Human Face Recognition Using Thermal Image

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Abstract

In this paper, thermogram was used to do human face recognition. The thermogram of human face was captured from infrared camera. Image processing technologies were used to preprocess the captured thermogram. Then several features were extracted from the processed thermogram. These features included the distribution of temperature statistics, the perimeter of the face, the length/width ratio of the smallest rectangle which contained the face, and the triangle formed from the three lowest temperature points of the two cheeks and the chin. A three-layer back-propagation neural network was used as the recognition tool. The samples were collected from 20 individuals, 16 of them with glasses. The total samples have 200 for without glasses and 96 for with glass. Different combinations of the extracted features were tested. It is shown that the recognition rates for without glasses and with glasses are 95% and 93%, respectively. The experimental results encourage the application of thermogram for human face recognition.

***Keywords*:** Thermogram, Human face recognition, Neural Network

Introduction

With the increasing awareness of people about the safety and protection, the traditional recognition methods, such as secret code, magnetic card, ID card, are no longer able to meet the present needs. The so-called biometrics identification has increased in its importance [1][2]. Biometrics uses physical characteristic or personal trait to compare with the pre-established data in the database to determine the possible candidates. Physical characteristic is suitable for strict identity confirmation and generally obtained from living human body. General used physical features are fingerprints, hand geometry, eye features-iris and retina, and facial features. Personal trait is more convenient in application but with less secure. It used the personal trait differences for identity recognition. The most used personal traits are signature and sound veins [3]-[6].

Recently, another physical feature, called thermal image, has been applied for anxiety detection and security screening. Thermal image techniques have been widely used in industry for on line detecting the faults of operating components or system [7]-[10]. Furthermore, the technology can also be extended for personal identification recognition. The distribution of blood flow in superficial blood vessels causes the changes of the local skin temperature. This is readily apparent in the human face where the layer of flesh is very thin. The human face and body emit both the mid- (3-5 μm) and far-infrared (8-12 μm) bands. Therefore, mid- and far- infrared thermal cameras can sense the temperature distributions in the face at a distance to produce 2D images (thermograms). These 2D thermal images are used for face recognition. In [11], thermal imaging technique has been employed to detect the deception by recording the thermal patterns from one's face. Pavlidis et al [12] also used the technique for anxiety detection. In this paper, thermogram was used for human face recognition. The image processing techniques and the extracted features for the preprocessing of the recognition were be described. A three-layer back- propagation neural network was applied as the recognizer.

The rest of this paper is organized as follows. Section II describes the used image acquisition system for this study. Section III describes the recognition algorithm, including image preprocessing, features extraction and neural networks. Section IV describes the experimental results and discussion. Then a brief conclusion is made in section V.

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Thermal Image Acquisition system

Any object with temperature higher than absolute zero degree (-273°C) will emit electromagnetic radiation spontaneously. This is known as natural or thermal radiation. By definition, all incident radiation will be absorbed by a black body in a continuous spectrum according to Planck's law [13]

$$W(l,T) = \frac{2phc^2 / l^5}{\exp(hc / lKT) - 1}$$

Where W(?,T) is blackbody monochromatic emissive power. c is light speed in vacuum field (2.9979 x 10^8m/sec). h is Planck's constant (6.6256 x 10^{-34}W.sec^2). k is Boltzmann's constant (1.3805 x 10^{-23}WSec/°K). ? is wave length (m). T is absolute temperature (°K).

The total energy of blackbody radiation can be obtained from the following equation

$$W(T) = \int_0^\infty W(l,T)dl = sT^4$$

where s is Stefan – Boltzmann's constant (5.670 x 10^{-8} W/m^{2o}K^4). By the equation, the energy can be computed from its temperature. From Wien's law[13], the relationship between the wavelength ? $_{max}$ (in µm) of the maximum emissive power and the temperature T of the back body is described by

$$l_{max} = \frac{2898}{T}$$

According to Wien's law, the frequency at which the maximum energy dissipated depends on the temperature of emitting object. For example, radiation from human body at 310°K is maximal at a wavelength of 10µm, and it is located in the infrared region. Therefore infrared thermal image is a suitable tool to measure the human skin temperature.

Infrared thermal imaging uses thermal camera to detect the distribution of the infrared radiation. With this process, human being can overcome the visual barrier to "see" the temperature distribution on the surface of an object. Most of the infrared imaging instruments are designed to detect the electromagnetic wave with wavelength 3-5 µm and 8-12 µm. Due to the very poor penetration of infrared for solid and liquid matters, the infrared imaging instruments are basically used to detect the radiation energy of the object's surface.

The infrared camera used in this paper is NEC SAN -EI Thermo Tracer TH2101. The main features is listed in Table 1.

Heat energy transmission can be achieved via the combination of radiation, convection and conduction. To reduce the effect of convection and conduction, the imaging ambient temperature was kept at constant temperature to avoid

Table 1. TH2101 Specification

Vender	NEC
Camera name	Thermo Tracer TH2101
Detector	HgCdTe
Estimate range	-50℃ ~2000℃ -50℃ ~200℃ 100℃ ~600℃ 400℃ ~2000℃
Temperature resolution	0.1℃
Space resolution	256×191
Measuring/distance	>20cm
Image capturing rate	20 frames/s

the changing in ambient temperature to generate heat convection effect. The room temperature was controlled at 26 ℃with variation of no more than 0.5℃. The captured infrared image was recorded in a personal computer for further processing via a GPIB interface connected to the thermal camera.

Recognition Algorithm

In this paper, the proposed recognition system can be divided into three parts. The first one is image preprocessing that segmenting the face area out of the background. The optimal thresholding method proposed by OTsu [14] is adopted. In this study, the ambient temperature is always lower than human body. It is easy to find the optimal threshold using Otsu's method. This selected optimum critical value is used to segment the face area out of the background. The second one is features extraction from the segmented image. In our proposed method, four features are used, to form the feature set for recognition. There are (1) the temperature distribution statistics, (2) the perimeter of the face, (3) the length/width ratio of the smallest rectangle which coverage the face, and (4) the edge lengths of the triangle formed from the three lowest temperature points of the two cheeks and the chin, respectively.

The temperature distribution statistics

Assume the segmented thermogram with nonzero gray level value pixels represent the face area. These pixels are all converted to the corresponding temperature value according to the following formula provided by the instrument's operation manual:

Temperature = (gray-level –128)x Sensitivity /8 + level

The sensitivity value is set to 0.3 and the constant value, level, is set to 29.0. The temperature distributions of the face area are then divided into nine sub-ranges.

After obtaining the corresponding temperature of all the pixels of the face area, the temperature range is divided into 9 sections, dividing the temperature range 30.5 °C to 33.5 °C with 0.375 °C each, into 8 sections and all those higher than 33.5 °C is made into one section, and calculates the number of pixels of each section(as shown in figure 1). In the figure 1, the x-axis coordinate of the right side bar represents the temperature section, and assigns one color to each section. Y-axis coordinate shows the number of pixels within each temperature section.

And, in addition to the statistic of face area temperature distribution, the temperature distribution of two cheeks and chin are also made into statistics. The selection method of the two cheeks and chin are:

1. To find the small rectangle that covers the whole face.
2. Move the four corner points of the rectangular simultaneously toward its center for one pixel, and check if any three of the four corner points of the newly formed rectangular are within the face area.

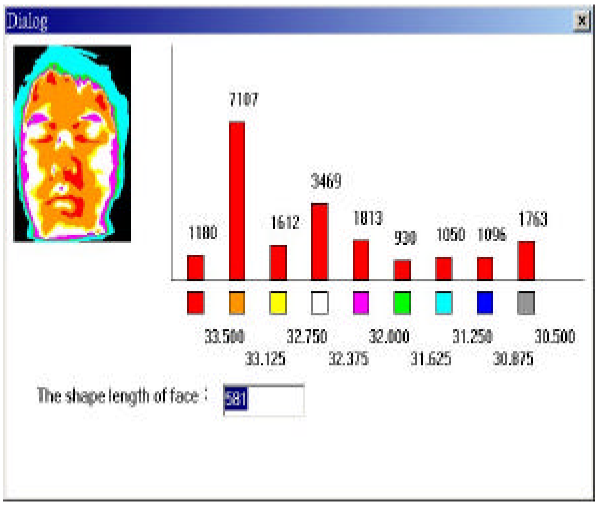

Figure 1. Statistical of Face Area Temperature Distribution

3. When there are three corner points within the face area, record the four corner points of the newly formed rectangular. If not, go to step 2; otherwise go to step 4.
4. The rectangle found in step 3 is divided into twelve sub-blocks as shown in figure2. In figure 2, the two sub-blocks pointed by horizontal arrows are called two cheeks, and the sub-block pointed by the vertical arrows is called the chin. The temperature distribution of these three sub-blocks are calculated and recorded.

The perimeter of the face contour

The boundary of the face can be easily found from the segmented thermogram. Then the number of pixels of the boundary is calculated to obtain the perimeter of the face contour. This parameter depends on both the view angle and distance between camera and object. To avoid these effects, the image was normalized to the same size.

The length/width ratio of the minimum covered rectangle

It is easily to find the minimum rectangle that fits the segmented face image. The length to width ratio of the minimum rectangle is used as another feature to describe the shape of the face contour.

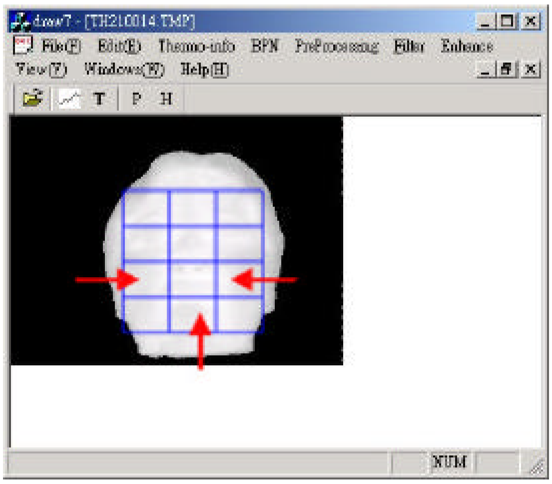

Figure 2. Two cheeks and chin portion

The edge lengths of the triangle formed from the three lowest temperature points of the two checks and the chin

The three sub-blocks found in figure 2 represent the area covering the two checks and the chin, respectively. The lowest temperature point of each sub-block is found. Then the distance for each pair of these three points are calculated, to form features, respectively.

Neural network architecture

In this paper, a back-propagation neural network [15] is used as face recognizer. The network consists of three-layer structure, namely, input layer, hidden layer and output layer. The neurons of input layer are 11, 20, and 26, respectively, to match the input number of features. The neurons of output layer are 20. This is the number of person participated in the experiment. The number of hidden layer neurons is shown as the following equation:

Number of neurons at the hidden layer = (number of neuron at input layer + number of neuron at output layer) /2

Also, the learning speed η in this study is set to 0.4, and momentum term α is 0.7.

Experimental results and Discussion

The thermograms for 20 subjects (15 males and 5 females) are acquired for study. Sixteen of them are near-sighted and with glasses. The testing thermograms are divided into two sets, without glasses and with glass, as described below:

Set 1: Without glasses: ten pictures are taken for each of 20 subjects, in different day. So there are 200 images without glasses.

Set 2: With glasses: those 16 near-sighted within the subjects, six pictures for each subject are taken with glasses. So there are 96 images with glasses.

The training samples consist of five images selected from set 1 for each subject. In total there are 100 images. The rest images in set 1 and the set 2 are the testing samples. (Total 196 images)

Experiment I

In this case, the input feature consists of nine temperature distribution statistics, perimeter and length/width ratio. It has totally 11 input features. So the input neurons of the neural network are 11. The hidden layer and output layers have 16 and 20 neurons, respectively. The recognition result for the testing samples is shown in table 2.

Table 2 The recognition result for experiment I.

	total	correct	wrong	Rates of recognition
Without glasses images	100	96	4	96.00%
With glasses images	96	77	19	80.21%

Experiment II

In this case, the input feature includes 12 temperature distribution statistics and 3 distances, the two cheeks and the chin, the perimeter and the length/width ratio. It is totally 17 input features. The numbers of neurons for input, hidden and output layers are 17, 19, and 20, respectively. The recognition result for the testing samples is listed in table 3.

Table 3 The recognition result for experiment II.

	total	correct	Wrong	Rates of recognition
Without glasses images	100	95	5	95.00%
With glasses images	96	90	6	93.75%

Experiment III

In this case, all the definite features are included. It is totally 26 input features and the number of neurons for input, hidden and output layers are 26, 23, and 20, respectively. The recognition result is shown in table 4.

Table 4 The recognition result for experiment III.

	total	correct	wrong	Rates of recognition
Without glasses images	100	99	1	99.00%
With glasses images	96	90	6	93.75%

From the above recognition results, it is shown that different feature combinations gets different recognition rate. But the recognition rate for without glasses is all near 100%. The recognition rate for without glasses is higher than that of with glasses.

Figure 3 shows the summary of the experiments. It is shown that the recognition rate for with glasses in experiment I is much lower than others. The reason that causes the reduction recognition rate for wearing glasses is that the lenses of glasses can isolate the heat transmission. It affects the features of temperature distribution. This situation is improved in experiment II and III which take into account the features obtained from the two cheeks and the chin.

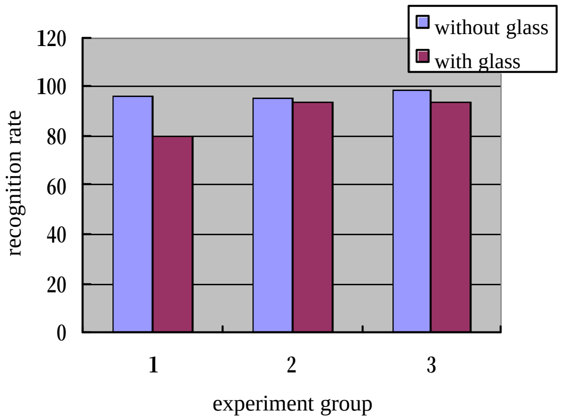

Figure 3. Recognition results for the experiments

Conclusions

Thermogram analysis for human face recognition was studied. The thermogram of human face was captured from infrared camera. Image processing technologies were used to preprocess the captured thermogram. Then several features were extracted from the processed thermogram. These features included the temperature distribution statistics of the thermogram, the perimeter of the face contour, the length/width ratio of the smallest rectangle which covered the face and the edge length of the triangle formed from the three lowest temperature points of the two cheeks and the chin, respectively.

Back-propagation neural network was used as the recognition tool. When compared with other biometrics such as fingerprints recognition, iris recognition, voice-print recognition, face shape recognition etc, using thermogram for the recognition has the following two advantages:

1. It is not affected by the ray of light coming from its surroundings. Even under no lamp light circumstances, it can still be workable.
2. It provides a non-contact, non-intrusion method so that the user won' t feel uncomfortable at all.

From the experimental results, it is shown that for subject without glasses cases, the recognition rate is more than 95%. For subject with glasses case, it also reaches 93% for experimental II and III. However, in this report, all images are taken in front of the person. It is practically not easy to control the picturing angle well to get front view's image. In this case, the proposed features may be modified or changed.

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