THERMAL IMAGING AS A BIO METRICS MOVES TOWARDS TO FACIAL SIGNATURE SUBSTANTIATION

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Abstract—Thermal imaging framework with distinctive feature extraction and correspondence dimensions for face recognition is presented. The research foundation is to design dedicated algorithms that would extract vasculature information, generate a thermal facial signature, and identify the personality. The anticipated algorithm is fully integrated and consolidates the critical steps of feature extraction through the use of morphological operators, and registered, and matching through unique similarity measures designed for this task. The narrative approach at emergent a thermal signature template using four images taken at various instances of time ensured that unforeseen changes in the vasculature over time did not affect the biometric matching process as the authentication process relied only on consistent thermal features. The highly truthful results obtained in the matching process evidently express the ability of the thermal infrared system to extend in application to other thermal-imaging-based systems.

Keywords—Biometric, Face recognition, Image registration, Image segmentation, Thermal imaging

I. INTRODUCTION

Identification systems rely on three key elements: 1) Attribute identifiers (e.g., Social Security Number, license number, and account number), 2) biographical identifiers (e.g., address, profession and education), and 3) biometric identifiers (e.g., fingerprint, iris, voice). It is rather easy for an individual to falsify attribute and biographical identifiers; however, biometric identifiers depend on intrinsic physiological characteristics that are difficult to falsify or alter. Applications for face identification can be found in the areas of entertainment, smart cards, information precautions, law enforcement, medicine, and security. Diverse techniques and systems have been created for face detection in areas that use cameras in the visible spectrum. Machine recognition of human faces has experienced great strides but remain challenged by intricate issues related to light variability and other factors like difficulty in detecting facial disguises. In this study, we extend this research by presenting an integrated approach that consolidates distinctive algorithms at extracting thermal imaging features, producing templates that rely on the most consistent features, and matching these features through newly developed similarity measures for authentication. Given the complex nature of human vasculature, this approach to face recognition using thermal imaging is checked against another existing database to prove the reliability of the algorithms designed for feature extraction, pattern generation, and authentication through comparison measures.

II. SYSTEM OVERVIEW

The work presented in this study consists of three major modules: 1) Thermal Infrared Image Registration & Face Segmentation, 2) Thermal Signature Extraction on, 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 ensure that authentication is made through features that are consistent through several image acquisition times and are therefore more likely to be part of the vasculature of the individual.

A. Collection of Thermal Images

Data collection was accomplished using the Android Application Thermal Vision camera. Thermal Vision Camera simulates the Effect of Heat Vision Goggles. Thermal Vision Camera tries to use phone’s camera capabilities to get better pictures and uses a luminance boosting algorithm to enhance the image brightness. It also tries to configure phone’s camera for maximum visibility in the dark by configuring your phone’s shutter speed, scene mode, etc. For this study, we collected thermal images from few different subjects. Each subject was asked to sit straight in front of the camera and asked to look straight into the lens and a snapshot of their frontal view was taken and registered into database.

B. Face Segmentation

In this step, the face of the subject was segmented from the rest of the image. The segmentation process was achieved by implementing the technique of localizing region-based active contours in which typical region-based active contour energies are localized in order to handle images with non homogeneous foregrounds and backgrounds. The face region segmented here does not take into consideration the neck of the person.
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This is achieved by localizing the contouring algorithm to a neighborhood around the point of interest with a localization radius of 5 pixels. Since some subjects tended to wear clothing that obstructed the neck region area, we opted not to include that region for uniformity in the segmentation process as well as in performing the similarity measurements to involve only the face. Let $\mathcal{Y} = \{ a \in \mathbb{R} \mid 0 \leq a \} = \gamma$ be a closed contour of interest. The interior of the closed contour $\mathcal{Y}$ is expressed in terms of the smoothed approximation of the signed distance function given as,

$$
\phi(x) = \begin{cases} 
1, & \phi(x) < -\varepsilon \\
0, & \phi(x) > \varepsilon \\
\frac{1}{2} \left( 1 + \frac{\phi(x) - \varepsilon}{\varepsilon} \right) \sin \left( \frac{\pi \phi(x)}{2\varepsilon} \right), & \text{otherwise} 
\end{cases} 
$$

where $\phi(x)$ is a smoothed initial contour and $[-\varepsilon, \varepsilon]$ represents the boundary of the Heaviside function in (1). In reference to (1), the exterior of the closed contour is given as $1 - H(\phi(x))$. In order to model the energies of the interior and exterior of the contour for face segmentation purposes, the well-known Yezzi energy is used. The Yezzi energy defines a dual-front active contour, which is broadly used for segmentation purposes in cases where the solution may fall in a local minima and yield poor results. The algorithm operates by first dilating the user-selected initial contour to generate a potential localized region $R$ for the optimal segmentation. Thus

$$
\mathcal{C}(x, y, t) = \frac{1}{1 + \left( \frac{\|\nabla f\|}{G} \right)^2} 
$$

where $S$ is a spherical structuring element of the localization radius (i.e., 5 pixels) and $\Box$ is the dilation operator.

The algorithm proceeds by developing the inner and outer boundaries of $R$ to reach minima here the inner and outer boundary contours intersect after applying a single iteration of the algorithm called the dual-front active contour region growing technique. The newly created intersection acts as a new initialization and the process is repeated until the Yezzi energy function is minimum. Fig. 3 shows the original thermal image and the resultant image after the segmentation procedure. It can be seen that the algorithm profitably segments out the face removing the neck and the hair region from the face.

C. Thermal signature extraction

After registering the thermal images for each subject, we proceeded to extract the thermal signature in each image. The thermal signature extraction process has three main sections: noise removal, image morphology, and post-processing. a) Noise removal: After the face was segmented from the rest of the thermal infrared image, we proceeded to remove unnecessary noise in order to improve the image for further processing. A standard Perona–Malik anisotropic diffusion filter is first applied to the entire thermal image. The significance of the anisotropic diffusion filter in this particular application is to condense spurious and speckle noise effects seen in the images and to improve the edge information for extracting the thermal signature. For the diffusion filter, a 2-D network structure of eight neighboring nodes (north, south, east, and west, northeast, northwest, southeast, and southwest) is considered for diffusion conduction. The conduction coefficient function used for the filter applied on the thermal images aims to privilege edges over wider regions in order to enhance regions of high thermal activity related with the thermal signature. Thus, the conduction coefficient function used for the application is given by

$$
\mathcal{C}(x, y, t) = \frac{1}{1 + \left( \frac{\|\nabla f\|}{G} \right)^2} 
$$

where $\nabla f$ is calculated for the eight directions and $G$ is the gradient modulus threshold that controls the conduction and avoids the blurring of facial features.
B) Image Morphology:

Image morphology is a way of analyzing images based on shapes. In this study, we assume that the blood vessels are a tubular-like structure running along the length of the face. The operators used in this experiment are opening and top-hat segmentation, which are detailed next. The effect of an opening operation is to preserve foreground regions that have a similar shape to the structuring element or that can entirely contain the structuring element, while eliminating all additional regions of foreground pixels. The opening of an image can be described mathematically as follows,

\[ I_{\text{open}} = (I \ominus S) \oplus S \]

where \( I \) and \( I_{\text{open}} \) are the facet segmented image and the output opened image, respectively; \( \Theta \) and \( \square \) are the morphological erosion and dilation operators.

The top-hat segmentation has two versions; for our intention, we use the erosion known as 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 selection of the top-hat segmentation is based on the reality that we desire to segment the regions connected with those of higher intensity, which demarcate the facial thermal signature. The task in this step is to enhance the maxima in the image. The top-hat segmented image \( I_{\text{top}} \) is thus given by,

\[ I_{\text{top}} = I - I_{\text{open}} \]

C) Post Processing:

After obtaining the maxima in the image, the skeletonization process is used to reduce the foreground regions into skeletal remains that largely preserve the extent and connectivity of the original region. This is a homotopic skeletonization process whereby a skeleton is generated by image morphing using a series of structural thinning elements from the Golay alphabet. Morphological thinning is defined as a hit-or-miss transformation which is basically a binary template matching where a series of template M1 through M8 are searched throughout the image. A positive search is annotated as 1 and a miss as 0. This annotation is the result of the following mathematical expression,

\[ I_{\text{skeletal}} = I_{\text{top}} \ominus (I_{\text{top}} \ominus M_i) \]

Where \( \ominus \) is the hit-or-miss operator and \( M_i \) is the set of structuring elements M1 through M8. The first two structuring elements used for the skeletonization process are shown as follows,

\[
M_1 = \begin{bmatrix}
1 & 1 & 1 \\
0 & 1 & 0 \\
0 & 0 & 0
\end{bmatrix},
M_2 = \begin{bmatrix}
0 & 1 & 0 \\
0 & 1 & 1 \\
0 & 0 & 0
\end{bmatrix}
\]

The rest of the six structuring elements can be obtained by rotating both the masks M1 and M2 by 90°, 180°, 270°.

D) Generation of Thermal Signature:

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, and many more. Taking into consideration the various factors that may affect the thermal signature; the projected approach relies on establishing a thermal signature template that preserves those characteristics in a person’s thermal signature that are consistent over time. The generation of a thermal signature template consists of taking the extracted thermal signatures for each subject and adding them together. The resulting image is a composite of four thermal signature extractions, each one slightly different from the other. The goal is to keep the features that are present in all the images as the dominant features that otherwise define best the individual signature. We then apply an anisotropic diffusion filter to the result of the added thermal signatures in order to fuse the predominant features additionally directional filter is added to get more vasculature information for thermal signature.

D. Distance-Based Similarity Measure for Thermal Infrared Signatures and Template Matching

Similarity measures are widely used in applications like image 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. In our study, we make use of similarity measures because we are attempting to find a thermal infrared template similar to the query thermal infrared signature. Given a thermal infrared signature P (non-reference image), and a thermal infrared template Q (reference image), the similarity measure between P and Q, denoted by \( S(P \rightarrow Q) \), is defined as follows:

\[ S(P \rightarrow Q) = \frac{1}{h(D_i + 1)} \]

where \( 1/h \) is the weight associated in matching a single feature (or thermal pixel). Parameter \( h \) denotes the minimum number of feature points found in either P or Q, i.e., \( h = \min(NP, NQ) \), where NP and NQ are the number of features in P and Q, respectively. Parameter \( h \) is the maximum number of features that we could obviously match. The parameter \( D_i \) is the minimum Euclidean or Manhattan distance between the ith feature point in Q and its closest feature point in P. In finding \( D_i \), the distance of all features in P to those in Q are computed, thus creating a vector containing \( h \) Euclidean distances for every feature point. The two features that correspond to the minimum distance in the vector are then matched; this process continues until all features are considered. Also, when two or more features in P
match the same feature in Q, it means that two or more features in P are equidistant to Q. In such a case, we decided to take the first feature in P and match it to Q. It is to be noted that the similarity measure defined in the study obeys the property of symmetry as long as the image with the minimum number of features (h) is referred to as the reference window or reference image. In addition to computing similarities with the skeletonized templates of the subject, we calculated the similarities between the diffused versions of the signatures and templates. The motive behind generating a diffused template and comparing to it was to see if minor errors resulting due to misalignment of the images have an impact on the similarities.

III. DISCUSSION

Some few subjects were used to create an in-house database and we successfully obtained the thermal infrared signatures and templates for the subjects. In existing system the matching using the similarity measures showed 88.46% accuracy in case of skeletonized feature signatures and 90.39% accuracy for anisotropically diffused feature signatures using Euclidean distances, whereas an accuracy of 90.39% was obtained using both skeletonized and diffused templates additionally we are adding directional filter to get accurate extraction of vasculature information so we expect high accuracy than existing system. Such high accuracies in the matching process clearly demonstrate the ability of the developed thermal infrared feature extraction and the distance-based similarity measure for accurate, low cost, and effective subject matching.

The technique demonstrated an accurate, fast, and user-initialization independent/free technique for registering thermal facial images. User-initialization independence is of great importance in automating the matching process in case of larger databases. The generalized structure of this approach, together with the uniqueness in the way thermal signature templates were generated and the similarity measure was formulated, allows this approach to extend to other thermal images and databases. Caution should be taken however on what really constitutes a thermal pixel that is assumed to belong to the vasculature or at least consistent through time using several thermal images. Thermal infrared image databases are available or research, but the image quality in these databases is unsuitable for our purpose due to the lack of NUC performed before gathering images which leads to erroneous feature extraction; other databases provide images of subjects in the outdoors and ho are too far away from the camera to be able to extract a meaningful facial signature. Since these databases were not collected with the purpose of extracting features such as facial blood vessels patterns, future work would be to obtain a greater number of subjects to build a larger database for testing the algorithm.

CONCLUSION

This paper has presented a new approach for biometric facial recognition based on extracting consistent features from thermal images. The approach used localized-contouring algorithms to segment the subject’s face. A morphological image processing technique was developed to extract features from the thermal images, thus creating thermal signatures; these signatures were used to create templates. Signatures are diffuse using Anisotropic diffusion filter are used and skeletonize to create templates, which were then matched using similarity measures. The matching between templates and signatures was done twice using a similarity measure based on 1) the Euclidean distance and 2) the Manhattan distance. In our proposed approach we additionally directional filter is added to extract high vasculature information in template generation and then skeletonize to obtain high accuracy in template matching.

REFERENCES

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