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Infrared thermal facial image sequence registration analysis and verification

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HIGHLIGHTS

- Determine the registration parameter for infrared thermal facial images by genetic algorithm.
- Create a fixed image for infrared thermal facial image through image preprocessing and eye localization.
- Propose a two-stage parameter optimization procedure to improve registration accuracy and efficiency.

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ABSTRACT

To study the emotional responses of subjects to the International Affective Picture System (IAPS), infrared thermal facial image sequence is preprocessed for registration before further analysis such that the variance caused by minor and irregular subject movements is reduced. Without affecting the comfort level and inducing minimal harm, this study proposes an infrared thermal facial image sequence registration process that will reduce the deviations caused by the unconscious head shaking of the subjects. A fixed image for registration is produced through the localization of the centroid of the eye region as well as image translation and rotation processes. Thermal image sequencing will then be automatically registered using the two-stage genetic algorithm proposed. The deviation before and after image registration will be demonstrated by image quality indices. The results show that the infrared thermal image sequence registration process proposed in this study is effective in localizing facial images accurately, which will be beneficial to the correlation analysis of psychological information related to the facial area.

1. Introduction

In recent years, research on facial expressions recognition using visible light has achieved good results, but there are still technical issues, such as variance in illumination and face pose, which have to be overcome [1,2]. Under general visible light environment, illumination changes will significantly affect the image information of the visible light. Therefore, many studies began using infrared thermal imaging to reduce the impact caused by illumination conditions.

Infrared thermal imaging equipment is commonly used in medical treatment to provide assistance in disease diagnosis, such as providing temperature distribution records and changes in the body [3,4]. In recent years, there have been studies on facial recognition using infrared thermal image. Mostafa et al., [5] and Budzan et al., [6] proposed localization procedures for facial and eye images at a lower resolution. In addition to static infrared thermal images, dynamic infrared thermal image samples have also been studied [6–8]. Its application includes biology, tracking, and face recognition. The requirements on the infrared thermal image sequencing vary depending on the objectives of different studies [9], of which, infrared thermal facial image registration is an important research topic. However, there have been a few studies on infrared thermal image sequencing. While collecting infrared thermal facial images, the head of the subjects are not fixated in order to ensure comfort. This leads to difficulties in subsequent correlation analysis. Therefore, image sequencing registration and alignment are crucial.

Image registration can be performed on the basis of feature or area. Registration based on feature is not suitable for high nonlinear deviations [10], Therefore, this study adopts an affine area technique [11]. In a thermal facial image, the center of the eyes is less measured than other facial features [5]. Therefore, in this study, the appearance and geometric information of the eyes are used for registration. In addition, although infrared thermal facial images can display the basic structure of temperature distribution, the difference between relative features is not significant. In 2013,

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Wang et al. [12] proposed an adaboost method for eye localization, which can achieve an accuracy of up to 86%.

In this study, the infrared thermal facial image sequences of subjects whose head is not fixated are collected in this study to generate a database and correct head deflection. First, influence of machine configurations and environmental factors are described in Section 2.1. As adaboost [13,14] localization requires a large amount of training samples and it is hard to obtain accurate eye localization using gray value projections [15,16], a method for the application of fixed images in infrared thermal facial imaging is proposed in Section 2.2. In Section 2.3, a two-stage GA (genetic algorithm) is proposed for the calculation of the similarity fixed and moving images by taking NMI (Normalized Mutual Information) as an objective function in order to accurately register the minor unintentional rotation. The results of the image registration in Section 2.3 are presented in Section 3. In Section 3, we explore the differences in the affine parameters and image quality indices before and after image registration are discussed. Finally, the results and discussion are provided in Section 4.

2. Proposed approach

2.1. Experimental setup

The facial skin temperature distribution matrix of this study is provided by the digital infrared thermal image system (Spectrum 9000-MB Series; United Integrated Service Co. Ltd). The infrared thermal facial images collected area 320 × 240 pixels temperature data matrix with sampling frequency is 2 fps. The DITIS specifications are shown in Table 1.

DITIS (Digital Infrared Thermal Image System) captures thermal radiation states. To avoid interference in experimental accuracy by other heat sources and destruction of the infrared thermal facial images, the impact caused by other thermal interferences must be reduced. The ambient temperature is maintained between 26 °C and 28 °C during the sampling process, and strong convection current and entry by unauthorized personnel must be avoided. The room is surrounded by three layers of curtains in order to minimize the reflection factor of thermal radiation.

During the sampling process, subjects are asked to watch a video that lasts for 8 min 50 s. The video is made of IAPS [17] pictures. A total of 1060 thermal images of the subjects under stimulation by the IAPS are collected synchronously by the DITIS to create a temperature distribution matrix. The equipment is pre-calibrated before each sampling to ensure the stability of thermal imaging. DITIS is calibrated using a Thermal Reference Source (TRS) which provides correction for responsiveness and gain differences via a two-temperature correction. The subjects are 1.5 m away from the DITIS in order to ensure the complete collection of infrared thermal facial images and maintain an appropriate space margin, as shown in Fig. 1.

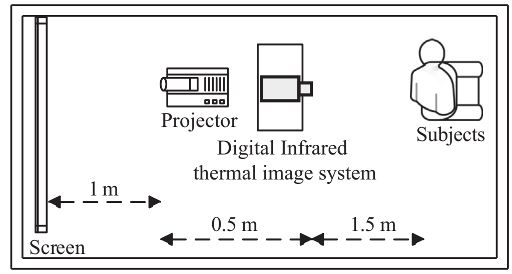

Fig. 1. Test environment setup.

2.2. Calibration of the fixed image

The priority of image sequence registration is to produce a fixed image that will serve as a basis for registration. The first frame is used to create the fixed image in this study, as shown in Fig. 2 and described below.

Table 1
Specification.

IR sensor type	Microbolometer
Noise equivalent temperature difference	0.07 °C
Temperature measurement range	10–40 °C
Image resolution	320(h) × 240(v)

2.2.1. Step 1: background removal

To ensure accuracy and efficiency for subsequent image registration, the background around the face should be removed. The original image before background temperature filtering is shown in Fig. 3(a). According to the facial contour temperature distribution in Fig. 3(b), the threshold facial temperature is found to be 29.5 °C. Any temperature value that is below this threshold is set to 0 °C to filter out the background and ambient temperature. The result after filtering is shown in Fig. 3(c). The image with the face area reserved is shown in Fig. 3(d).

2.2.2. Step 2: eye localization

The operator will roughly select the location of the eyes as shown in Fig. 4(a) as the zero level contour of DRLSE algorithm. The temperature difference between the eyes and face can be used to determine the eye contours automatically using the DRLSE method [18], as shown in Fig. 4(b). The parameters required for the DRLSE calculation are shown in Table 2. The center of mass of the region is calculated using the eye contours to obtain the center of mass of the eyes.

2.2.3. Step 3: generation of fixed image

Image translation and the rotation angle are determined using the center of mass of the eyes and the midpoint between the

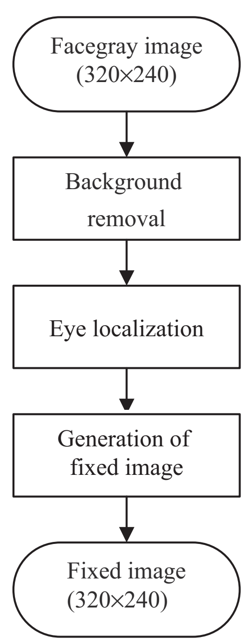

Fig. 2. Fixed image processing flow chart.