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Multispectral face recognition using hybrid feature

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Abstract

This paper presents multispectral imaging as an alternative to conventional color imaging that showed deficiencies. Thermal infrared images have useful signatures are insensitive to different illuminations and viewing directions. Multispectral imaging by the information fusion of the visible images and thermal infrared images provides rich data information that can be used in face recognition. Comparatively to traditional face recognition, multispectral imaging can separate illumination and reflectance information of facial images.

The use of fusion of visible and thermal images in face recognition shows better performance than traditional imagery [4].

Keywords: *multispectral, face recognition, image fusion, visible, thermal infrared*

Introduction

Recent studies show multispectral imaging as an alternative to the traditional color imaging approach that showed deficiencies. This study focuses on face recognition using multispectral images by fusion of visible and thermal infrared images. Several wavelengths of the visible and infrared provide useful information for face recognition [6] [2]. On the one hand, the visible images provide information about the face skin reflectance, and on the other hand, thermal infrared images produce unique characteristics due to the emissivity of the thermal radiation of faces The main interest of thermal infrared images is to overcome the weakness due to several difficulties such as: smoke, snow, dust, extreme illumination, darkness, different face poses, wearing glasses and facial expression. Some experiments were carried out using IRIS database [3] that contains spectral face images. Indeed, in this experience, multispectral imaging by fusion method allowed to obtain composite images by combining visible and thermal infrared informations. So, the fused images provide additional information with face reflectance and radiation to improve traditional face recognition methods [4].

In this paper, there are two main contributions which are presented below:

- a Multispectral Face Recognition using Hybrid Feature called MS-FRHF. First, multispectral visible / thermal infrared are built. Then, for face recognition the hybrid feature leverages key points and texture extraction for face recognition;
- the improvement of traditional face recognition using color images by a multispectral face recognition.

The proposed MS-FRHF method

The proposed method MS-FRHF is an approach of face recognition using fused images of visible and thermal with attention [8]. Concerning feature extraction, two features are used and they are interest points and texture. The whole process is articulated in three stages which are image fusion, feature extraction and face recognition.

Image fusion

Image fusion is a process to combine relevant informations for several images into one image containing a high information quality. Before fusing images, image registration must be taken into account. In image database used, there are pair of facial images acquired in different poses and illuminations. Every pair is composed of a visible image and a thermal infrared image.

To assess the amount of information of each image, the equation (1) defining the entropy is used. The entropy measures the information contained in an image. It is sensitive to noise and other unwanted rapid fluctuations. An image with high information content gives high entropy.

$$\text{He} =-\sum_{i=0}^{L} h_{I_f}(i) log_2\, h_{I_f}(i) \quad (1)$$

Two pairs of visible and thermal infrared images are presented in Figure 1. The face has the same position with two different illuminations.

(a) (b) (c) (d)

Figure 1 .Two different illuminations of faces in IRIS Thermal / Visible database. (a) and (b) are visual and thermal corresponding faces with Left Light On (Lon). (c) and (d) are visual and thermal corresponding faces with Left and Right Off (Off).

First, the entropy calculation of images showed that thermal infrared images contain more information than the visible corresponding visible images. Then using Formula (2), the Mutual Information (MI) is calculated for each pair of images. Thus, this shows the usefulness of having a multispectral image with better information quality by fusion of thermal infrared and visible images.

$$\text{MI} = \sum_{i=1}^{M} \sum_{j=1}^{N} h_{I_r I_f}(i,j) log_2 \left(\frac{h_{I_r I_f}(i,j)}{h_{I_r}(i,j) h_j(i,j)} \right) \quad (2)$$

The correlation of different pairs is given by the similarity measure of Sum of Squared Differences (SSD) in Formula (3) and represented in Figure 2.

$$\text{SSD}=\sum_{(i,j j)\in W}(I1(i,j)-I2(x+i,y+j))^2 \quad (3)$$

Figure 2. Representation of similarity between visible and thermal infrared images. From left to right: thermal image, visible image, SSD Disparity Map

Several fusion methods exist and some metrics of these fusion methods guide the choice of one of them. The methods studied are IMSVD, PCA and AVG. Among all these methods only the PCA fusion gives the best results. Figure 3 shows that it is better to use the thermal image as reference image.

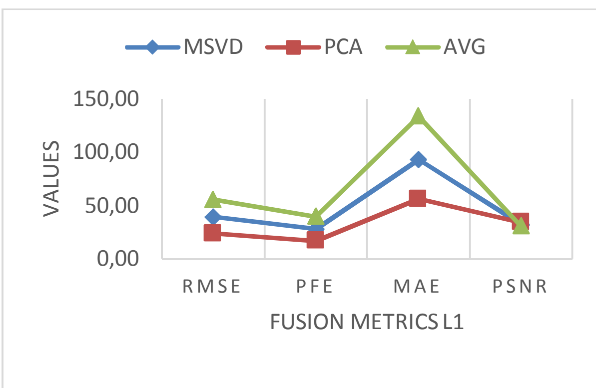

Figure 3. Comparison of 3 fusion methods using four metrics with a thermal image as reference

The different used metrics are: the Root mean Square Error (RMSE), the Percentage Fit Error (PFE), the Mean Absolute Error (MAE), the Peak Signal to Noise (PSNR). They are respectively given by Formulas (4), (5), (6) and (7) and described in [10] [9].

$$\text{RMSE} = \sqrt{\left(\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(I_r(i,j)-I_f(i,j))^2\right)} \quad (4)$$

$$\text{PFE} = \frac{norm(I_r-I_f)}{norm(I_r)} * 100 \quad (5)$$

where norm is the operator to compute the largest singular value.

$$\text{MAE} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}|I_{r(i,j)} - I_f(i,j)| \quad (6)$$

$$\text{PSNR} = 20log_{10}\left(\frac{L^2}{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(I_r(i,j)-I_f(i,j))^2}\right) \quad (7)$$

PCA fusion method is used to fuse thermal infrared and visible images as presented in Figure 4.

Figure 4. From left to right: thermal image, visible image, fused image by PCA fuision method with Lon illumination.

Feature extraction

For key point extraction, Maximally Stable Extremal Region (MSER) has been compared with SURF and BRISK to extract key points. This MSER which gives the best results is robust [7]. This method coupled with texture extraction based on the Gray-Level Co-Occurrence Matrix (GLCM) is adapted and robust to fourteen textural features. In this experience, four important features [5]: contrast, correlation, energy and homogeneity were taken into account. The following formulas are used to present different textural features:

$$\text{Contrast} = \sum_{i,j}|i-j|^2\, p(i,j) \quad (8)$$

$$\text{Correlation} = \sum_{i,j}\frac{ij\,p(i,j)-\mu_x\mu_y}{\sigma_x\sigma_y} \quad (9)$$

$$\text{Energy} = \sum_{i,j} p(i,j)^2 \quad (10)$$

$$\text{Homogeneity} = \sum_{j,j}\frac{1}{1-(i-j)^2}\, p(i,j) \quad (11)$$

The different formulas (8), (9), (10) and (11) allow texture characterization by giving information about the amount of local variations, the measure of linear dependency of grey tones, the uniformity of texture and the closeness measure of the element distributions, respectively.

Finally, these two feature extraction tools give a hybrid feature analysis using interest points and textures simultaneously.

Face recognition

The face recognition is based on neural network [1] for face detection. And after detection, a test is done with Fusion Similarity Metric (FSIM) presented by Formula (12) to verify the result of the face recognition.

$$\text{FSIM} = \sum_{w\in W} sim(I_1,I_2,I_f|w)\begin{pmatrix} QI(I_1,I_f|w) \\ -QI(I_2,I_f|w)\end{pmatrix} + QI(I_2,I_f|w) \quad (12)$$

where : $sim(I_1,I_2,I_f|w) =$

$$\begin{cases} 0 & if \quad \frac{\sigma_{I_1I_f}}{\sigma_{I_1I_f}+\sigma_{I_2I_f}} < 0 \\ \frac{\sigma_{I_1I_f}}{\sigma_{I_1I_f}+\sigma_{I_2I_f}} & if \quad 0 \le \frac{\sigma_{I_1I_f}}{\sigma_{I_1I_f}+\sigma_{I_2I_f}} \le 1 \\ 1 & if \quad \frac{\sigma_{I_1I_f}}{\sigma_{I_1I_f}+\sigma_{I_2I_f}} > 1 \end{cases}$$

Experimental results

The database is extracted from Imaging Robotics Intelligent System (IRIS) database [3]. In this database there are visible and thermal infrared images. This study uses facial images in visible and infrared of 14 faces looking in four directions with different illuminations: Lon (Left Light On), Off (Left and Right Off) and Ron (Right Light On). In all, there are 336 facial images. Then, the fusion gives 168 fused images.

For feature extraction, L1, L2 and L3 are infrared thermal images, then V1, V2 and V3 are the corresponding visible images. The fused images obtained are PCA-L1V1, PCA-L2V2 and PCA-L3V3. Table 1 and Figure 5 recapitulate some results.

Table 1: Features presentation of three pairs of images and the fused images. From left to right, Con: Contrast, Cor: Correlation, Ene: Energy, Hom: Homogeneity, Key: Key Point.

	Con	Cor	Ene	Hom	Key
L1	0.62	0.94	0.12	0.84	117
V1	0.27	0.94	0.29	0.93	44
L2	0.40	0.92	0.16	0.86	147
V2	0.34	0.95	0.30	0.91	57
L3	0.50	0.92	0.10	0.92	107
V3	0.24	0.97	0.31	0.94	52
PCA-L1V1	0.43	0.94	0.15	0.84	84
PCA-L2V2	0.30	0.93	0.16	0.88	55
PCA-L3V3	0.23	0.96	0.19	0.91	51

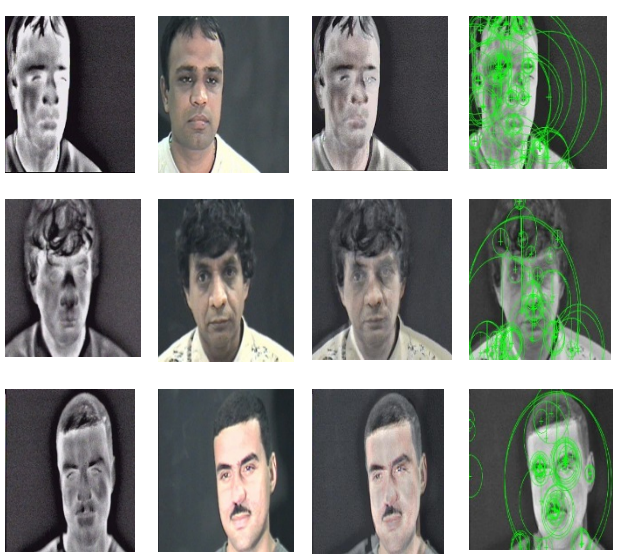

Figure 5. MSER key points extraction on fused images. Each line presents visible image, corresponding thermal infrared image, corresponding fused image by PCA fusion method, MSER key points on fused image respectively

By observing Table 1, the fused images are the best candidates for face recognition. Therefore, MS-FRHF is a novel way of face recognition to improve traditional methods. The different tests and results confirm this assumption.

Conclusion

The performance of face recognition by multispectral imaging compared to classical face recognition is a major issue. This study uses multispectral images by fusing visible images and thermal infrared images. Infrared thermal images have advantage of having a unique signature of thermal emission of the skin and are robust for face recognition in different illumination and various poses. These thermal images are combined with visible images that use the reflectance characteristics of the skin. The composite images obtained by fusion give good performance in face recognition.
Finally, as an extension of this work, multispectral imaging focuses on other challenges such as total darkness, disguises(makeups, hats, glasses, etc.), and facial expressions. In the future, we will work on how to combine different spectral images separately.

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Author Biography

Professor, ADOU Kablan Jerome as obtained a PHD in mathematics at university of Paris VI, 1989 and a PHD of mathematic model at University of Cocody Abidjan (Côte d'Ivoire), 1998. He works in the fields of mechanical, signal processing and computer science. He is also the manager of professional courses and research.

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