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Machine Learning System for Human Ear Recognition Using Scale Invariant Feature Transform

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Abstract

Biometrics techniques are the standard of a wide group of many applications for a human's identification and verification issues. Because of this reason, a large scale of security needs to search for a new way to identify the person arises. In this paper, a machine learning approach for a human ear recognition system is proposed. This system combines four main phases: ear detection, ear feature extraction, ear recognition, and confirmation. The proposed system's essential is to divide the ear image into the skin and non-skin pixels using a likelihood skin detector. The likelihood image processes by morphological operations to complete ear regions. Scale-invariant feature transform (SIFT) uses for extracting the fixed features of the ear. Ear recognition includes two modes identification mode and verification mode. Euclidean Distance Measure (EDM) uses for similarity measure between the first image in the database and a new image. According to the three experiments conducted in this paper, the results of the different datasets, the accuracy ratio are 100%, 92%.and 92%, respectively.

Keywords: Biometrics; Ear Detection; Distance Measurement; Morphological Operations; Scale-invariant feature transform;

1. Introduction

In the field of universal interconnection for the society of information, the necessity for authentication and identifying individuals is more growing. The Biometrics that depend on authentication has raised the most reliable solutions (Arun et al., 2006). Biometrics is defined as a science concerned with establishing an identity based on the person's attributes (physical, chemical, or behavioral) (Anil et al., 2008; Stan-Li, 2009). The characteristics of the physiological attribute obtain directly by measuring parts from the body of the human. The most distinguished kinds of Biometrics are fingerprints, face recognition, scans of iris, ear print, hand scans, and palm print (Peter and Michael, 2008).

The characteristics of the behavior that depend on the events of the individual performance are considered non-immediate measurements for the form of the human. The Biometrics of behavioral has major attributes that utilize metric of time such as signature, gait, speech patterns, and keystroke-scan (Peter-Yeng, 2008). Behavioral characteristics or each human physiological characteristic cannot be considered as features for Biometrics unless meeting the requirements illustrated now: Universality, Uniqueness, Permanence, Collectability, Performance, Acceptability, and Circumvention (Peter and Michael, 2008).

In biometric systems, registration of a new user has performed in an enrolment stage, while verification of the user's identity has carried out in a verification stage. In the enrolment stage, the system acquires biometric data from a user; pre-processes the acquired data (e.g., noise reduction); the process of features extraction extracts features from the data (e.g., minutia from a fingerprint image), and stores the extracted feature set as a template in the database. In the verification stage, the same steps as in the enrolment have been performed except the last one. In verification, instead of storing the extracted feature set, it is compared against the template set of features stored within the database to clarify the person's identity in question. The process of decision making for accepting or rejecting depends on the similarity between acquired and template feature sets using a threshold value.

The biometric system performs the identification mode in addition to the verification mode based on the application. In this mode, the system either establishes the identity of an unknown sample or announces no match by comparing the unknown sample to all templates in the database. In other words, the verification searches for the answer to the question "Am I who I claim I am?" (one-to-one comparison). At the same time, the identification seeks the answer to the question "Who am I?" (One-to-many comparisons). In the paper, we will use the term" recognition" when referring to verification and identification. Ear biometrics has gotten much consideration as of late due to its predictable conduct over time. The shape of the ear does not change because of the face's expressions and aging. It is not like the face (Lahkar and Borbora,2019; Prakash and Gupta, 2012).

The ear is entirely alluring biometric applicant essentially because of its (i) rich and stable structure that is saved since birth and is very interesting in people, (ii) being constant to the adjustments instance and outward appearance, and (iii) generally resistant from tension, protection, and cleanliness issues with a few other biometric hopefuls (Kumar and Wu, 2012). Ear as a biometric identifier has pulled in much consideration in the PC vision and biometric groups lately (Ibrahim et al., 2010). The great difference between people in the shape and geometry of the ear made the ear structures of the biometrics trait (Abaza et al., 2011). The concha, the antitragus, the tragus, the lobe, the antihelix, and the external helix are components of the outer ear that it's a characteristic appearance. (See Figure 1.2). Despite the fact that the right ear and the left ear demonstrate a few likenesses, they are not symmetric (Pflug and Busch, 2012). The specific look, anatomical features, and the topography of the human's ear for several years have been utilized as a biometric sign (Abaza and Ross, 2010).

Ear as a biometric sign possesses many advantages in comparison to the whole face as; there is considerably less spatial resolution; there is an even variation of the colors and with minimum changes occurring with the alteration of facial expressions and the face positioning (Alemran, and Bahbibi,2019; Ali and Javed, 2007). In 2010, (Kisku et al. 2010) proposed a more robust system for identifying a human ear, which was built through the incorporation of an ear segmented into slice regions and create SIFT features of color. Using K-L divergence and vector quantization algorithm for a combination of Gaussian with constructing the model from the ear and that from through utilizes the Gaussian mixture model. Invariant feature extraction part of each color slice region, after which the SIFT features are taken out from these regions. Indi and Raut (2013) proposed a uniquely identifying a person using the biometrics aspects found in the person's ear. In 2015, (Asmaa et al. 2015) placed forward a more streamlined algorithm for recognizing the ear using the geometrical feature extraction such as (Euclidean distance, centroid, mean, shape, and between pixels).

2. Research methodology

The proposed system is a multistage process that consists of two main phases: enrollment phase and recognition phase. MATLAB software is used to implement the proposed framework. In addition, each phase has a number of successive stages. Figure 1 gives an adequate description of these steps.

2.1. Enrolment Phase

The goal of this phase is to gather the input images as a vector feature or a template in the database to utilize later at matching stage. As well as, the phase implements in sequence three stages as follows: image acquisition, image pre-processing, and feature extraction.

I. Image Acquisition

The ear images database obtains from the AMI ear database based in the Department of Computer Science of the Universidad de Las Palmas de Gran Canaria (ULPGC). The database contains 175 color images for ear. Images are available in JPEG format. The resolution of the images in question is (492 x 702) pixels. The database samples shown in Figure 2.

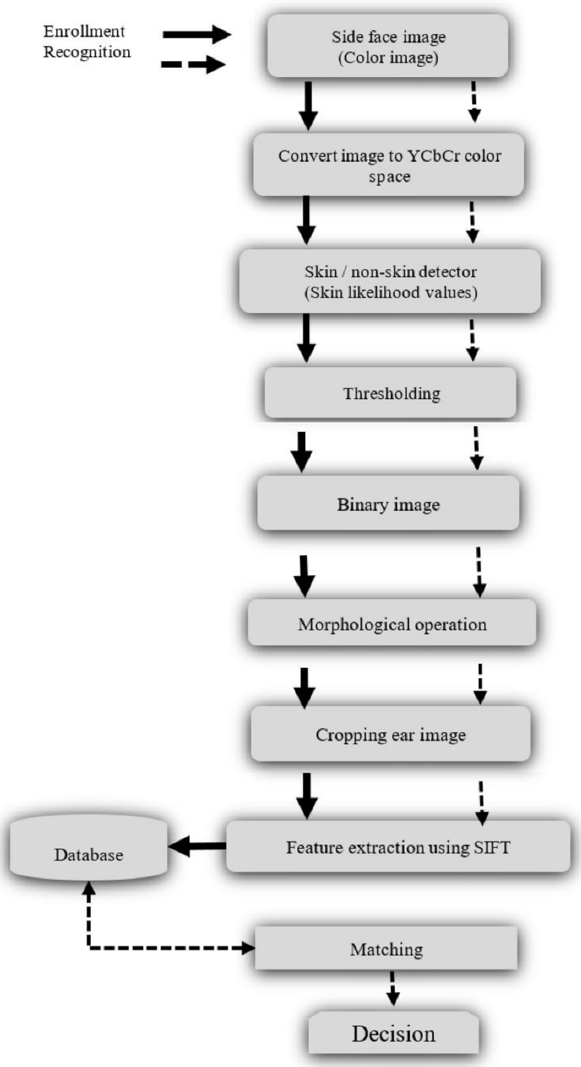

Figure 1: The Block diagram architecture of the ear recognition system

II. Preprocessing Stage

Essentially, preprocessing is the first stage in the ear recognition system. It enhances the images and eliminating unwanted effects. This stage includes three main processes:

The first process converts RGB into YCbCr color space. The second process detects the skin / non-skin in the side face image after conversion to the YCbCr color space. The third process uses the morphological operations to recover what has been lost and remove unwanted information from the previous process. Figure 3 describes the steps of the algorithm of the preprocessing stage.

Figure 2: Samples from the database.

The following two equations were used in this work, which defined as follows:

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 65.481 & 128.553 & 24.966 \\ -37.797 & -74.203 & 112 \\ 112 & -93.786 & -18.214 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (1)$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 0.00456621 & 0 & 0.00625893 \\ 0.00456621 & 0.00153632 & -0.00318811 \\ 0.00456621 & 0.00791071 & 0 \end{bmatrix} \begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} - \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} \qquad (2)$$

```
Algorithm (1): preprocessing algorithm.
Input: Side face image.
Output: Ear color image.
   Begin
   |     Step1: Select image from the database.
   |     Step2: Convert RGB image to YCbCr color space using Eq. (1).
   |     Step3: Detected skin / non-skin by chrominance component Cb and Cr.
   |     Step4: Converting the image from previous step to a binary image.
   |     Step5: Morphological operation (closing) is using to fill gaps in small regions
   |                and remove unimportant information.
   |     Step6: Convert image to RGB image to obtain on ear color image using Eq. (2).
   End.
```

Figure 3: The steps of the algorithm of the preprocessing stage.

➢ *RGB into YCbCr color space*

The color of the side a face image converts into YCbCr color space as presented in Eq. (1) and illustrated in Figure 4.

➢ *Skin detection*

The aim of this step is to determine the skin from the input image thereby reduce the amount of unimportant information. Then, it uses a certain threshold to segment the ear of the skin. This threshold illustrates as defined in equation 3:

$$77 \leq Cb \leq 127 and 133 \leq Cr \leq 173 \quad (3)$$

➢ *Binary Image Conversion*

This step converts the resulting image from the previous step into a binary image. The purpose of this step is preparing the image to the morphological operations step. Figure 5 shows the result of this step.

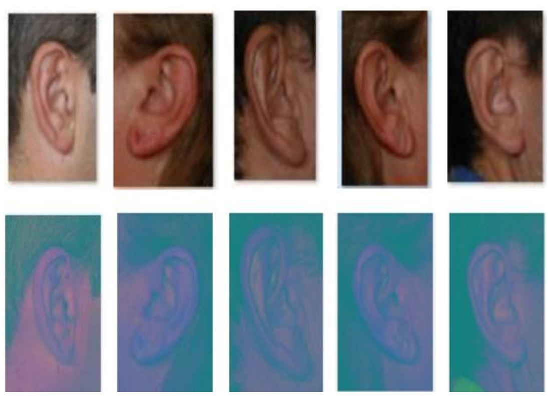

Figure 4: Converting images from RGB into YCbCr color spaces.

Figure 5: The result of binary image conversion.

➢ *Morphological Operation (Closing)*

In this step, the closing morphological operations use for filling the holes and gaps in the image (see Eq.4), as shown in Figure 6. Figure 7 defines the steps of the close morphological operation algorithm.

$$(A \oplus B) \ominus B \quad (4)$$

Figure 6: The closing morphological operations.

➢ *Ear Detection*

Finally, ear is detected and submitted to the feature extraction stage. Through this step, the image converts into the original RGB color space (see Figure 8). Figure 9 shows an example of all steps of the pre-processing stage.

Algorithm (2): Morphological Operation (closing).
Input: Binary image.
Output: Ear color image.
Begin
| Step1: Input binary image.
| Step2: Create a morphological structure element using the option “strel” with radius=30.
| Step3: Applied the closing process including the dilution process to fill gaps in small regions.
| Step4: Implements the erosion process to remove any pixel has fewer from 150 Pixel for
| obtaining a complete ear image
End.

Figure 7: The steps of the close morphological operation algorithm.

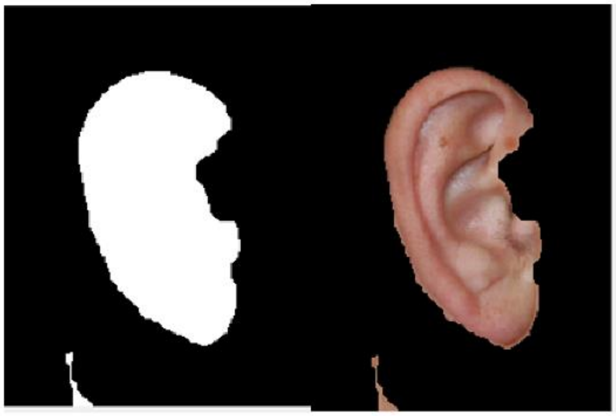

Figure 8: Ear isolating from side face image.

Figure 9: An example of all steps of the pre-processing stage.

- ***Feature Extraction Stage***

The purpose of this stage is to extract and represent the stationary features and store in the database in a convenient form. The SIFT technique is utilized for this purpose. The following steps represent the mechanism of SIFT calculations:

- **Step1.** Formation a scale space: It considers as the first step of the preparation process. An internal representation creates the original image to establish the presences of scale invariance. The above process achieves by the generation of a "scale space".
- **Step2.** Approximation of LoG: The Laplacian of Gaussian is a tool of great value for determining points of interest (or keypoints) located within an image. Nevertheless, the downside associated with it requires significantly high computational powers. Hence, bypassing of this step fixes by the approximation of the previous representation.
- **Step3.** Determining keypoints: It uses the extremely efficient and speedy methods of approximation as the keypoints. These amounts signify the maxima and minima in the Difference of Gaussian image.
- **Step4.** Elimination of bad keypoints: Bad key points are areas of edges and places that show a reduced contrast. Removal of such points allows for more efficient and powerful functioning of the algorithm.
- **Step5.** Orientation assignment to the key points: For every keypoint, a special orientation is commutated. Additional calculations that will be done later are done with respect to the above orientation. This successful negates any unwanted influence of orientation, thus resulting in a rotation invariant.
- **Step6.** Production of SIFT features: Lastly, keeping both the scale as well as the rotation invariance in position, generation of one more number of representations is done. This process assists in clearly demarcating and determining the features.

- ***Storing Feature Vector in the Database***

Feature vectors save in the database and is the last step in the enrolment phase. These vectors compare with a new vector in the matching process.

2.2. Recognition Phase

The goal of this phase is to recognize a new input image. Stages with new image are acquisition stage, pre-processing stage, feature extraction stage, and matching stage. The basic operations of proposed system are divided into two modes: **identification mode and verification mode**. The number of steps in the identification mode differs from that in the verification mode. Matching algorithm identifies the similarity/dissimilarity between two given data groups. Figure 10 describes the steps of matching algorithms implementation.

Figure 11 and Figure 12 illustrate the descriptions of identification mode algorithm and verification mode algorithm respectively.

Algorithm (3): Matching Algorithms Implementation
Input: New image (feature vector).
Output: Make the decision.
Begin
| Step1: input a new image.
| Step2: Finding the feature vector of new image.
| Step3: **IF** Identification mode THEN determine the class of the input image,
| and matching a new image (feature vector) with feature vectors in
| database to obtain on decision known or unknown.
| Step4: **ELSE**, verification mode THEN input ID of the new image, and
| matching a new image with the image in database to obtain on
| decision reject or accept.
End.

Figure 10: The steps of matching algorithms implementation.

Algorithm (4): Identification mode Algorithm.
Input: Feature Vector.
Output: Make the decision.
Begin
| Step1: Input new image (new feature vector).
| Step2: Detecting the closest feature vector by comparing a new feature vector
| with feature vectors in the database.
| Step3: **IF** the new vector has similarity with one of the feature vectors in
| database THEN decision matches.
| Step4: **ELES** the new vector has not similarity with anyone of the feature
| vectors in database THEN decision is not matching**.**
End.

Figure 11: The descriptions of identification mode algorithm.

Algorithm (4): Verification mode Algorithm.
Input: Feature Vector.
Output: The decision.
Begin
| Step1: Input a feature vector (new image).
| Step2: Determine the ID of the person.
| Step3: Matching the new vector with feature vector in the database.
| Step4: IF the new feature vector is matching THEN accept. ELSE, the new
| feature vector is not matching THEN reject.
End.

Figure 12: The descriptions of verification mode algorithm.

3. Experimental Results

The purpose of this step is to examine the activity of the proposed system for all given images. The number of people and the number of images for each person are randomly specific for the database. Additionally, the system is going to exam the different sizes of the database.

Later, the identification and verification modes are both checked via the proposed system. Three types of experiments are used. The first experiment checks the images in the same database. As expected, the matching process was 100% accurate, therefore, error was insignificant and had no role in the result obtained. The second experiment checks the images that do not belong to the database but belongs to the same people in the database (i.e., known people). The purpose is to examine the system's ability to (determine) known persons. This experiment is going to match images for registered persons in the database with images that are not found in the database. There are many parameters that can be influenced the accuracy rate of our system such as, the number of individuals in the training set, the number of images for each individual. As a result, in this experiment, there is also a reference to the effect of these parameters on the system's accuracy.

The third experiment checks the images of unknown people (i.e., people who were not present in the database). The purpose of the third experiment is to examine the system's capability to reject (not determine) known persons. Internally, all images of the database have arranged (before preprocessing and feature of extraction) in sequence for the simplifying of searching and retrieving images from the database. For instance, the dataset consists of twenty-five people (subset-1); everyone has ten images; images are numbered from 1 to 250. The first ten images represent the person one and the second ten images signify the person two, and so on. Table 1 and Table 2 display accuracy rates of the experiments and the Rejection state respectively. The results will be "success" when the system correctly detects the right individual and will be "unknown" when the system cannot detect the right individual. In addition, there is another case called confused case, which happened when the system fails to detect the right individual and detects another one. "SU" will refer to the success case, "UN" to the unknown case, and "CF" to the confused case.

Table 1: The number of persons and system accuracy rate.

Number of Person	*SU Rate*	*UN Rate*	*CF Rate*	*Total accuracy rate (%)*
5	0.98	0.02	0	98%
10	0.97	0.03	0	97%
15	0.95	0.05	0	95%
20	0.936	0.087	0.00625	93.625%
25	0.925	0.0625	0.0125	92%

Table 2: The Rejection state of the proposed system.

# Person in the database	*Success*	*Failure*	*Total accuracy rate (%)*
5	0.7083	0.3916	70.83%
10	0.778	0.224	77.41%
15	0.8416	0.1693	83.16
20	0.8933	0.1006	89.34%
25	0.92	0.07	92%

Table 3: The comparison with other methods.

NO.	*Authors*	*Method*	*Recognition Rate (%)*
1	Banafsh and Mark [2015]	Gabor sampling filter	65%
2	Shritosh Kumar, Vishal Shrivastar [2015]	Gabor mean feature Extraction	83%
3	Proposed system	SIFT feature	92%

4. Conclusion

In this paper, an ear recognition system is proposed. The primary commitments of the proposed strategy are the accompanying: Ear Extraction utilizing skin detection by YCbCr shading space calculation, Ear detection utilizing close morphological operation, ear identification and confirmation utilizing the Scale-invariant component change Euclidean Distance Measure. Ideally, on behalf of recognition, features are extracted using a scale invariant feature transforms once at least three features of the ear image are unambiguously distinguished. Whereas, in the pre-processing stage, the skin detector used for determining the skin from non-skin. Preferably, the ear area finds the best results. Finally, morphological operations have their role in enhancing parts of the ear that were missing. Thus, they are highly positive in the process of recognizing individuals.

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