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AN APPROACH FOR BIOMETRIC FACIAL RECOGNITION BASED ON EXTRACTING CONSISTENT FEATURES FROM THERMAL INFRARED IMAGES

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ABSTRACT

An approach for biometric facial recognition based on extracting similar features from the thermal infrared images. The main objective of this work is to identify the individual thermal facial signature. This approach is fully integrated and combines the major steps of image registration using MATLAB tool, feature extraction through the use of some morphological operations, and matching through similarity measures based on Euclidean distance. The approach collected input thermal images using Mobile (Android apps) camera system which operates in thermal vision. The matching using similarity measures showed an accuracy of 100% skeleton zed signatures and templates.

Index Terms**—** Facial recognition, data collection, image registration, feature extraction, image segmentation, image morphology.

1. INTRODUCTION

The face of an individual is a biometric trait that can be used in computer-based automatic security system for identification or authentication of that individual. The main challenge of recognizing a face through a machine is to accurately match the input human face with the face image of the same person already stored in the face-database of the system. The various applications of face recognition relate mainly to the field of security. Having so many applications of this interesting area, there are some challenges as well as pros and cons of the systems. The basic input of any face recognition system is the face image of a subject. Face images may be of different types like visual, thermal, sketch and fused images.

A face recognition system suffers from some typical problems. For example, visual images result in poor performance with illumination variations, such as indoor and outdoor lighting conditions, low lighting, poses, aging, disguise etc. So, the main purpose is to overcome all these problems to give an accurate automatic face recognition. These problems can be solved using thermal images and also using fused images of visual and thermal images. The image produced by employing fusion method provides the combined information of both the visual and thermal images and thus provides more detailed and reliable information which helps in constructing more efficient face recognition system.

Any typical face image is a complex pattern consisting of hair, forehead, eyebrow, eyes, nose, ears, cheeks, mouth, lips, philtrum, teeth, skin, and chin. Also human face has other additional features like expression, appearance, adornments, beard, moustache etc. The patterns of specific organs such as the eyes or parts are used in biometric identification to uniquely identify individuals. Thermal face recognition deals with the face recognition system that takes thermal face as an input. Thermal human face images are generated due to the body heat pattern of the human being. Thermal Infra-Red (IR) imagery is independent of ambient lighting conditions as the thermal IR sensors only capture the heat pattern emitted by the object. According to the temperature and characteristics, different objects emit different range of Infra-red energy. The range of human face and body temperature nearly same and quite uniform, varying from 35.5°C to 37.5°C providing a consistent thermal signature. The thermal patterns of faces are derived primarily from the pattern of superficial blood vessels under the skin. The vein and tissue structure of the face is unique for each person and, therefore, the IR images are also unique.

Using the thermal infrared mid-wave infrared (MWIR) portion of the electromagnetic (EM) spectrum, any foreign object on a human face such as a fraudulent nose could be detected, as these foreign objects have a different temperature range than that of human skin. Due to these advantages, a lot of effort has been taken for developing human face recognition systems using MWIR spectrum. However, the cameras working in the MWIR portion of EM spectrum are available at a much higher cost than their visible band equivalent, but the research done in human face recognition in the MWIR spectrum is still in its infancy.

In this study, we expand this research by presenting an integrated approach that combines unique algorithms at extracting thermal imaging features, generating templates that rely on the most consistent features, and matching these features through newly developed similarity measures for authentication. The approach to face recognition using MWIR imaging is checked against another existing database to prove the reliability of the algorithms designed for feature extraction, template generation, and authentication through similarity measures.

2. MATERIALS AND METHODS

The work presented in this study consists of three important modules: 1) collection of thermal images, 2) feature extraction, and 3) feature matching. In each of these modules, different instructive steps and safeguards starting from camera calibration to facial thermal signature extraction are taken to assure the authentication through the consistent features.

A. Collection of Thermal Images

Data collection was accomplished using the Mobile (Android apps) camera system which operates in the thermal vision. For this study, we collected thermal infrared images using android mobile camera. Each subject was asked to sit in front of the thermal infrared camera and asked to sit straight and a snapshot of their frontal view was taken.

B. Feature Extraction

After the thermal camera is calibrated, one of the most challenging tasks of any biometric face recognition system is the feature extraction process. Thermal feature extraction from facial images was obtained by executing the morphological operations such as opening and top-hat segmentation to attain thermal signatures for each subject. The major contribution of the process at this stage is in the way unique signature templates are generated for each individual, which through anisotropic diffusion and unique registration processes. This is a necessary step that guarantees the facial authentication. Fig. 1 displays the flowchart of the entire procedure showing the steps required for the feature extraction process to generate thermal signature templates which will then matched against any facial signature as input to the system.

1) Thermal Infrared Image Registration: One of the challenging task in the field of image processing is image registration. The process of aligning two or more images of the same scene is the Image registration. For image registration, different techniques are available for medical images and for images in biometric applications. The image registration of the collected thermal infrared images was performed using MATLAB tool for image registration. This type of image registration is based on features of the image. Image processing toolbox provides a complete set of reference standard algorithms, functions and applications for image processing analysis and visualization. Image enhancement, image segmentation, feature detection, image registration etc can be performed using this toolbox. This toolbox support diverse image type like high dynamic range, gigapixel resolution. It supports images generated by a wide range of devices including digital cameras, satellite and airborne sensors, medical imaging devices, microscopes, telescopes and other scientific instruments. The main purpose of the image registration is to account any movements of the subject that could have taken place during data collection from the subject. This reduces the overwhelm of the signatures and templates, and makes similarity measurements more meaningful. Fig.2 shows the results of the registration process for the input image.

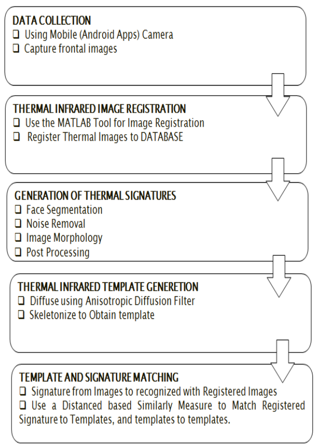
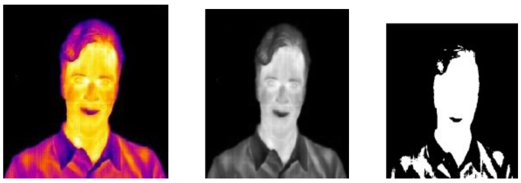


Figure. 1. Flow diagram of the entire biometric face recognition based on consistent features from thermal infrared images.



(a) (b) (c)

Figure. 2. Results of thermal image registration procedure. (a) Input test image. (b) Image to be registered. (c) Registered image after using the matlab registration tool.

2) Thermal Signature Extraction: After registering the thermal images for the subject,we then proceed to extract the thermal signature in each image. The thermal signature extraction has four main sections. They are face segmentation, noise removal, image morphology, and post processing.

a) Face segmentation: In this step, only the face of the subject was segmented out from the rest of the image. The segmentation process was carried out by implementing the technique of dual-front active contour region-growing technique. This technique is for detecting the object boundaries and it is an iterative process. The face region segmented here does not take into consideration the neck of the subject. This is achieved by creating a mask similar to the input image and then segmented out only the face through some iteration steps using the mask. Since some subjects tended to wear clothing that obstructed the neck region area, we chose not to include that region for uniformity in the segmentation process as well as in performing the similarity measurements to include only the face.

The well-known Yezzi energy is used to model the energies of the interior and exterior of the contour for face segmentation purposes. The Yezzi energy may defines a dual-front active contour, which is widely used for segmentation purposes. The dual front evolution provides the automatic stop criterion in each iteration and the computational cost is reduced significantly. The algorithm proceeds by evolving the inner and outer boundaries to reach minima where the inner and outer boundary contours intersect after applying a single iteration of the algorithm called the dual front active contour region growing technique. Fig.3 shows the original thermal image and the resultant image after the dual-front active contour segmentation.

b) Noise removal: After the face was segmented from the rest of the thermal infrared image, we continued to remove unwanted noise in order to enhance the image for further processing. For this we combined directional filter and diffusion filter. A standard directional filter is first applied to the entire thermal image. This is for increasing recognition accuracy.

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. Also this filter eliminates the aliasing effects.

c) Image morphology: A way of analyzing images based on shapes is known as Image morphology. The top-hat segmentation and opening are the operators used in this experiment. The top-hat segmentation has two versions: white top-hat segmentation and red top-hat segmentation. In this paper we use the white top-hat segmentation as this process enhances the bright objects in the image. This operation is defined as the difference between the input image and its opening. The process of the top-hat segmentation is based on the requirements to segment the regions associated with those of higher intensity,which demarcate the facial thermal signature. The objective in this process is to enhance the maxima in the image. The top-hat segmented image is given by

$$I_{top} \quad I \quad I_{ope} \qquad (1)$$

The outcome of an opening operation is to protect foreground regions that have a similar shape to the structuring element or that completely contain the structuring element, while eliminating all other regions of the foreground pixels.

$$I_{ope} \qquad I \Theta S \; \oplus S \qquad (2)$$

Θ and $\oplus$ are morphological erosion and dilation operators.

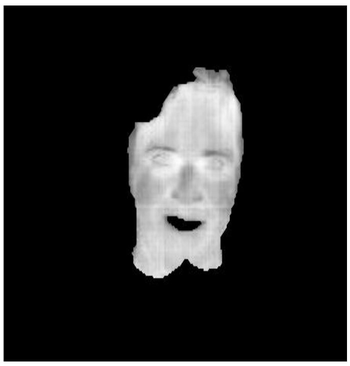


Figure. 3 Result of the segmentation process showing the input thermal image and the face segmented image.

Figure. 4 shows the resultant of top-hat segmentation and its complement image.

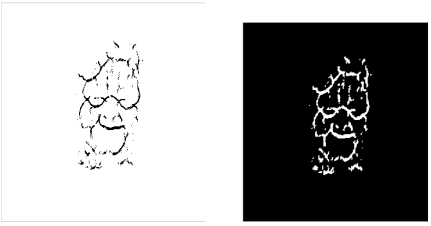


Figure.5. Result of the image morphology process showing the top-hat segmented image and its complement image.

d) Postprocessing: After the image morphology process, the skeletonization process is used to reduce the foreground regions into a skeletal portion. The skeletonization process is done by a morphological operation known as thinning. Thinning is used to remove selected foreground pixels from binary images. Morphological thinning is defined as hit-miss transform. Fig. 5 shows the resultant image after the postprocessing approach. Fig. 5(b) shows the image of the thermal signature of the particular subject.

e) Generation of thermal signature template: Thermal signatures in an individual vary slightly from day to day due to various reasons like exercise, environmental temperature, weight, health of the subject, temperature of the imaging room, etc. Taking into consideration the various factors that may affect the thermal signature, this paper establishing a thermal signature template that preserves those characteristics in a person's thermal signature that are consistent over time. We then applying an anisotropic diffusion filter in order to fuse the predominant features. The generation of thermal signature template of the subject is illustrated in Fig. 6.

Fig. 7 shows how the thermal signature template is overlaid on the thermal image of the subject.

C. Feature Matching

Similarity measures are widely used in applications like databases, in which a query image is a partial model of the user's desires and the user looks for images similar to the query image. We make use of similarity measures because we are attempting to find a thermal infrared template similar to the query thermal infrared signature. The matching between templates and signatures was done using a similarity measure based on the Euclidean distance.

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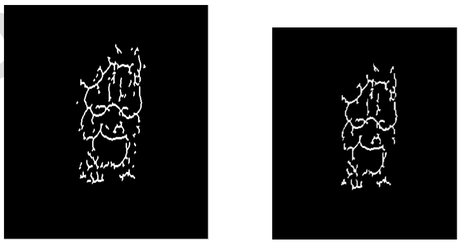
We take a thermal infrared signature A and thermal infrared template B then the similarity measure between A and B, denoted by $S \quad \rightarrow \quad B)$, is defined as follows:

$$S \quad \rightarrow \quad \sum \quad \frac{}{} \qquad (3)$$

where *1eh* is the weight associated in matching a single feature. The parameter *h* denotes the minimum number of feature points found in either A or B. The parameter D*i* is the minimum Euclidean distance between *i*th feature point in B and its closest feature point in A.

(a) (b)

Figure. 6. Result of the signature extraction procedure. (a) Original image. (b) Thermal signature.



(a) (b)

Fig. 7. Generation of thermal signature template. (a) Closed skeleton image. (b) Thermal signature template of the subject.

3. RESULTS

To demonstrate the recognition accuracy of the generated templates for each of the subject, we calculated the similarity between the various templates using similarity measures based on Euclidean distance. The matching using the similarity measures showed 100% accuracy using Euclidean distances. The data collection is acquired using Mobile (Android apps) camera system which operates in the thermal vision. Then this images were registered using MATLAB tool. After registration the thermal signature of the images were extracted through various methods: face segmentation, noise removal, image morphology, and post processing. In enhancement the noise removal was done by combining the directional filter and anisotropic diffusion filter for increasing recognition accuracy. The feature matching was done using similarity measures based on Euclidean distance. The recognition accuracy obtained using similarity measures based on Euclidean distances was 100%. Also this method showed lower accuracy, less than 10%, for invalid images in the database.

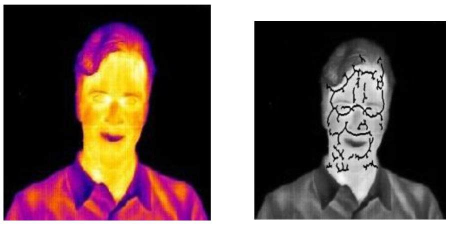


Figure. 8 Illustrative of thermal template overlaid on the thermal image of the subject.

4. CONCLUSION

This paper has presented an approach for biometric facial recognition based on extracting consistent features from thermal infrared images. This approach accomplished data collection using Mobile (Android apps) camera system. Then this images were registered using MATLAB tool and dual-front active contouring algorithms are used for face segmentation.

The noise removal was done using combined directional filter and diffusion filter. The morphological image processing methods were developed to extract features from the thermal images. Then using these features thermal signatures were created. These signatures were used to generate thermal signature templates which were then matched using similarity measures based on Euclidean distance. The matching between templates and signatures was done using similarity measure based on Euclidean distance. Using Euclidean distance based similarity measure, we obtained 100% recognition accuracy. The accurate results acquired in the matching process clearly show the ability of thermal infrared system to be used on other thermal imaging based systems and their related databases.

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