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A new segmentation method for phase change thermography sequence☆

Xiao-nian Wang*, Zu-ren Feng, Miao Zhang

State Key Laboratory for Manufacturing Systems Engineering, Systems Engineering Institute, Xi'an Jiaotong University, Xi'an 710049, China

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Abstract

A new segmentation method for image sequence is proposed in order to get the isotherm from phase change thermography sequence (PCTS). Firstly, the PCTS is transformed into a series of synthesized images by compression and conversion, so the isotherm extraction can be transformed into the segmentation of a series of synthesized images. Secondly, a virtual illumination model is constructed to eliminate the glisten of the aerocraft model. In order to get the parameters of virtual illumination model, a coordination-optimization method is employed and all parameters are obtained according to the similarity constraint. Finally, the proving isotherms are gained after the threshold coefficients are compensated. The eventual results demonstrate the efficiency of the proposed segmentation method.

Keywords: Image segmentation; Phase change thermography sequence; Illumination model; Threshold coefficient

0. Introduction

The phase change thermography technique [1,2] is a test technique in wind tunnel for measuring thermal flow in a large area. The phase change material sprayed on the aerocraft surface changes opaque into transparent when its phase changes, so the portion where the phase has changed appears the aerocraft's color (black), while the rest still appears the white, and the boundary of these two parts is called isotherm (phase change line). We can see this phenomenon in Fig. 1. The temperature of employed phase change material is fixed, so the location of the isotherm indicates the surface temperature of this position. If the motion of specific isotherm is obtained from phase change thermography sequence (PCTS), the temperature field of the aerocraft's surface can be easily calculated, so getting the isotherm accurately is the key task of phase change thermography technique.

Among the following methods for sequence image segmentation, we have learned that Roux et al. [4] gets the search region based on the difference of two frames; Zheng et al. [5] obtains the search region of the next frame based on the statistic technique; Hajdu et al. [6] implements segmentation based on the distance among colors in two consecutive frames; Zhou et al. [7] regards external force of active contour models (ACM) as the function of light flow vector. All the literatures mentioned above reveal such a fact that the segmentation outcome of the latter frame depends on the result of the current one. The zonal region exists in the procedure of phase change due to the existence of two-phase zones [3,8]. Take the 250th frame as an example (shown in Fig. 1c); the extracted edges with Sobel and Canny method are, respectively, shown in Fig. 2a and b; it is hard to find out the expected contour of such frame. So in this instance, the ambiguous contour of the current frame provides no clues for the latter. With time, the position of isotherm would shift from the head to the end monotonously, so this constraint must be adequately utilized to get rational segmentation.

The computation load will be considerable if the 600 frames are segmented and the relationships among them are considered at the same time. In this paper, firstly, the initial PCTS is transformed into a series of synthesized images by compression and conversion. Secondly, in order to eliminate the influence of specular reflection, a virtual illumination model is formulated. Thirdly, the parameters of illumination model are obtained with coordination-optimization method. Finally, the approving isotherm is gained after the glisten is removed.

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* Corresponding author. Tel.: +86 29 82665487.
E-mail address: dawnyear@mail.xjtu.edu.cn (X.-n. Wang).

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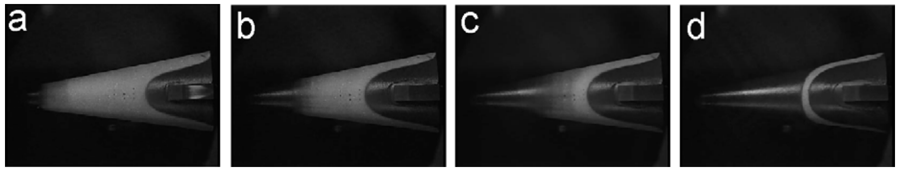

Fig. 1. The 50th, 150th, 250th, 500th frame of PCTS.

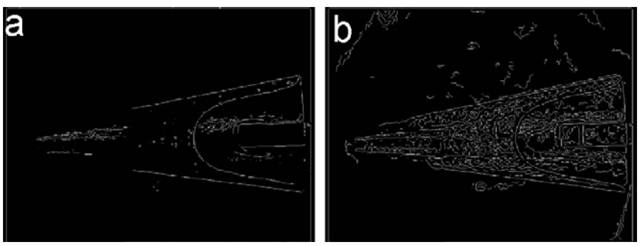

Fig. 2. Edges of the 250th frame, (a) Sobel method, (b) Canny method.

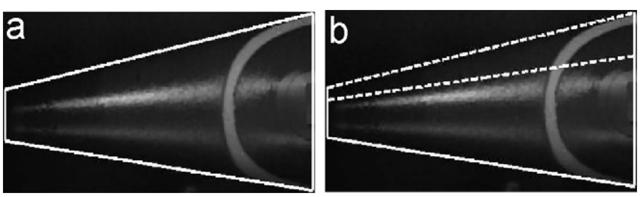

Fig. 3. Division: (a) profile of the aerocraft image; (b) division of sub-region.

1. Initial segmentation

In this section, the PCTS is transformed into a series of synthesized images first, and then every synthesized image is segmented by thresholding.

1.1. Synthesized images from PCTS

The position of aerocraft is fixed in the wind tunnel, so the aerocraft image is also motionless. A trapezium of 500 pixel height, in which all isotherms are covered, is selected manually, shown as the white solid line in Fig. 3a. The profile of the aerocraft in every frame of PCTS can be selected in this manner.

Firstly, the image of aerocraft is divided into many sub-regions, one of which is shown as the white dot trapezium in Fig. 3b. Then, a sub-region is vertically compressed into a row, the value of which at the jth column is equal to the average brightness of all the points at the jth column in the sub-region ($j = 1, 2, \ldots, 500$). In this paper, the image of aerocraft is divided into 19 sub-regions, and the length of the upper bottom of every sub-region is equal, and so is the lower bottom. We can get 19 rows from one frame of PCTS and the *characteristic image* is formed when the 19 rows are arranged together. One of the actual divided instances and the characteristic images are shown in Fig. 4a and b, respectively. The isotherm in every sub-region is almost in the same column, so the isotherm in every sub-region is represented as the phase change point in the corresponding row. Actually, these phase change points in every row make up the new isotherm of this characteristic image. In this paper, we suppose that the positions of isotherms in characteristic images represent the positions of isotherms in PCTS. That is to say, the approximate error can be omitted.

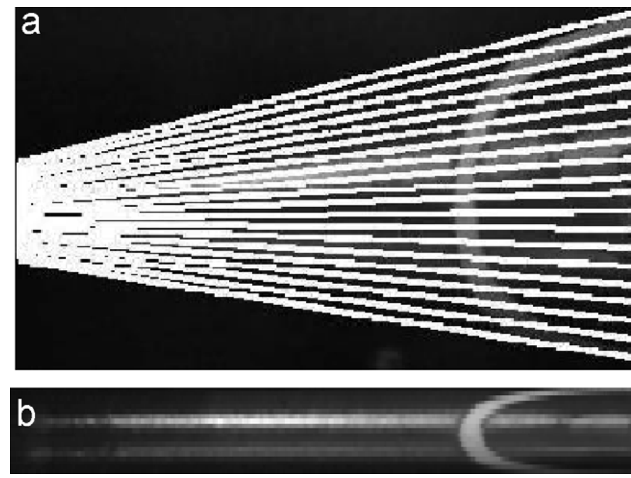

Fig. 4. Construction of characteristic image: (a) divisions of sub-region; (b) characteristic image.

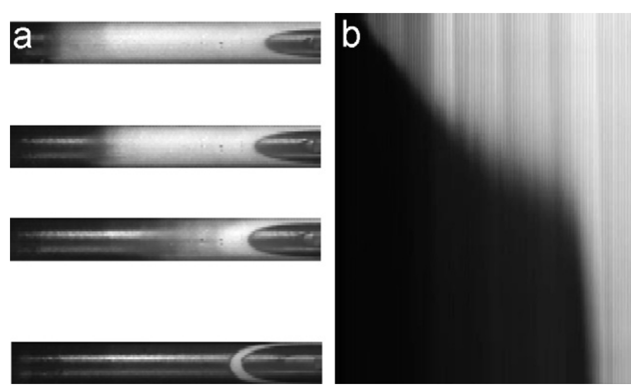

Fig. 5. Construction of synthesized image: (a) characteristic images; (b) synthesized image.

The height of every sub-region mentioned above is 500 pixels, so every frame of PCTS is compressed into a characteristic image which has $19 * 500$ pixels. There are 600 frames in PCTS and therefore 600 frames of characteristic images are obtained.

The ith synthesized image is formed if the ith rows of all characteristic images are arranged together ($i = 1, 2, \ldots, 19$). It is clear that the 1st synthesized image consists of the first