in the system, the subject's eigenface is mapped to a series of numbers. Like all facial recognition technologies, eigenface technology is best utilized in properly lit, and only in frontal image captures.

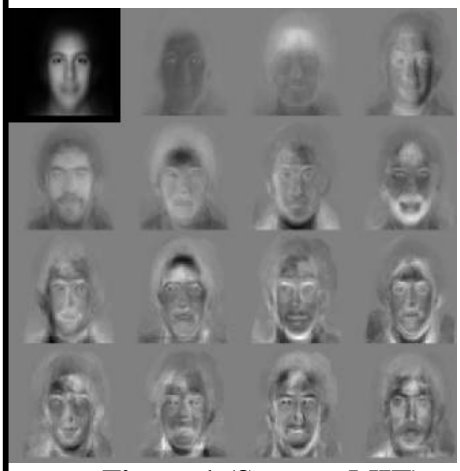

Figure 1 (Source: MIT)

Figure 2 (Source: MIT)

Figure 1 shows the standard Eigenfaces.

The first step is to enroll the face in the database. When shown an image, the program captures its Eigenface characteristics, which are then encoded into numbers.

Figure 2 shows the encoding and decoding of the image.

To verify the face, the data is compared with those in the database and if a match is found, the face is identified.

VIII.II. Feature Analysis

Feature analysis is one of the most widely used facial recognition technology used in the industry. This technique is used in many vendor products. This technique is related to eigenface, but it is more capable of accommodating changes in appearance or facial aspect (e.g. frowning vs. smiling) and changes in poses and lighting. Since feature analysis is not the global recognition of the face, it can accommodate angles up to 25 degrees in the horizontal plane and 15 degrees in the vertical plane. This technology focuses on the inner region of the face, which runs from temple to temple and just over

the lip. This is most stable because it can be used even though the subject may wear glasses, grow their beard or put on weight or age.
Local Feature Analysis (LFA) uses individual features of the face. These features are used as building blocks from which the facial image can be reconstructed.

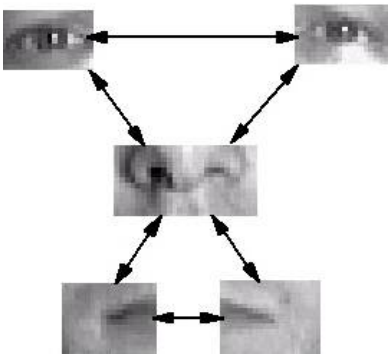

Figure 3

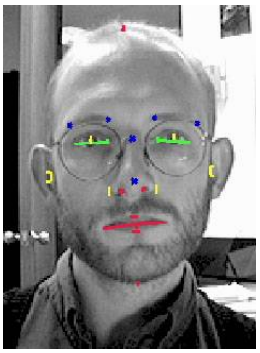

Figure 4

As can be seen from Figure 3, the eyes, nose and the lips are the features that LFA chooses.
To identify a person,

1. Take an image of that person
2. Determine the pattern of points that make the individual differ the most from other individuals
3. The next step is to create patterns either randomly or based on the average eigenface
4. For each selection, the computer constructs a face image and compares it with the face that needs to be identified
5. If none is found, new patterns are created until a facial image that can be matched with the target can be constructed
6. When a match is found, the pattern of a real person is sought

VIII.III. Neural Network

In neural network mapping technology, features from both faces – the enrollment and verification face – vote on whether there is a match or not. It extracts features from the face as visual contrast elements, quantifying, normalizing and compressing them into a 1KB template code. After that, it employs an algorithm to determine the similarity of the unique global features of live versus enrolled or reference faces, using as many details of the facial image as possible. An incorrect outcome prompts the matching algorithm to modify the weight it gives to the various facial features. This method, in turn, would lead to an increased ability to identify faces in several difficult conditions. Neural network facial recognition can do either 1-1 or 1-many recognition. Some people believe that neural network technology is the next step in face recognition.

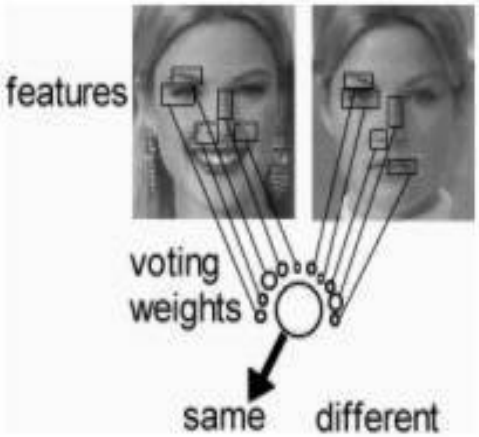

Figure 5

As can be seen from Figure 5, the features are extracted and the compressed into a template code.
Further information on neural network is given later on in this paper.

VIII.IV. Automatic Face Processing (AFP)

Automatic Face Processing (AFP) is a more rudimentary technology, using distances and distance ratios between easily acquired features such as eyes, nose, mouth, ears, etc… It is the simplest method of facial recognition. Though this technique is not as vigorous as eigenfaces, neural network or feature analysis, but AFP may be more effective in dimly lit, frontal images.

The first step is to locate the facial features such as the eyes, nose, cheeks, mouth, etc… Then these features are measured. The size of these features and the distance between other features is then calculated to produce distance ratios. The resulting string of ratios is used to create a facial code that is used to store and search the database. To expedite the search process the facial database is divided into classes. For example all people with 7cm mouths may be stored in the same class thereby reducing the time required to match a person with a 7cm mouth and a 5cm nose.

IX. Current Technology

The technologies mentioned above can also be classified as 2D technologies with the exception of neural network. Neural networks form a part of 3D face recognition technology and they are a step above LFA.
Given below is an algorithm, which is used to train and test an image, using a neural network

IX.I. The Training Algorithm

1. Apply Gabor filter to the face image
2. Apply Gaussian weighting
3. Locate peaks in image
4. Extract feature vector at located peaks
5. Store vector, location and class label for each of the located peaks

IX.II. The Testing Algorithm

1. Step 1 - 4 are same as Training algorithm
2. For each extracted feature vector, compute distance to all feature vectors in the gallery
3. Based on class label to the nearest matching feature vectors, assign points to corresponding class

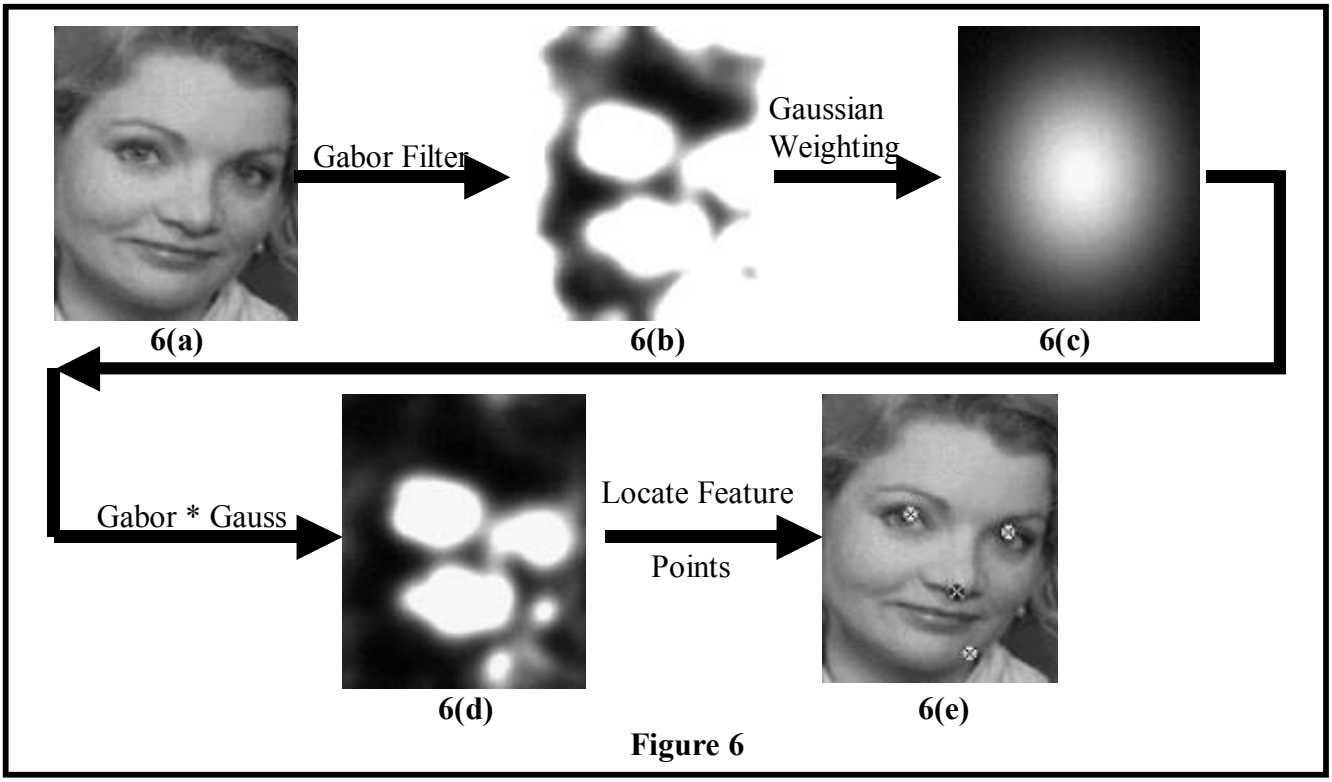

Figure 6

As can be seen from the above figure 6,
1. Figure 6(a) is the original image; we then apply Gabor Filter to it
2. Figure 6(b) shows the effect of the Gabor filter; we then apply Gaussian weighting to it
3. Figure 6(c) shows the effect of this weighting; we then combine the Gabor filter image and the Gaussian weighting image.
4. Figure 6(d) shows a combination of Gabor and Gauss; it clearly shows the eyes, mouth and parts of the ear.
5. Figure 6 (e) shows the feature points that include the eyes, nose and part of the chin.

Using the steps given above, a number of similar images are shown to the system. The system trains itself to become better and better at recognizing the images by using several back-propagation techniques. This technique also allows reducing the number of errors by passing the errors backward from the Error Criteria. Errors in the back propagation component are used to change the weights in the network – this is where the learning occurs.

X. My Idea

Almost all the technologies discussed above have certain constraints specifically with respect to the pose of image, lighting, quality of the image, number of pixels in the image, and facial expressions.

While doing this research I thought about several ways how to handle some of these problems.

1. Controlled Lighting: Lighting will have to be controlled in order to have a clear and well-lit image. If the image is still not clear, filters will be used to enhance the lighting effect of the image. Color normalization would be done in order to adjust the hue and brightness of the image.

2. Image Shot (Pose): The enrollment image will be captured using three cameras, front, right and left. But a major emphasis would be given to the frontal image. It would be made sure that any third object does not obstruct the image. The right and the left side images will help to store the image as a 3D object (which is the future of face recognition technology).

3. Multiple Images: Multiple images with different facial expressions will be taken. This would ensure that the face is verified correctly even if the facial expression of the person is different at the times of enrollment and verification

4. Reduced Image: The main emphasis would be given only to an area where there is a lot of skin color. This would speed up the algorithm and also be helpful in eliminating false detections.

5. Detect Corners: This will be a slightly longer and a more time consuming idea. The corners of the face at each feature point such as the eye, nose, ears, chin, etc… would be recorded. In the case of aging over a period of time, the neural network will be programmed in such a way that it will be able to change the template according to the corners of the face.

XI. FAQ

Q. How can controlled lighting help and what if the lighting is poor?
A. Controlled lighting will allow the system to save all images with the same amount of brightness, hue and color. If the lighting is poor, the system will not be able perform to its full capability. But it will try to correct the lighting automatically.

Q. Why would you take the image from three sides since the right and left sides are identical?
A. The three images will be beneficial to store the image in 3D form. Even though someone might argue that the right and the left side of a person are identical, there might

be instances where the one of the side might have a deep scare, which would make identification difficult. Also in case of twins, the minor differences in the two sides will be beneficial to distinguish between two different individuals.

Q. Why would you take images with multiple facial expressions?
A. Since a human can have several facial expressions, there are only a few expressions that are completely different from others. This means that all the other expressions are slightly different from one main expression. Thus we would capture those few main expressions in our images.

Q. How would the system work in case of make-up, facial hair and such other characteristics that change regularly?
A. Facial hair is not a big problem. The face recognition techniques have enough robustness and redundancy to be able to compensate for mustache or beard. Change in hairstyle is not a big problem since it is not a part of the face recognition. But if the hair occludes a significant portion of the face, face recognition accuracy will naturally be comprised. Once the system is implemented, the neural network will be still under its training stages during the initial few months. This is done in order to ensure that the users are recognized correctly. Thus when a person's image is taken and compared with the one in the database, the neural network will learn the slight difference in the new image and change the template accordingly. This would ensure that even if the person is wearing make-up or having facial hair or having a different expression will be recognized in the future without much difficulty.

XII. Conclusion

Biometrics is an incredibly fascinating and exciting field, which has been growing exponentially in recent years. The wide-variety of physically unique traits that a human body has to offer will soon allow us to live in a world that will be free of any password or ID-cards. So far, no single face recognition technology can guarantee a 100% success rate. But if a technology with the plus points of all the technologies mentioned above is combined and my suggestions such as controlling the light, taking three pictures with various facial expressions and detecting corners is jointly implemented, there might be chances that we will get an accuracy rate which will be very close to 100%. Thus in the near future if you are going to a mall, be careful; the billboard might start talking to you offering you an idea to buy that wonderful pair of jeans (if male) or skirt (if female) at affordable price from a designer store that you had always wanted to buy.

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