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Automatic Measurement of Human Body Temperature on Thermal Image Using Knowledge-Based Criteria

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Abstract. Instead of thermometer, an infrared camera could be uti-lized to scan body temperature instantly and non-contact. This paper proposed a non-contact measurement of human body temperature by au-tomatically locating inner-chantus on thermal images. The inner-canthus were detected in both eyes individually. It located inner-canthi based on temperature where inner-canthi has the highest temperature in face area. A Thresholding based on 9-highest temperature were applied to detect candidates of inner-canthus' blob as it must have minimum 9 pixel area according to the Standard. Three knowledge based on characteristic of eye were also applied in the algorithm as several spot in face usually falls within the temperature threshold. The result show accuracy of al-gorithm to detect eye is 82% whether the eyelids were open or closed. There is no signi cant di erent of temperature between closed and open eyes based on paired t-test. The algorithm also showed similar result to thermometer measurement based on paired t-test.

1 Introduction

Thermometer is the most common tool used for measuring human body temper-ature. There are oral, axillary and rectal type of thermometer measurement. It is cheap, handy and reliable. Nevertheless, the measurement is time consuming and need to be in-contact with skin. There is also infrared-based thermometer that was aimed to forehead and tympanic. The later thermometer have faster measurement time. However, it perform a single body measurement at a time.

Thermal infrared camera was a perfect tool to be used for mass screening. The screening on human body temperature usually carried out in airport or other public place during global epidemic of viral infection [1][2][3]. O cers would screen the walking passenger and stare at the screen continuously to look for elevated body temperature. This manual screening would be easier if it is automatic. A screening machine that would buzz an alert once a passenger is detected to have fever would ease the process. The measurement would be fast and non-contact as well.

This paper proposed an automatic algorithm to measure human body tem-perature using thermal camera. The camera captures infrared radiation that is emitted by object using micro-bolometer sensor. The infrared radiation is acknowledged as temperature of the object. The algorithm used other part of human body that is also notable as location for temperature measurement, which is inner-canthus. It is located in inner-tip of eyes and one of measurement spot for temperature [4] [5]. The inner-canthus is exposed body part compare to oral, axillary and rectal, hence it is suitable for non-contact and mass measurement.

A novel eye localization for inner-canthus detection has been proposed using template-matching, knowledge-based and modi ed Randomized Hough Trans-form (RHT) [6]. The algorithm used parameters of ellipse to be lled in the Hough Space. Face is identi ed as the biggest ellipse whilst eyes were located using knowledge-based of eyes. Inner-canthi was identi ed using region growing with the highest temperature in the eye as the initial seed. The result con rms a very accurate method for inner-canthus localization although complexity to ll the Hough Space required extra calculation.

In other research, [7] create a template using anthropometry to locate inner-corner of eyes where distance between eyes are one- fth of the head breadth. The template were two peaks with similar magnitude in such distance. The method is simple and fast but eyes must be horizontally parallel. It searched eyes in pairs.

2 Method

This paper developed an early algorithm to measure human body temperature that is limited to frontal face pose. It search inner-canthus in each eye individu-ally to result more adaptive localization. The face must not wearing glasses since the inner-canthus would be covered and infrared could not transmit through glass. Images were acquired using thermal infrared camera with locked range of temperature of 26 C - 37 C. Face detection algorithm for infrared images has been explained in [8] which used human temperature as threshold. The seg-mented face from background is shown in Fig.1(a).

2.1 Inner-canthi Blob Selection based on High Temperature

Inner-canthi has high temperature compare to other part of face. Standard for fever screening using thermal camera is strictly requisite that inner-canthi must be at least 9 pixels blob mentioned in [4] [9] based on ISO documentation. Assuming that each intensity in inner-canthi has 9 di erent high intensities, then the very rst step on the algorithm was locating the 9-highest intensities in face. These segmentation is performed by applying simple "Thresholding" method. Intensities that falls within threshold of 9-highest intensities would be given value of 0. Fig.1(b) shows the location of these temperatures as black blobs in original image of Fig.1(a). Area of blob that was smaller than 9 pixel were eliminated to follow the ISO standard on minimum pixel size of inner-canthus. Area of blobs was determined by addressing number of pixels within each connected-component of 0 values. The elimination was shown in Fig.1(c).

As shown in Fig.1(c), high temperature was not only present in eye coordi-nate. It usually appears in forehead, nose-tip and mouth-tip. Hence localizing inner-canthi solely based on high temperature would be inaccurate. A pattern recognition of eye is required to distinguish blob of inner-canthi from others.

2.2 Inner-canthi Blob Selection using Knowledge-based Template of Eye

Inner-canthi is located in eyes, hence knowledge about eye was used to segment the detected blob of eye from others. Eye-frame candidates were drawn from the location of the black blobs. Each frame's size was set according to facial proportion. Normal eyes has width of one- fth the head's width and height of two-third the eye's width [10]. Area of blobs that was bigger than this size of eye-frame were eliminated. This second elimination is shown in Fig.1(d).

Each black blobs was proposed for frames of right-eye and left-eye. For left-eye candidate, the black blob was in the middle-rightmost. Coordinate of middle was de ned as the maximum vertical coordinate plus the minimum vertical coordi-nate divided by 2, whilst the rightmost was de ned as the maximum horizontal coordinate. For right-eye candidate, the black blob is in the middle-leftmost. Coordinate of middle was de ned as the maximum vertical coordinate plus the minimum vertical coordinate divided by 2, whilst the leftmost was de ned as the minimum horizontal coordinate. Suppose that a blob has vertical coordi-nate with maximum 70 and minimum 40, and has horizontal coordinate with maximum 70 and minimum 60, then the coordinate (x; y) of middle-rightmost is (70; (70 + 40)=2) and middle-leftmost is (60; (70 + 40)=2). From the middle-rightmost coordinate, a frame of left-eye candidate was drawn with eye's width to the left. frame for right-eye candidate was drawn with eye's width to the right. Each blob's left-eye candidates are shown in Fig.1(e) and right-eye candidate are shown in Fig.1(f).

Once the eye-frame candidates were enlisted, a knowledge-based template were compared to each candidate. The knowledge were based on unique charac-teristic of eyes, which are:

1. Inner-canthi is located in inner-tip of eye

   Inner-canthi which has high temperature in eye-frame is located in the inner-tip of eye. The black blob of inner-canthi should appear and only appear in right-half for left-eye and left-half for right-eye.

   The algorithm checked the present of black blob by enlisting its coordinates. It eliminated eye-frame candidates which has black blobs outside the criteria.
2. Eye location based on facial proportion

   Eyes are located in the second and fourth of one- fth of face-width [10]. Thus, eyes should not be located in edge of face.

   The algorithm eliminate eye-frame candidate that was located in edge of face. It partially has non-face pixel as the result of face segmentation.

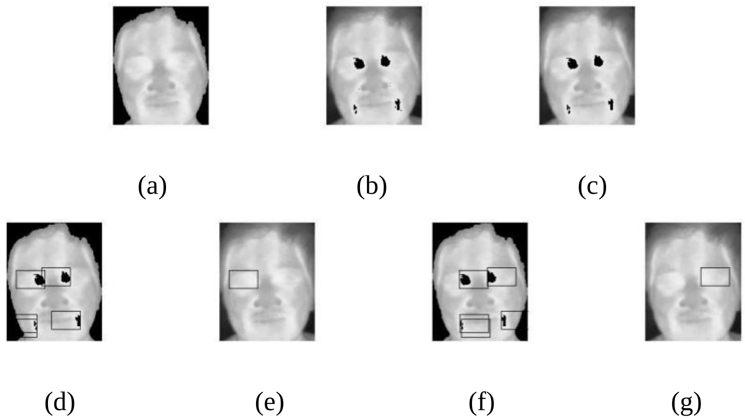

Fig. 1. Inner-Canthus Localization Process; (a) Segmented face, (b)Inner-canthus candidate based on high temperature, (c) Inner-canthus candidate based on blob area, (d) Left-eye candidate, (e) Left-eye detected, (f) Right-eye candidate, (g) Right-eye detected

3. Inner-chanti is nearly round

   Inner-chanti appears as a nearly round blob. In the algorithm, round was de ned as having similar proportion between width and height.

   The algorithm check the width to height ratio of each inner-canthi's black blob in eye-frame candidates. Nearly round blob was assumed to has the smallest width to height ratio.

The most nearly-round blobs from eye-candidates that meets knowledge num-ber one and two were selected from candidates. The detected frame of right and left eye are shown in Fig. 1(e) and Fig. 1(g), respectively.

2.3 Calculate Human Body Temperature

Once eye-frame/s were detected, inner-canthus were simply the blob in it. It has meet the criteria in the Standard which has minimum 9 pixel area. To determine the temperature in the inner-canthi, the highest intensity in the blob was chosen. It then converted from scale of 0 - 255 into the temperature range during data acquisition which is 26 C - 37 C. Temperature that was chosen between left and right eye to represent the temperature of particular face was the highest between the two. If only one eye-frame was detected, then its temperature was assigned as the temperature of the face.

3 Result and Discussion

The algorithm was tested in 8 faces. Each has its eye closed (left) and open (right) resulting 16 test images. Result of eyes and inner-canthus localization is

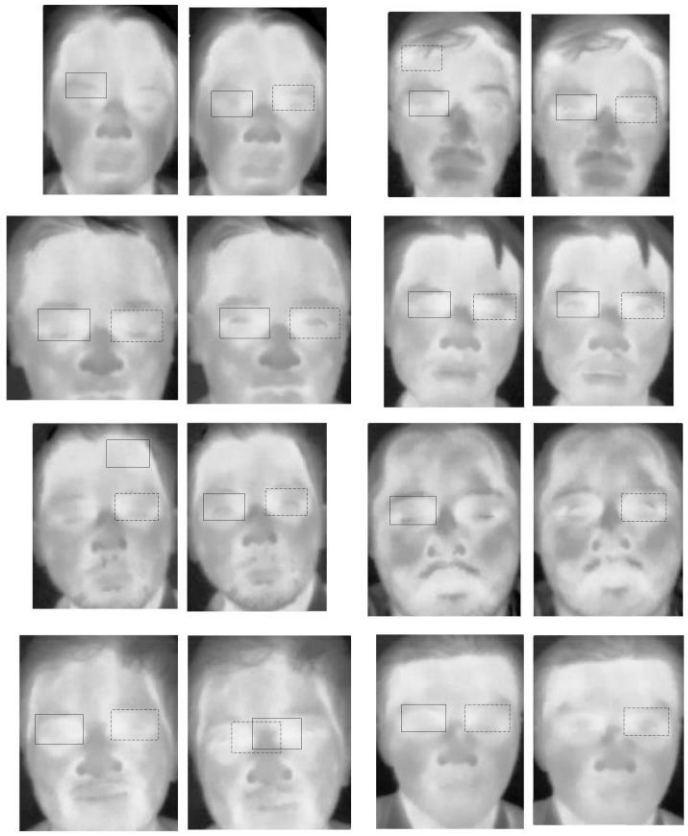

Fig. 2. Detected eye from 6 person with open and closed eye

shown in Figure 2. Detected left eye-frame is shown as frame in continuous line, whilst right eye-frame is shown in dashed line. From total 28 detected eye-frame, left or right, 5 eye-frame were inaccurate compare to visual observation resulting accuracy of 82%. The inaccurate eye-frame localization were found in image ID (1)-closed-left eye, (2)-closed-right eye, (5)-closed-left eye, (7)-open-left eye, and (7)-close-right eye.

The rst criteria of inner-canthi was based on temperature where only 9 high temperature was set as the candidates. Most images showed that the threshold was able to locate both inner-canthi in left and right eyes. Nevertheless, few im-ages showed only inner-canthi in one eyes was detected as shown by Figure 3(a). Both inner-canthus were di er 9 intensity which equal to 0.4 C in temperature range of 26 C - 37 C. Thus the rst knowledge of eyes in the second criteria was not met that could result false detection. For example in Figure 3(a), the rst knowledge of eye in the second criteria should eliminate the frame from right

(a) (b)

Fig. 3. False detection of eye-frame candidate when: (a) only one inner-canthi was segmented based on temperature, (b) distance between two inner-canthus is larger than one- fth of face-width

(a) (b)

Fig. 4. False detection of eye-frame candidate based on round knowledge of eye in the second criteria; (a) left eye-frame candidates (b) detected left eye-frame

eye-frame candidates. Instead the algorithm still detect it as the right eye-frame candidate.

Compare to when both inner-canthus were detected as in Figure 1 (d) and (e), the rst knowledge in second criteria could eliminate the false left and right eye-frame from candidate. The knowledge also fails to eliminate false left and right eye-frame when distance between both inner-canthus are larger that one-fth of face-width as stated in facial proportion of normal face as in Figure 3(b)

The detected blob of inner-canthi usually appears as nearly round. Neverthe-less, few images show the opposite as seen in Figure 4(a). The algorithm chosen smaller blobs' width to height ratio between the two candidates to be the left-eye-frame. The middle eye-frame candidate was not part of the selection since it fails to meet the rst knowledge in the second criteria. The result in Figure 4(b)shows false detection of left eye-frame.

The temperature of 8 person determined by algorithm was compared to temperature measured using axillary thermometer that were taken simultaneously during image acquisition. The comparison is shown in Table 1. Each person has temperature where its eyes were open and closed. A paired t-test was performed between temperature measured by thermometer and average temperature mea-sured by algorithm in open and closed condition of eye. Two-tailed P values between the two is 0.4254 in 99.9% value of statistical signi cance. The paired t-test fail to reject the null hypothesis meaning that there is no signi cant dif-ferent of temperature between thermometer measurement and the algorithm. Thus, algorithm of inner-canthus detection on thermal images has similar result to the thermometer measurement.

Table 1. Temperature comparison between thermometer and the algorithm in open and closed eye

Person No.	Temp. Thermometer(C)	Temp. Algo.(C) Eyes Closed	Temp. Algo.(C) Eyes Open
1	35.4	35.8	36.1
2	36.4	36.3	36.1
3	36.4	36.2	36.3
4	36.0	36.4	36.5
5	36.2	36.2	36.2
6	36.4	36.1	36.1
7	36.3	36.6	36.6
8	36.2	36.3	36.3

Two-tailed P values between temperature when eyes were open and closed is equals to 0.6263 in 99.9% value of statistical signi cance. Average of temperature in closed eyes is 36.238 and open eyes is 36.263 with standard deviation of 0.233 and 0.192, respectively. The paired t-test fail to reject the null hypothesis meaning that there is no signi cant di erent of temperature between closed and open condition of eyes. Thus the algorithm was able to handle variation of eyelids condition.

4 Conclusion

This paper developed an algorithm to automatically locate inner-canthus in ther-mal images for temperature measurement of human body. It able to locate inner-canthus in individual eyes with good accuracy. Further study should investigate additional discriminant features of eyes or inner-canthus to increase the local-ization accuracy. The algorithm should also be extended to handle variation in face condition.

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