FACE RECOGNITION AS A BIOMETRICS APPROACH USING THERMAL IMAGES

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Abstract— Biometrics is a technology used for measuring and analyzing a person's unique characteristics. Making a secure biometric system is not as easy as it might appear. The word biometrics is very often used as a synonym for the perfect security. Human Biometrics is now moving towards thermal imaging. Thermal imaging is simply the technique of using the heat given off by an object to produce an image of it. A thermal image provides more accurate information than the visual image. Hence a novel approach to face recognition based on thermal imaging is implemented here. The thermogram of the human face was captured from an infrared camera. In this work, an effective method to extract the thermal pattern of the human face using thermal images is presented. Thermal pattern of the human face is obtained by implementing the image processing techniques. Segmentation of human face from the rest of the image is the fundamental step in this process. After the face segmentation, the noise in the thermal image is removed using an appropriate standard filter. Then the morphological operations such as opening operation and top-hat method are performed on the image. From the result of the top-hat segmentation method, the features such as three quantitative distance measures are selected and compared with different subjects. Thirty volunteers were involved in this experimental procedure.

Keywords— Thermal imaging, Face recognition, Thermogram, Biometrics, Anisotropic diffusion, Thermal pattern, Feature extraction

I. INTRODUCTION

BIOMETRICS is the science of recognizing humans. Recognition is based on the anatomical and behavioral traits of an individual. It is a technology used for measuring and analyzing a person's unique characteristics. There are two types of biometrics: behavioral and physical. Behavioral biometric is generally used for verification. While physical biometric is used for either identification or verification.

Human Biometrics is comprised of DNA matching, ocular biometrics, olfactory biometrics, iris recognition, retina recognition, fingerprint recognition, finger geometry recognition, hand geometry recognition, vein recognition, gait, voice recognition, signature recognition and face recognition.

Much work is still needed to improve the biometric security systems. There are a number of reasons to choose face recognition for designing efficient biometric security systems. The most important one is that no physical interaction is needed.
Many hospitals and healthcare organizations are in progress to deploy biometric security architecture. In medicine, biometrics is used for patient identification. The need to identify patients with a high degree of certainty arises at reducing risks of fraud. Voice recognition and signature recognition are used for securing the electronic medical records using biometric authentication. Presently face recognition has become the modern approach for identification and verification.

In face recognition, the facial features or patterns for the authentication or recognition of an individual's identity is analyzed. However, face recognition is still a challenging area due to various facial expressions, poses, non-uniform light illuminations and occlusions. Mainly there are two methods of capturing an image. One is visual imaging and the other is thermal imaging. Visual images captured by optical cameras are more common than thermal images captured by infra-red cameras. Thermal Imaging has more advantages when compared to visual images. Currently the human biometrics is moving towards thermal imaging. Thermal imaging, also known as infrared thermography (IRT), is a form of biometrics.

Thermal imaging can be seen as a method of improving visibility of objects in a dark environment by detecting the object's infrared radiation and creating an image based on that information. New thermal imaging frameworks for detection, segmentation and unique feature extraction and similarity measurements for human physiological biometrics recognition are reviewed.

The tasks of face detection, location and segmentation are relatively easier and more reliable for thermal face images. Unlike visible spectrum imaging, IR imaging can be used to extract not only exterior but also useful subcutaneous anatomical information, such as the vascular network of a face or its blood perfusion patterns. Finally, thermal vision can be used to detect facial disguises as well. Thermal imaging has better accuracy as it uses facial temperature variations caused by vein structure on facial surface as the distinguishing trait.

Thermography is a non-invasive imaging technique that uses special infrared-sensitive cameras to digitally record images of the variations in surface temperature of the human body. Thermographic cameras can detect radiation in the infrared range of the electromagnetic spectrum and produce images of radiation known as thermograms. A thermal infrared camera with reasonable sensitivity provides the ability to image superficial blood vessels on the human skin. Researchers have been using thermal imaging for good results considering it as an efficient approach when compared to the visual images.

The proposed method provides a novel approach to face recognition based on thermal imaging and image processing techniques using MATLAB. After the collection of thermal images from different subjects, image processing techniques can be applied to the images. Finally the features are extracted from the thermal pattern created for each and every individual.

II. MATERIALS AND METHODS

The materials used for this experiment is a Thermal camera, coupled with a computer installed with FLIR software and MATLAB software. The primary equipment used for this study is a thermal infrared camera. The computer/laptop receives the detected images from the thermal camera and processes them using the MATLAB program.

A. Collection of Thermal Images

In this work, the thermal images were captured by means of FLIR A305sc infrared camera. In this experimental procedure, thirty subjects were involved. The recording of the thermal infrared images was done in a room with an average room temperature of 23 ◦C. The thermal camera was placed on a tripod at a distance of 1 m from the subject who is asked to sit on a fixed chair to facilitate the picture-taking process. The subjects were asked to look straight into the camera lens and a snapshot of their frontal view was taken. This process was repeated at least five more times at different time intervals. The experimental setup is shown in fig 1.

Fig 1. Experimental setup

The FLIR software tool plays a major role in the image acquisition stage. The images acquired by the thermal camera are stored inside this software tool for future use. The display of this software tool is shown in fig 2.

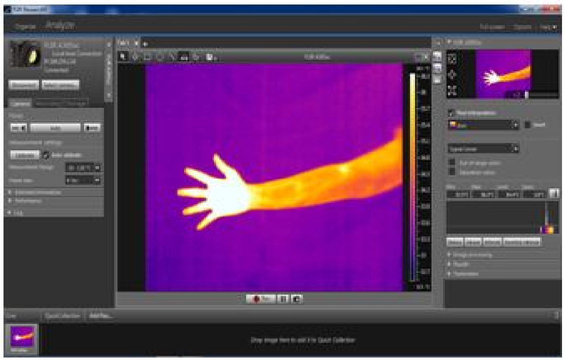

Fig 2. Display of FLIR software tool

The images are then processed using image processing techniques with suitable matlab codes. Then pre-processing techniques are applied to the image. The facial temperature information from a thermal image is heterogeneous in nature; an appropriate segmentation method has been chosen to successfully separate background temperatures from facial temperatures. The next step is the segmentation of thermal features, we use anisotropic diffusion to reduce noise and enhance edges in the image. This is followed by a white-top hat segmentation technique to enhance the bright objects, which results in producing a thermal pattern. Using these morphological operators a thermal facial pattern is created. Then these thermal patterns are used in the feature extraction module.

B. Implementation of image processing techniques using MATLAB

After the collection of thermal face images, image processing techniques are implemented using MATLAB. The algorithm proceeds as follows:

1. The human face is manually cropped from the entire thermal image.
2. By using anisotropic diffusion operation, remove the noise and enhance the edges.
3. Apply morphological operations to enhance the bright objects in the image.
4. Implement the top-hat method to obtain a thin thermal pattern.

Face segmentation is a first step for face biometric systems. Therefore face segmentation has to correctly extract only face part of given large image. In this work, manual segmentation of the face is initially implemented.
Thermal infrared images contain noise, which many times distort significant information and details that are important for the interpretation of the image. After the face was segmented from the rest of the thermal infrared image, unwanted noise is removed in order to enhance the image for further processing. The noise in the image should be removed and

simultaneously the image information should be kept unaffected. This problem can be handled using anisotropic diffusion. A standard anisotropic diffusion filter is first applied to the entire image with the segmented face. Anisotropic diffusion is a technique used to reduce the image noise without removing significant parts of the image content like edges, lines or other details that are very important for the interpretation of the image. The significance of the anisotropic diffusion filter in this particular application is to reduce spurious and speckle noise effects seen in the images and to enhance the edge information for extracting the thermal signature. Anisotropic diffusion is to smooth the signal, preserve strong edges and enhance the contrast of edges.

After the noise removal step in the process, morphological operations are performed on the image. Image morphology is a way of analyzing images based on shapes. In mathematical morphology, a structuring element is a shape, used to probe or interact with a given image, with the purpose of drawing conclusions on how this shape fits or misses the shapes in the image. It is typically used in morphological operations, such as dilation, erosion, opening, and closing, as well as the hit-or-miss transform. The morphological operators used in this experiment are opening and top-hat segmentation.

The effect of an opening operation is to preserve foreground regions that have a similar shape to the structuring element or that can completely contain the structuring element, while eliminating all other regions of foreground pixels. The opening operator therefore requires two inputs: an image to be opened, and a structuring element. The opening of an image can be described mathematically as follows:

$$I_{open} = (I \Theta S) \oplus S \tag{1}$$

where I and Iopen are the face segmented image and the output opened image, respectively; S is the structuring element, Θ and $\oplus$ are the morphological erosion and dilation operators.

After the opening operation, top-hat segmentation method is implemented. A top-hat method is a combination of erosion and dilation operators in a gray-scale image. Generally a top-hat method helps to enhance the bright (‘hot’) ridge-like structures in the image. The top-hat segmentation is of two forms: white top-hat segmentation and black top-hat segmentation. Here we use white top-hat segmentation. In this method, the original image is first opened and then, this opened image is subtracted from the original image. The top-hat segmented image Itop is thus given by

$$I_{top} = I - I_{open}. \tag{2}$$

where Itop is the top-hat segmented image, I and Iopen are the face segmented image and the output opened image.

C. Feature extraction

The features are extracted from the result of the top-hat segmentation method. The features extracted here are the distance measures. Three distances are measured using suitable matlab codes. Initially, the distance between the two eyes is measured. Secondly, the mid distance between the eyes is measured. Finally, the nose width is measured. The distances measured are compared for at least 3 images of the same subject. Hence we observed that these extracted features from the human face are unique for each individual.

III. RESULTS

Thermal imaging is a very vast area that is used for different applications. In this work, thermal imaging is used as a biometrics approach in face recognition. We have recorded real thermal image data of human face by a FLIR A305sc infrared camera in an indoor environment. The image size is 240 × 320 pixels. The thermal images are then processed using image processing techniques. The input image, the results of the morphological operations on the image and the final output images are represented as follows:

Fig 3. Input image

Fig 4. Segmented face image

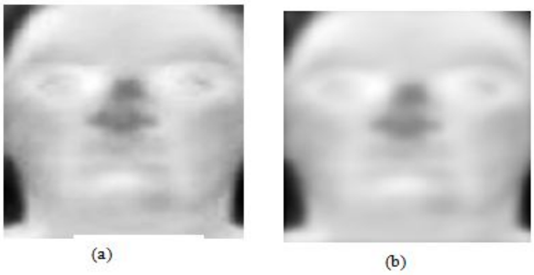

Fig 5. (a) Grayscale Image, (b) Output obtained using anisotropic diffusion filter

Fig 6. Result of the Opening operation

Fig 7. Result of Top-hat segmentation

Fig 8. Distance measure-1 output image

(The entire distance between the right eye to the left eye)

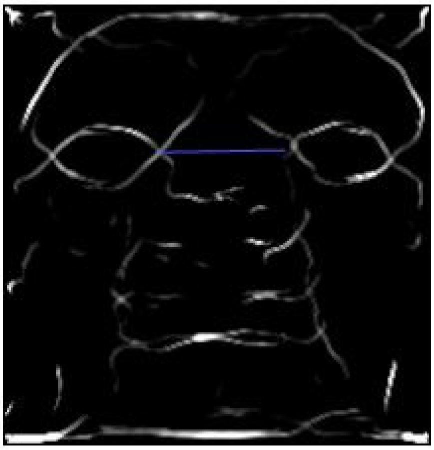

Fig 9. Distance measure-2 output image

(The mid-distance between the two eyes)

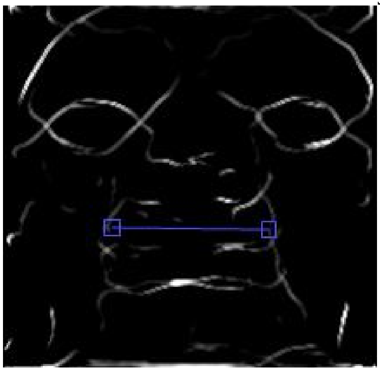

Fig 10. Distance measure-3 output image

(The width of the nose)

The feature values such as the three distance measures of the human face are tabulated for three subjects as shown below:

TABLE I

TABULATED FEATURE VALUES FOR THREE DIFFERENT SUBJECTS

SUBJECT	IMAGE NO	FEATURE-1 MEASURE	FEATURE-2 MEASURE	FEATURE-3 MEASURE
Subject 1	1	160	50.09	66.2
	2	160	50.08	66.2
	3	160	50.08	66.1
	4	160	50.09	66.2
	5	160	50.08	66.2
Subject 2	1	155.2	54	60
	2	155.2	54	60
	3	155.2	54	60
	4	155.2	54	60
	5	155.1	54	60
Subject 3	1	165	48.9	70.05
	2	165	48.9	70.05
	3	165	48.9	70.05
	4	165	48.7	70.05
	5	165	48.7	70.05

IV. DISCUSSION

Guzman et al. discussed a thermal imaging framework that consolidates the steps of feature extraction through the use of morphological operators and registration using the linear image registration tool. The matching showed an average accuracy of 88.46% for skeletonized signatures and 90.39% for anisotropically diffused signatures. Facial skin temperature is closely related to the underlying blood vessels; thus by obtaining a thermal map of the human face we can also extract the pattern of the blood vessels just below the skin. The object of interest in this work is mainly the thermal pattern in the face region and part of the neck area. Before the face region can be segmented from the image, it is necessary to enhance the quality of the image. After segmenting the face region from the image, the next step is to identify superficial blood vessels from segmented face region. The actual temperature of a blood vessel is higher than that of the surrounding tissues and therefore can be considered as a heat source.

P. Buddharaju et al. demonstrated the feasibility of the physiological framework in face recognition and opened the way for further methodological and experimental research in the area.

G. Koukiou et al. discussed the activity of the facial blood vessels of drunk persons using thermal infrared images. Nonlinear anisotropic diffusion is applied to enhance the vessels on the images and after that top-hat transformation is used for isolating them from the rest information on the face. Simple thresholding is applied to raise the more active vessels. Registration procedures are employed to easily compare the vessel activity on the face of the drunken person with that on the sober person. In drunken persons, vessels around nose and eyes as well as on the forehead become more active. This work constituted a preliminary study, which aims at qualitative and not quantitative results. Basically, the restricted number of the 20 persons that participated in the experiment is not considered adequate for statistical inference.

In this study, thermal images of thirty volunteers were taken in an indoor environment. The proposed method comprises a novel approach to face recognition using thermal images. The thermal images are collected and image processing methods are applied to the images. The object boundaries are enhanced by performing the anisotropic diffusion filter operation and the thermal map was extracted by using morphological top-hat operation. Other studies using thermal images have shown similar accuracies; however, this work produces a defined methodology creating a thermal pattern where the features are extracted from it.

CONCLUSION

We have outlined a novel approach for biometric facial recognition based on extracting consistent features from multiple thermal infrared images. The thermal infrared images are acquired using a FLIR A305sc thermal camera. In this experimental procedure, thirty subjects were involved. The acquired images from different subjects are then processed using image processing techniques. In this approach manual and automatic segmentation is used so as to obtain only the face from the rest of the image. Morphological operations like opening and top-hat segmentation are performed on the image in order to enhance the bright objects in the image. Finally, a thermal pattern is created for each individual. This thermal pattern is then used for the feature extraction.. Then the features are compared as quantitative distance measures between different subjects. One of the major advantages of this approach is the ease of implementation. Therefore the experimental results encourage the application of thermogram for human face recognition.

However, this approach is applicable to front views and constant background only. It may fail in unconstraint environments like natural scenes. The future work would be the implementation of training classifiers for the matching process. More efficient database and methodology for the classification stage can be created in order to compare the features of each and every individual with better accuracy.

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