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A Novel Algorithm to Tackle Eyeglasses and Beard Issues in Facial IR Recognition

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Abstract

Face recognition via thermal infrared (IR) images is a modern recognition method that has found so interesting for many researchers during last decade. This method which operates via thermal features and the situation of human face vessels has much more benefits than visual-based methods. In these images, the changes of environmental light, which is one of the most important problems of face recognition via visual images, are completely eliminated. The most important face recognition problem via thermal IR images is the existence of diffusion obstacles like glasses, which blocks an accurate extraction of the face vessels situation. Using the proposed algorithm, this problem has been completely removed. In this article face recognition is performed through face vessels. In fact, the proposed method solves the issues of face recognition (like glasses wearing) in the thermal infrared domain. For extraction of the face features, the situation of vessel branches is used. Also, by choosing appropriate classification, fake vessels and false branches are removed. On the other hand, the best feature is extracted by using Dynamic Time Wrapping (DTW) algorithm which is resistant to nonlinear changes. The simulation on UTK-IRIS gallery set shows that the accurate recognition rate 95% and 97% on the images with glasses and beard, respectively. Thus, the proposed method has improved the recognition rate about 10% on same gallery set compared to the best other methods.

Keywords- Face recognition; Thermal infrared images; Facial vessel; DTW

1. Introduction

Face recognition technology has found a wide range of potential applications related to security and safety including surveillance, information security, access control, and identity fraud. For example, detection of criminals, observation and security systems and similar applications are some cases held in this compass and therefore accurate face recognition can play an effective role. In recent years, face recognition has been used in research fields related to biometrics, pattern recognition and machine vision [1, 2].Several face recognition algorithms have been developed in recent years mostly in visible and a few in IR domain.

Infrared images are classified as: Near IR (NIR), MWIR and LWIR. NIR image is similar to visual images, but difference is source of light. In NIR image the source of light is IR. On the other hand, face recognition method in NIR image is similar to visual image [14, 15].

A serious problem in visible face recognition is light variability [3], due to reflective nature of incident light. In addition, in visual images each external object placed on the face is considered as a part of the face. Thus, the face recognition based on visual images cannot function properly.

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In the proposed method which is based on the recognition of face vessels in thermal IR images [4], the images are not being affected by environment light as shown in Fig. 1. The identification between real and fake images and the low affectability against facial expression changes are some power points of the proposed method. Due to dependency of the thermal IR images to vessels situation, the age factor has low effect on performance of the system.

However, thermal face images with eyeglasses may fail to provide useful information around the eyes since glass blocks a large portion of thermal energy (see Fig. 1). In this paper, by using DTW comparator, this problem is removed.

The proposed system operates in the following two phases for face recognition:

- **Creation of Best Thermal Minutia Point (BTMPs) database**: In this phase, the Thermal Minutia Points (TMPs) image is extracted for existent thermal facial images (we have four images in frontal pose per individual person) and the best of them is saved for each person. This phase is illustrated in Fig. 2.
- **Online phase:** In online phase, TMPs image of probe thermal facial image are extracted and matched against those of the corresponding images stored in the BTMPs database (see Fig. 3).

Figure 1: Ineffective light variability for thermal IR images, (a) Visual images with light variability and (b) Thermal IR images.

In following sections, we describe the proposed face recognition methodology and its performance in details. In section 2, we present how BTMPs database is created. In section 3, we discuss the matching algorithm in online phase. In section 4, we present the experimental results and attempt a critical evaluation. We conclude the paper in section 5.

2. Creation of BTMPs database

In this part the processes of creation of BTMPs database shown in Fig. 2 is described.

2.1 Face Segmentation

Due to physiology issue, a human face consists of "hot" parts corresponding to tissue areas that are rich in vasculature and "cold" parts result in tissue areas with sparse vasculature [6]. This causes that the human face is considered as a bimodal temperature distribution entity, which can be modeled using a mixture of two normal distributions. Similarly, the background can be described by a bimodal temperature distribution with walls being the "cold" objects and the upper part of the subject's body dressed in cloths being the "hot" objects. The consistency of bimodality across subjects and image backgrounds is striking. For face segmentation in IR images, Bayesian algorithm suggested in [5] has been used. The reason for using this algorithm is existence of almost equal distribution of human's face temperature from 25 to 30. For face detection, first, the face and background thermal distribution is determined based on histogram diagram quantity and then the two Gaussian estimating functions, estimate the face and background thermal distribution [7]. In Bayesian algorithm, training data including the areas of background and face are used in two separate vectors to estimate the parameters of face and background thermal distribution. Fig. 4 shows a sample of training data. In this figure, the areas of background hair and clothes and the areas of face between forehead and chin have been selected. Fig. 5 indicates the result of face segmentation.

2.2 Vessel Extraction

In a thermal imagery of human tissue, the major blood vessels have weak sigmoid edges. This is due to the natural phenomenon of heat diffusion, which entails when two objects with different temperatures are in contact (e.g., vessel and the surrounding tissue) heat conduction creates a smooth temperature gradient at the common boundary [5]. These weak sigmoid edges can be handled effectively by using anisotropic diffusion. The anisotropic diffusion filter is formulated as a process that enhances object boundaries by performing intra region as opposed to inter region smoothing.

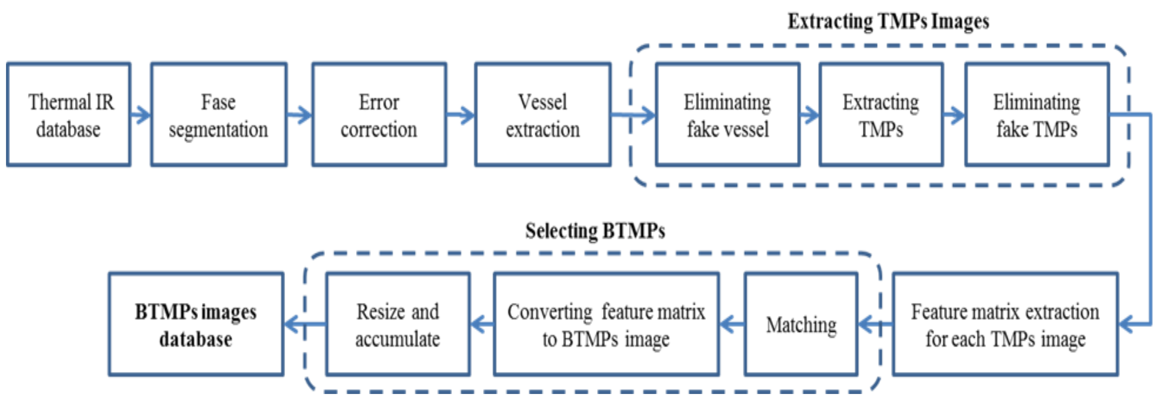


Figure 2: Architecture of creating BTMPs database

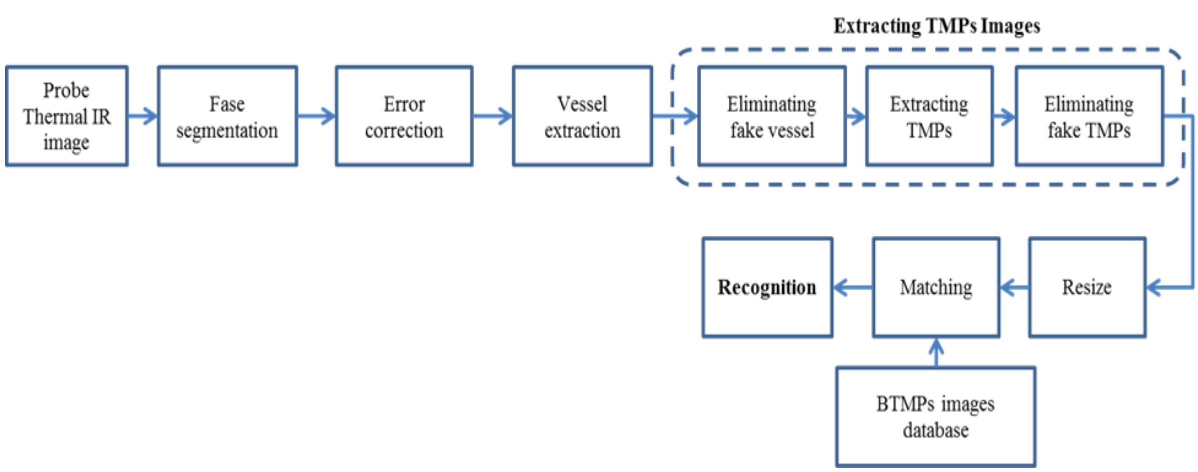


Figure 3: Architecture of online phase

Figure 4: Face and background training data, black square indicates face area and white squares indicates background area.

(a) (b)

Figure 5: Result of face segmentation, (a) Original image and (b) Result of applying Bayesian algorithm

One can visualize this clearer in an area with sparser vasculature than that of the face. Image morphology is then applied on the diffused image to extract the blood vessels that are at a relatively low contrast compared to that of the surrounding tissue. For this purpose, we employ a top hat segmentation method, which is a combination of erosion and dilation operations [5]. Fig. 6c shows the vessels extracted via white top hat segmentation.

2.3 Extracting TMPs Images

The TMPs extraction from binary images is performed after thinning the vessels out in previous section. These points are the crossing place of the vessels and they are extracted as features. For increasing efficiency and decreasing errors, the fake crosses (the small bridges between the vessels) and the fake TMPs are eliminated and the appropriate TMPs are selected. The extracted TMPs are formed by 3 parts which are: eliminating fake vessel, extracting TMPs and eliminating fake TMPs. In the following steps, they will be briefly stated.

(a) (b) (c)

Figure 6: The result of error correction, (a) Result of applying Bayesian algorithm (Fig. 5b), (b) Result of error correction and (c) Vessel extraction.

2.3.1 Elimination of fake vessel

In vessel images, some of the cross points do not belong to vessels and they are the results of nonlinear changes of the anisotropic diffusion and Bayesian algorithm. For eliminating these crosses, the pruning morphology operator has been used. Pruning algorithm eliminates short branches in vessel image and reduces errors in selecting TMPs. In this method, the binary image is pruned by element structure as:

$$B^1=\begin{bmatrix}\times & 0 & 0\\ 1 & 1 & 0\\ \times & 0 & 0\end{bmatrix},\ B^2=\begin{bmatrix}\times & 1 & \times\\ 0 & 1 & 0\\ 0 & 0 & 0\end{bmatrix},\ B^3=\begin{bmatrix}0 & 0 & \times\\ 0 & 1 & 1\\ 0 & 0 & \times\end{bmatrix},\ B^4=\begin{bmatrix}0 & 0 & 0\\ 0 & 1 & 0\\ \times & 1 & \times\end{bmatrix}$$
$$B^5=\begin{bmatrix}0 & 0 & 0\\ 0 & 1 & 0\\ 1 & 0 & 0\end{bmatrix},\ B^6=\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 0\end{bmatrix},\ B^7=\begin{bmatrix}0 & 0 & 1\\ 0 & 1 & 0\\ 0 & 0 & 0\end{bmatrix},\ B^8=\begin{bmatrix}0 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix} \quad (1)$$

Fig. 7 indicates the result of applying this method on vessel image.

2.3.2 Extracting TMPs

Where 3 or more vessels cross each other in one place is called TMPs. These points are specified by Crossing Number (CN) algorithm. CN algorithm is used to extract the cross points of finger print. This method for extracting TMPs has been suggested in [5]. If CN(P) (P is a point on the vessel) is more than 2 P is called TMP. The mathematical equation describing this algorithm is given by[8]:

$$CN(P)=\frac{1}{2}\sum_{i=1}^{8}\left|Val(P_{i \bmod 8})-Val(P_{i-1})\right| \quad (2)$$

Fig. 8 illustrates the result of CN algorithm under explained condition.

2.3.3 Eliminating fake TMPs

Fake TMPs are included in two types. In the first type, some extracted TMPs which are in a close neighbourhood to each other must be eliminated [9]. These points are created because of applying morphology algorithms and if being selected as TMPs, they increase the errors and time of calculation. To solve this problem, all the neighbors of each point are eliminated in a radius of three squares. In the second type, in thermal infrared images, the areas of the face which are covered by eyebrow, hair and glasses become darker. These factors block the diffusion of thermal IR waves and they are considered as external disturbances. On the other hand, the vessel extraction algorithm detects the edges of the image (like the border line between face and glasses) as vessel. Then, CN algorithm extracts TMPs from these vessels. To detect and eliminate these TMPs, the reported method in [10] has been used. In this method, applying K-mean clustering algorithm, the neighbours of each TMP are divided into two clusters. By applying Euclidean distance of the center of each cluster, the real and fake TMPs are distinguished. When the difference between two clusters in one neighbourhood within the radius of ten pixels is less than 90 (in grey level unit), this TMP is fake and will not be selected. Fig. 9 indicates two sets of (A) and (B) to describe this method. The set (A) is obtained from head's hair (abnormal vessels) and the set (B) is obtained from the vessels (normal vessels) (see Fig. 9b). If the number of neighbours of each TMP in sets (A) and (B) is N_A and N_B, respectively, and each neighbor is divided into two clusters by using K-mean algorithm, then the difference between the center of the two clusters can separate normal and abnormal TMPs. According to Tab. 1, the TMP in set (A) is abnormal (its difference is more than 90) and will be eliminated and the TMP in set (B) will remain.

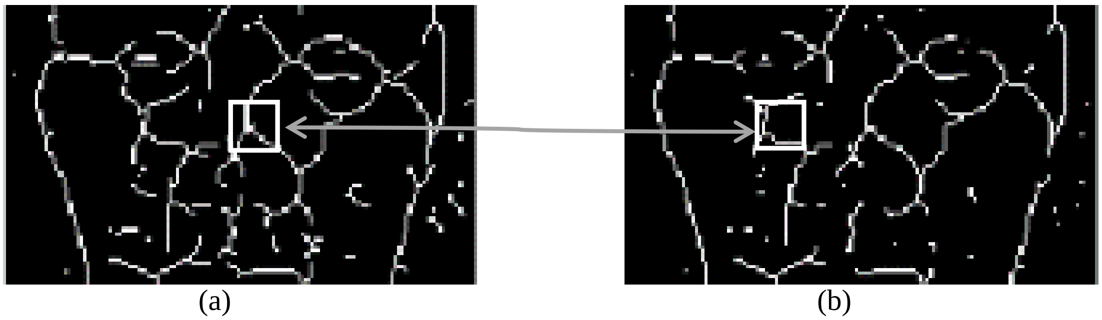


Figure 7: Eliminating fake vessel, (a) Original image (Fig. 6c) and (b) Result of applying pruning algorithm.

Figure 8: Extracting TMPs, (a) Result of applying pruning image and (b) Result of applying CN algorithm.

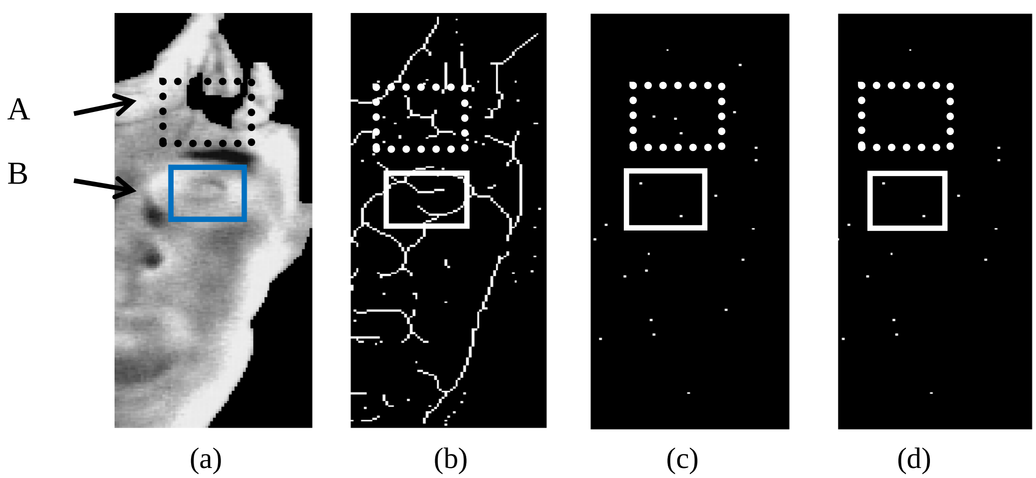


Figure 9: (a) Original image, (b) Result of vessel extraction, (c) Result of TMP extraction and (d) Result of applying K-mean clustering.

Table 1: Results of K-Mean clustering algorithm

	Center of 1st cluster	**Center of 2nd cluster**	**Difference**
Set (A)	195	95	**100**
Set (B)	210	186	24

Finally, Fig. 10b shows the result of elimination of fist type and Fig. 10b shows the result of elimination of second type fake TMPs. After this phase, all remained TMPs are used for feature extraction.

2.4 Feature Matrix Extraction for each TMPs Image

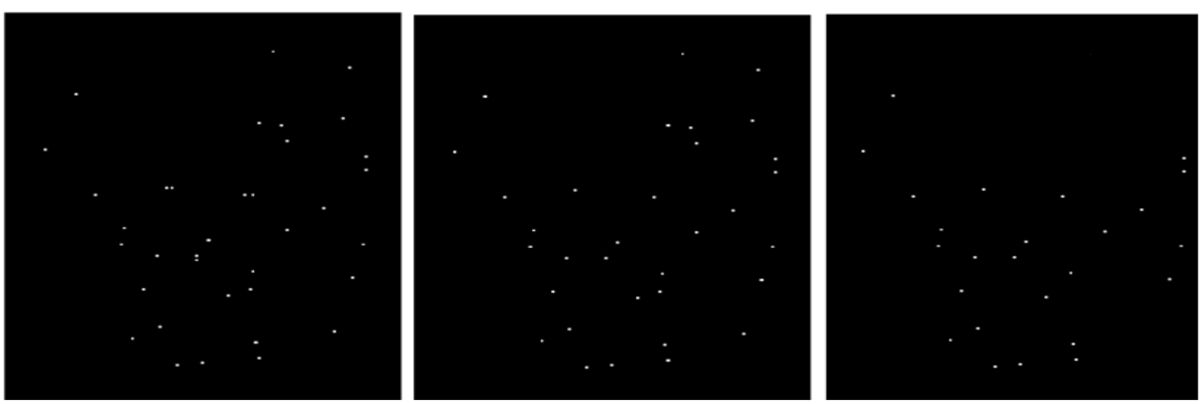
For face recognition, we need to extract a feature vector of each TMP. The extracted vector consists of the formed angle between each TMP with all other TMPs. The angles are defined by numbers within the range of -180 to 180 degree and so there is no need to normalize them. Fig. 11 shows the process of forming feature vector for TMP (a). If n is the number of TMPs, the feature vector is calculated for TMP (a) in j^{th} image by:

$$\vec{a}_j = [\theta_b^a \quad \theta_c^a \quad \theta_d^a \quad \ldots]_{1\times n-1}$$
$$\theta_i^a = \arctan\left(\frac{y_a - y_i}{x_a - x_i}\right) \quad i = b, c, \ldots, g \quad i \neq a \tag{3}$$

Where x_i and y_i are coordinates of i^{th} TMP. Finally the feature matrix consisting of the feature vectors of each TMP is formed as:

$$I^j_{n\times(n-1)} = \left[\overrightarrow{a_j}, \overrightarrow{b_j}, \overrightarrow{c_j}, \ldots\right]^T \tag{4}$$

Where I^j is the j^{th} feature matrix.



(a) (b) (c)

Figure 10: Eliminating fake TMPs, (a) Original image (Fig. 8b), (b) Result of elimination of fist type fake TMPs and (c) result of elimination of second type fake TMPs (original TMPs).

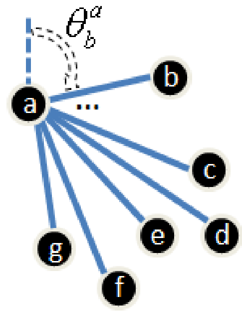


Figure 11: How forming feature vector for TMP (a).

2.5 Selecting BTMPs

Some of the extracted TMPs increase recognition error. These points due to low quality IR images and a change in temperature distribution are created. This method, by selecting appropriate TMP, can increase the correct recognition rate and decrease the factors discussed. These points, which in this research are called BTMPs, are located at almost constant positions in all individual person images. As shown in Fig. 12, for selecting BTMPs, four feature matrixes belonging to an individual person are compared together by DTW algorithm [10]. Time series (like feature matrixes) are a ubiquitous form of data occurring in virtually every scientific discipline. A common task with time series data is to compare one sequence with another. In some domains a very simple distance measure, such as Euclidean distance will suffice. However, it is often the case in which two sequences have approximately same overall component shapes, but these shapes do not line up in X-axis. Fig. 1 shows this with a simple example. In order to find the similarity between such sequences or as a preprocessing step before averaging them, we have to "warp" the time axis of one (or both) sequences to achieve a better alignment. The DTW is a technique for efficiently achieving this warping. In addition to data mining, the DTW has been used in gesture recognition, robotics, speech processing, manufacturing and medicine. In this paper, comparison and scoring the feature vectors have been performed based on DTW algorithm which is resistant to nonlinear changes (like increase or decrease the number of TMPs in the individual facial image) and indicate better results. In this method, two first feature matrixes are compared and if the likelihood score for each feature vector is more than value of *Tr*, that vector will be selected:

$$
\begin{aligned}
x_s &= \max\left(DTW(g_t, p_s)\right), \quad 1 \le t \le n, \quad 1 \le s \le m \\
Tr &= 1.3\left(\frac{1}{m}\sum_{s=1}^{m} x_s\right)
\end{aligned}
\tag{5}
$$

Where DTW(.) is likelihood score based on DTW algorithm, g_t and p_s are first and second feature vectors, respectively, for first and second feature matrix and 'm' and 'n' are the number of ventures (or TMPs) in each matrix. The value of 1.3 is selected experimentally. The selected vectors are reconstructed in a new matrix that is called, 1th Intermediate Feature Matrix (1th IFM). Then 3th IFM and 1th IFM are compared. This process is implemented twice and three IFM matrixes will be extracted. After this phase, IFM matrixes are converted to intermediate TMPs images (ITMPs). Then three ITMPs are resized to 80×100 pixels, added up together and final image is constructed which is called BTMPs. The BTMPs image is constructed by four (0 up to 3) gray levels. Level 3 indicates important and effective TMPs and level 1 indicates ineffective TMPs for face recognition. The BTMPs of each individual person are stored in BTMPs images database and they are used in recognition process.

3 Matching

In online phase, the thermal facial images are captured by an IR camera. As shown in Fig. 3, we extract TMPs images for each subject as same as offline phase. Also, the TMPs images are resized to 80×100 pixels. Therefore, the resized TMPs image is compared to BTMPs images existed in BTMPs images database using Principal Component Analysis (PCA) algorithm [11]. PCA is a useful statistical technique that has found application in some fields such as face recognition and is a common technique for finding the patterns in high dimension data. A reduced representation of original data is obtained which is smaller in size but having enough information to deal with. These variables are arranged regarding to their importance and the magnitude of each eigenvalue which describes the variance in the direction of its corresponding eigenvector. So, the importance of each variable can be considered with its eigenvalues. All the BTMPs images are transferred to the PCA domain and saved in PCA database. In this stage, the high grey levels have high weights and low grey levels have low weight. Therefore, in PCA domain, the effective TMPs have high weights. Euclidean distance is used for comparing and recognising purposes. The probe vector in PCA domain is compared to vectors existed in PCA database:

$$\varepsilon_k = \left\| \Omega_p - \Omega_k \right\| \tag{6}$$

Where Ω_p is probe vector, Ω_k is k^{th} vector in PCA database and ε_k is the likelihood error of the Ω_p with respect to the Ω_k. If ε_r is the minimum, r^{th} image in BTMPs images database is recognized.

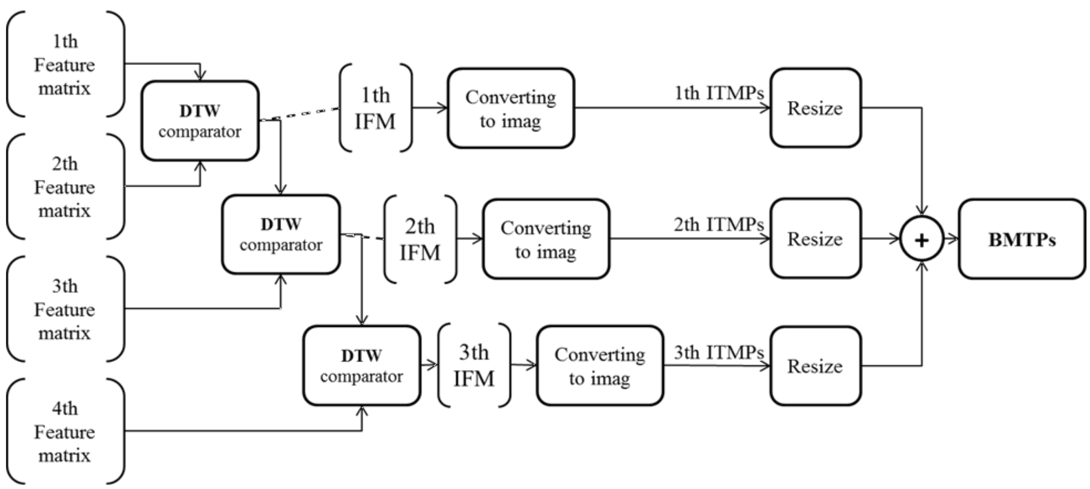


Figure 12: How comparing four feature matrixes based on DTW.

4 Exprimental Results

The proposed algorithm has been applied on UTK-IRIS gallery. For providing the images in this gallery, a thermal camera has located on a shaft with 80 cm in length and rotates between zero to 180 degree. Desired person is placed in 2 meter far from center of the camera. For every camera rotation, 11 images are recorded in different angles for happiness, sadness and normal situations. Also, the person may or may not wear eyeglasses and can be bearded or beardless. Therefore, 4 images including with and without eyeglasses, and also bearded or beardless at zero angle are available for each person. These images are recorded by uncooled camera with 240×320 pixel in resolution. The Log Wave IR (LWIR) is between 7 to 12 micrometres.

In this research, a part of this gallery is used which consists of 4 images for each person. The number of people is 24. The proposed method removes the effect of eyeglasses and beard for full face recognition. In training stage, in order to create BTMPs image database, we use 4 images in normal situation for each person and happy and sad images are not considered due to creating nonlinear additional changes besides on eyeglasses and beard effects. Figure 13 shows some samples of training images. In order to evaluate the proposed method, we use two criteria: ROC curves and CMC [12]. The ROC curve is a criterion which specifies correct face recognition. In this curve, the vertical axis is True Positive Rate (TPR) and the horizontal axis is False Positive Rate (FPR). The value of (FPR, TPR) = (0, 1) indicates perfect recognition. Because, all known input images for the system are recognised (TP) and all unknown input images are not recognised (TN). The point of (FPR, TPR) = (0, 0) indicates that none of images (known or unknown) are recognised whereas the point of (FPR, TPR) = (1, 1) induces all images can be recognised. The point of (FPR, TPR) = (1, 0) is the worst case in which no correct recognition has occurred. In this case, all known input images are not recognised (FN) whereas all unknown input images are recognised (FP).

Another criterion for evaluation of the proposed method is CMC. In order to calculate the CMC, we allow the algorithm to find “n” images from BTMPs data bank having the most similarity with the query image. If the query image exists among in “n” found images, the correction will be correct otherwise is incorrect. In following, the experimental results according to the above mentioned criteria applied on two groups of people, spectacled and bearded, are presented.

Figure 13: Some sample of traning images for 4 persons.

4.1 The experimental results for spectacled people

One problem in thermal infrared image recognition is the existence of the eyeglasses in image. The eyeglasses blocks the diffusion of infrared waves and causes to eliminate important information about the eyes and their surrounding vessels. This issue has remained unsolved for face recognition based on vessels [5]. On the other hand, the researches based on combination of thermal infrared images and visual images have many challenges confronted the face recognition with eyeglasses [13]. In this subsection, the obtained results for such images using the proposed algorithm are presented and compared to those results reported in [5] and [13]. The reason for selecting the method reported in [13] is to have similar database and also to be relatively a new method. Also, we have used and improved some techniques indicated in [5] and therefore the obtained results are compared to the results in [5]. The spectacled images in UTK-IRIS database have low resolution and so they are unsuitable for extraction of TMPs. Therefore, in this research, in order to have spectacled images and to update the indicated process in Fig. 2, one image of 4 images related to a person having higher quality is selected and the eyes area is manually masked, as shown in Fig. 14. Fig. 15 compares the obtained ROC curve from the proposed algorithm against one obtained in [5, 14, 15] applied on spectacled images. For generating the ROC curve in Fig. 14, in addition to 24 existed images in UTK-IRIS gallery (known images for the system), 20 unknown images are applied on the proposed algorithm after generation of artificial eyeglasses on images. To examine TPR severely, these 20 images are selected with Middle wave IR (MWIR) quality. In these images, the number of the extracted TMPs is nearly twice that of the extracted in BTMPs for each person and therefore probability of incorrect recognition increases. As observed, the surface of under curve is very close to one which indicates that the proposed method provides higher correct recognition rate for spectacled images. Fig. 16 compares CMC curves obtained by the proposed algorithm to those reported in [5, 13, 14, 15]. As shown, the proposed algorithm results in higher correct recognition rate for different ranks (or different n). In TMP matching case, the CMC curves show that in rank=1, the recognition rate is 70%, 84%, 73% and 55% reported in [5, 13, 14, 15], respectively whereas for the proposed method is 95%. This indicates that the proposed algorithm is highly robust to deformations caused in vascular network by facial expression variations.

(a) (b)

Figure 14: (a) Thermal images in UTK-IRIS database and (b) Converted thermal image with glasses

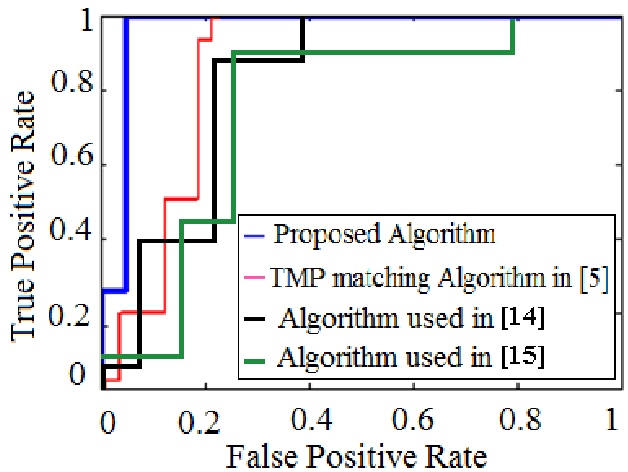


Figure 15: ROC Experimental results on faces with glasses UTK-IRIS gallery

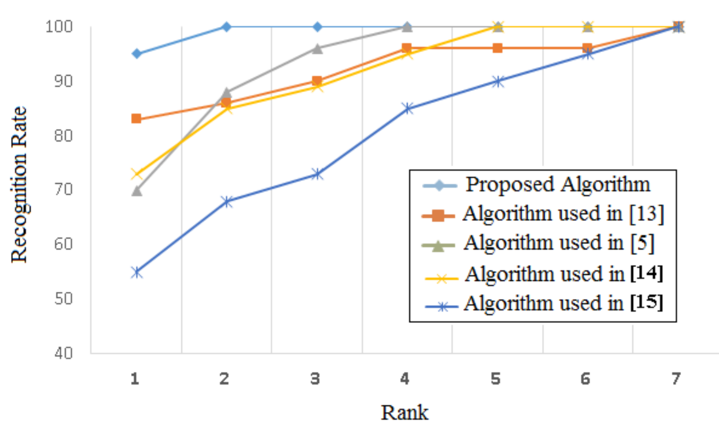


Figure 16: CMC Experimental results on faces with glasses UTK-IRIS gallery.

4.2 The experimental results for bearded people

Another problem in face recognition in thermal infrared images is existence of beard. In order to create bearded people, we perform the same process applied on a person with artificial eyeglasses. Fig. 17 shows a sample of such images presenting artificial bearded people. Since the method reported in [13] is applied on just for spectacled people, it is not compared to the proposed method. Fig. 18 and Fig. 19 show ROC curves and correct recognition rate, respectively, for bearded people. As observed, the proposed method results in better performance in different ranks. In n=1, which is the most important, the proposed method provides higher correct recognition rate, nearly 40%, compared to [5, 14, 15].

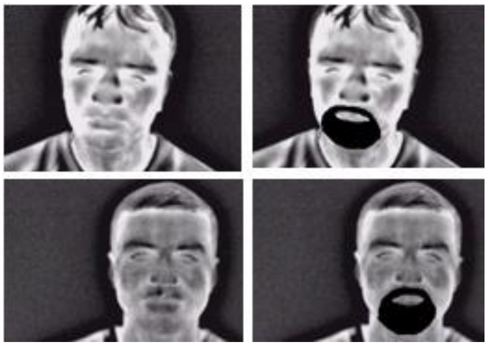

(a) (b)

Figure 17: (a) Thermal images in UTK-IRIS database and (b) Converted thermal image with beard.

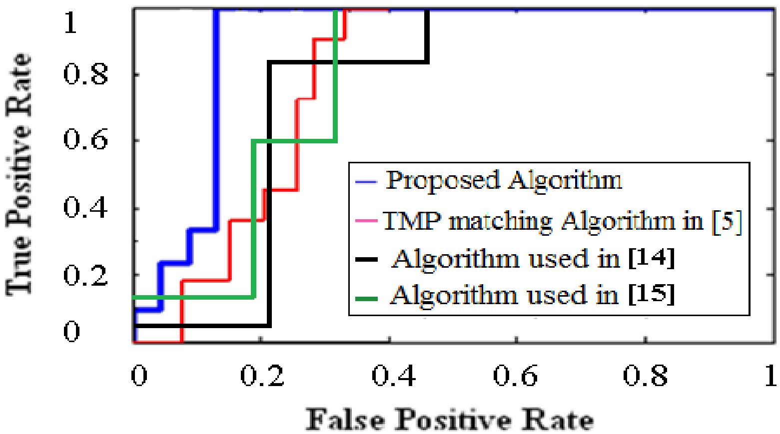


Figure 18: ROC Experimental results on faces with beard UTK-IRIS gallery.

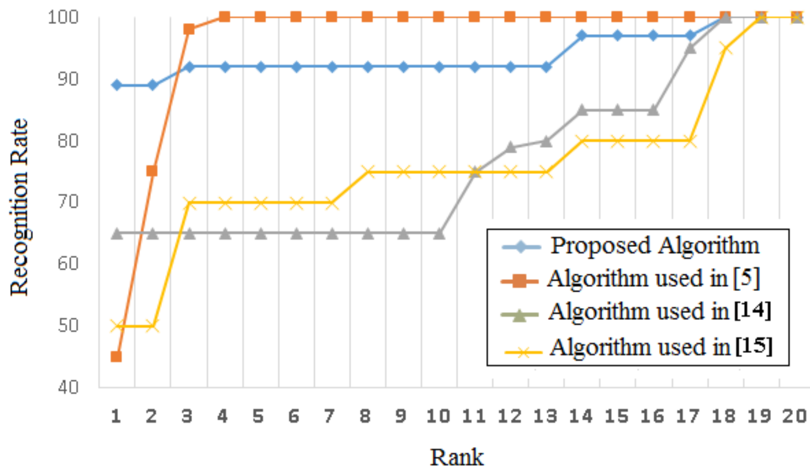


Figure 19: CMC Experimental results on faces with beard UTK-IRIS gallery.

5 Conclusions

This paper presents a new algorithm that substantially improves the performance of face recognition in LWIR images. One of the most important problems is selection of features which do not change with passage of time. Thermal sampling devices have recorded different records of human face in different times because of the nonlinear changes. On the other hand, the existence of eyeglasses and beard in the images and nonlinear changes of the facial expressions are the most important factors which still cause problems in face recognition in IR domain. In the proposed method by selecting appropriate feature vectors, the recognition rate of spectacled and bearded images are improved. In this method by using DTW algorithm which is properly resistant to nonlinear changes, the best TMPs are selected and recognition is performed by a common clustering algorithm like PCA. The obtained results indicate that choosing appropriate feature plays an effective role in correct face recognition.

Finally, the experimental results of DF suggested algorithm in [13] and TMP matching algorithm in [5, 14, 15] with the proposed method show the proposed algorithm has performed much more successfully in recognition face with eyeglasses and beard.

Future work plans include, first, a study of SIFT algorithm, second applying this algorithm to select BTMPS and using adaptive filter to calculate weight of ITMPS in MWIR images.

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