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Infrared and Hyper-Spectral Imaging for Face Recognition

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Abstract

Thermal emissions from skin are an intrinsic property independent of illumination. Therefore the face images captured using thermal IR sensors will be nearly invariant to changes in ambient illumination. The illumination variation problem is one of the well-known problems in face recognition in uncontrolled environment. Infrared imaging sensors have become an area of growing interest. Thermal IR imagery has been suggested as an alternative source of information for detection and recognition of faces, while visual cameras measure the ultra-magnetic energy in the visible spectrum range(0.4-0.7um), sensor in IR cameras respond to the thermal radiation in the infrared spectrum range at 0.72-14.0um. While sacrificing colour recognition, thermal IR face recognition techniques can be used to identify faces when there is little or no control over lighting conditions.

To address this serious limitation of IR it is proposedto fusing IR with other forms of facial recognition techniques by combining IR with hyper-spectral face recognition for a better identification system.

1. Introduction

Hyper-spectral imaging (HSI), or chemical imaging (CI), is the combination of spectroscopy and digital imaging. A spectral image contains many spectra, one for each individual point on the sample's surface. The image contains valuable information about the spatial distribution of the materials within the sample. For the purposes of this webpage, we refer to hyper-spectral imaging in the ultraviolet (UV) to long-wave infrared (LWIR) range, the latter of which is known as mid-infrared in general spectroscopy. Hyper-spectral images offer new revolution to face recognition schemes as they have one more dimension to the single 2D image. The newly added dimension is termed as spectral dimension. With this dimension there comes need to modify the existing algorithms which were applicable to 2D images only. To make them applicable to hyper-spectral images and maintain same performance is a challenge[1]. The difference between B/W, grey-scale and hyper-spectral imaging is shown below in Fig.1.the given image provides a simple idea of how hyper-spectral imaging works.

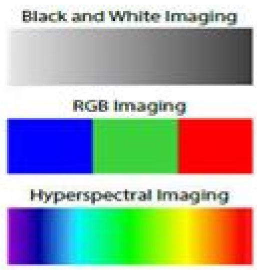

Fig. 1. Difference between B/W, grey-scale and hyper-spectral imaging.

1.2 Problem Statement

Infrared facial detection

Recognition of faces using different imaging modalities, in particular infrared (IR) imaging sensors has become an area of growing interest[2,3]. Electromagnetic spectral bands below the visible spectrum such as X-rays and ultraviolet radiation are harmful to the human body and cannot be employed for face recognition applications. Thermal IR imagery has been suggested as an alternative source of information for detection and recognition of faces. While visual cameras measure the electromagnetic energy in the visible spectrum range (0.4–0.7 lm), sensors in the IR camera respond to thermal radiation in the infrared spectrum range at 0.7– 14.0 lm. The paper further deals with how the two technologies can be used together efficiently.

2. Methodology :

Thermo vision methods, employing arrays detectors, provide an image (in real time) of the observed scenery. Usefulness of this method results from the fact that a lot of substances and have their absorption bands in IR. The devices operating in IR, used for detection have spectral characteristics and resolution matched to the absorption bands of compounds to be detected. Two types of such devices can be distinguished. One, it is a system similar to typical thermal camera but additionally equipped with the filter system ensuring the required spectral resolution and the signal analysis system. The other type includes the device based on the principles of the Fourier spectroscopy (Fourier transform infrared spectroscopy FTIR) that is expensive and so not readily available[4].

2.1 Fourier-transform infrared spectroscopy (FTIR):

Fourier-transform infrared spectroscopy (FTIR)is a technique used to obtain an infrared spectrum of absorption or emission of a solid, liquid or gas. An FTIR spectrometer simultaneously collects high-spectral-resolution data over a wide spectral range. This confers a significant advantage over a dispersive spectrometer, which measures intensity over a narrow range of wavelengths at a time.

The term Fourier-transform infrared spectroscopy originates from the fact that a Fourier transform (a mathematical process) is required to convert the raw data into the actual spectrum. The figure 2. gives a generic idea of how the proposed methodology is going to work.

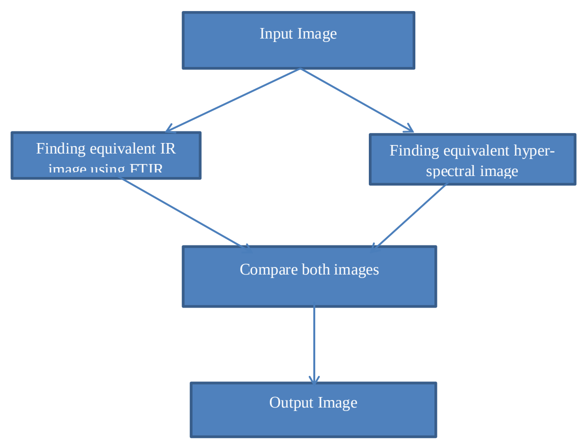

Fig. 2 Proposed Methodology

The input image is converted into respective IR and hyper-spectral images. These obtained images are then in turn matched with the images stored in the database. After being compared the resulting image is displayed for the user.

3.Face recognition using infrared imagery and hyper-spectral imagery

3.1Face recognition using infrared imagery

Thermal IR images or thermo-grams represent the heat patterns emitted from an object. Objects emit different amounts of IR energy according to their temperature and characteristics. The range of human face and body temperature is quite uniform, varying from 35.5 to 37.5 LC providing a consistent thermal signature. Skin temperature in a 21 LC ambient room temperature also has a small variable range between 26 and 28 LC. The thermal patterns of faces are derived primarily from the pattern of superficial blood vessels under the skin. The vessels transport warm blood through-out the body, and heat the skin above. Skin directly above a blood vessel is on the average 0.1 LC warmer than adjacent skin. The vein and tissue structure of the face is unique for each person, and therefore the IR images are also unique. It is known that even identical twins have diûerent thermal patterns. The range and sensitivity are well within the specification of current IR imaging technology. The passive nature of the thermal IR systems lowers their complexity and increases their reliability[5]. The figure below shows a brief comparison of visual and thermal IR images under variations in illumination and facial expression.

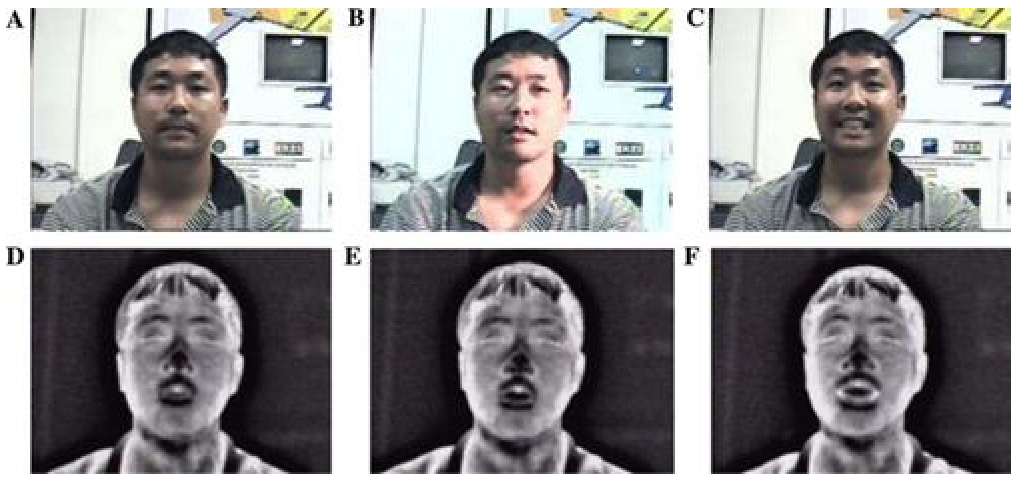

Fig.3. Comparison of visual and thermal IR images under variations in illumination and facial expression. (A) and (B) visual face images with different illumination directions. (C) Different facial expression. (D) (E), and (F) are the corresponding thermal images to (A), (B), and (C).

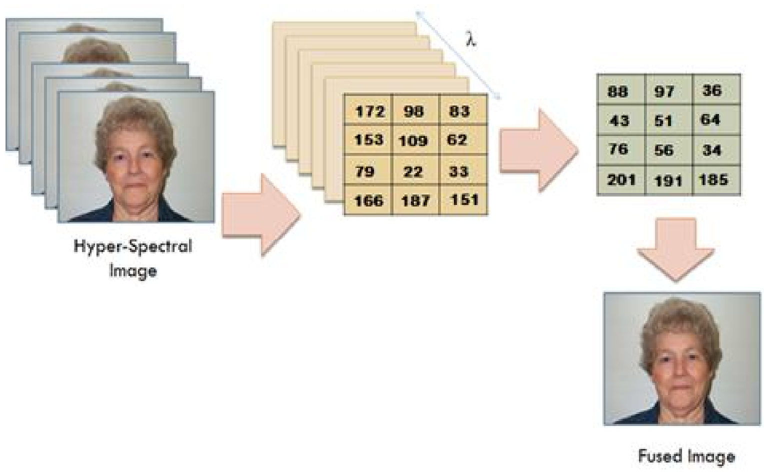

Fig. 4. Feature extraction in hyper-spectral face recognition

3.2 Face recognition using hyper-spectral imagery:

Hyper-spectral images offer new revolution to face recognition schemes as they have one more dimension to the single 2D image. The newly added dimension is termed as spectral dimension, which helps in obtaining a single matrix for simplified face recognition (Fig. 3). With this dimension there comes need to modify the existing algorithms which were applicable to 2D images only. To make them applicable to hyper-spectral images and maintain same performance is a challenge. For hyper-spectral face recognition aband fusion approach is used along with Gabor wavelet and local directional pattern[6].

3.2.1Local Directional Pattern :

Local Directional Patter overcomes the drawbacks of LBP and is additional strong for classification. The local descriptor LDP considers the edge response values altogethertotally different directions rather than surroundingpixel intensities like LBP. As edge response magnitude is more stable than pixel intensity LDP provides a consistency in noise and illumination changes also[7]. The LDP relies on LBP. Within the LBP operator, a grey-scale invariant texture primitive, has gained vital quality for describing texture of a picture. It labels each pixel of a picture bythresholdingits P-neighbouringvalues with the middle value by changing the result into a binary range by using Equation one[8].

LDP considers the edge response values in each totally different direction. It's composed of 3 steps. First, eight directional edge response values (m_0… m_7) are obtained by applying kirsch masks (Fig. 5) in eight orientations (M_0…M_7).

To encodeGabor magnitude pattern of a picture LBP also can be used, LBP is powerful to monotonic illumination changes in grey scale. However, it's sensitive to non-monotonic illumination variation, random noise. Therefore its economical to useLocal Directional Pattern (LDP) to resolve these issues. Whereas, the LBP considers neighbouring pixelintensities. The LDP considers the edge response values in each totally different direction.

$$\begin{bmatrix}-3&-3&5\\-3&0&5\\-3&-3&5\end{bmatrix}\begin{bmatrix}-3&5&5\\-3&0&5\\-3&-3&-3\end{bmatrix}\begin{bmatrix}5&5&5\\-3&0&-3\\-3&-3&-3\end{bmatrix}\begin{bmatrix}5&5&-3\\5&0&-3\\-3&-3&-3\end{bmatrix}$$

$$\begin{bmatrix}5&-3&-3\\5&0&-3\\5&-3&-3\end{bmatrix}\begin{bmatrix}-3&-3&-3\\5&0&-3\\5&5&-3\end{bmatrix}\begin{bmatrix}-3&-3&-3\\-3&0&-3\\5&5&5\end{bmatrix}\begin{bmatrix}-3&-3&-3\\-3&0&5\\-3&5&5\end{bmatrix}$$

Fig. 5. Kirsch Mask

The second step is top t values of the edge response values m_i (i=0-7) are selected and set them to 1. The other (8-t) bit of 8 bit LDP pattern is set to 0, thus we can obtain information about significant directional edge responses. Finally, we convert the binary code into a decimal number as shown in fig below :

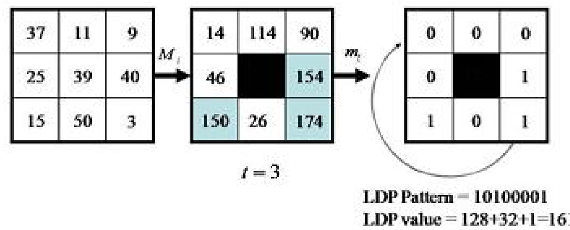

Fig. 6 Obtaining LDP Pattern

3.2.2 Gabor Filter :

Face detection and feature extraction from facial image is done using Gabor filter. They are spatial filters which uses Gaussian function that apply sin/ coslocalization[8,9,10,11]. Gabor filters are defined as:

$$\Psi_{\mu,v}(z) = \frac{\left\|k_{\mu,v}\right\|^2}{\sigma^2} e^{\left(-\left\|k_{\mu,v}\right\|^2 \|z\|^2 / 2\sigma^2\right)} \left[e^{ik_{\mu,v}z} - e^{-\sigma^2/2}\right] \quad (1)$$

Where μ defines orientation of Gabor kernel.
v defines scale of Gabor kernel.
Z = (x,y) and ||.|| denotes the normalization operator.
The frequency vector $k_{\mu,v}$ is given as:

$$k_{\mu,v} = k_v e^{i\emptyset_\mu} \quad (2)$$

4. Results

Hyper-spectral imaging is already being used along with infrared imaging in the field of agriculture and environmental studies. The technologies perform differently under different conditions. They have the capability of adapting to the immediate changes. These capabilities can be exploited in the field of face recognition to overcome the limitations due to illumination and other factors, because IR overcomes the problems created due to illumination. Changes in facial expressions also does not have much effect on the image as the thermal radiation does not change.

5. Conclusion

Face recognition is an ever growing field, with day-to-day advances being made to make it better and more effective than ever. Each new technology provides with a new and fresher approach to be promising and vision changing. The two technologies suggested above in the paper can be used together as they provide different prospects to facial recognition, which if merged together can be proven very helpful in the field.

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