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Fuzzy Logic Based Viola Jones Fever Detection Method in Thermal Imaging System

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Abstract

This paper presents an effective automated fever detection method in thermal imaging system. It utilizes the Viola Jones method for eye detection, mean sample method for canthus region detection and fuzzy logic based for fever classification. It integrates the Viola Jones eye localization method, mean sample canthus region detection method and fuzzy logic based fever classification method into an automated fever detection algorithm to be applied in thermal imaging system on contactless human body temperature measurement. The detailed fever detection algorithm is explained in the paper explain in this paper with proper experimental results. Several conditions have to be fulfilled prior to the fever detection. There should be one person facing the thermal camera and no other external heat-emitting objects in background are captured by thermal camera. Overall, the fever detection method demonstrates 63% of accuracy.

Fever screening; eye localization; canthus region detection; thermal imaging; computer vision; image processing

I. INTRODUCTION

Fever which also known as pyrexia is a common medical sign that indicated by an elevation of human body temperature above the normal range of 36.5-37.5 °C. There are two methods to measure the human body temperature which are contact and contactless method. The contact method is a direct measurement using thermometer on certain parts of the body which is the most accurate parts is the anus followed by oral and skin temperature measurement. The contact method are time consuming, had injury risk due to broken thermometer, non-comfortable if the temperature taken in sensitive area like anus and not suitable for public screening. On the other hand, contactless method is temperature measurement using infrared thermometer and thermal imaging. Infrared thermometer measurement method also time consuming since the method is almost the same with conventional method which is it need someone to point at certain body parts like forehead and ear, the advantage is just it is hygienic since it is contactless. The infrared thermal imaging is an imaging technique used for constructing thermal maps of emitting objects by detecting the infrared radiation emitted from the surface and by converting into measurable signal [1]. It is suitable for public screening and it is used since outbreak of H1N1 in 2006. This method is reliable, fast, more comfortable, no injury risk, may help to limit the spread of viral disease. The most reliable parts to measure core body temperature for thermal imaging is in the human facial which are at the forehead, ear region and inner canthus of eye. Based on [2-4], the most accurate part to measure human body temperature is at inner canthus of eye which it is most consistently warmest area on the head when ambient temperature change, most stable area and this canthus region is fed by internal carotid artery with the blood circulation coming from brain whereas the rest of the face is supplied by external carotid artery, so it is less reliable indicator of core body temperature. Previous thermal imaging temperature measurement method [4] is not automated fever detection since it need human operator to manually operating the system. The result might not be accurate due to operator skills dependent or carelessness. The accuracy of recent finding [1] for automated fever detection which measure the temperature in whole human facial may be doubted since [2-4]stated that the most accurate parts to measure human body temperature is at inner canthus of eye.

As far as the problem of facial component is concerned which are thermal images have low signal to noise ratio, edges are diffuse and knowledge applicable for color face image is not applicable for thermal images and also the facial components are hardly visible [5]. Viola Jones method [6-7] are proposed for eye detection in this research since it is robust to noise, respond to coarser aspects of the image and computationally efficient. A novel mean sample canthus region detection method is proposed which will use for temperature measurement and a fuzzy logic based fever classification method is proposed for fever screening.
The paper is organized as follows; Section II describes the system model, followed by the proposed fever detection in Section III. Experimental results are explained in Section IV. Lastly, Section V reports the conclusion and enlists some future works.

II. THERMAL IMAGING BASED FEVER SCREENING SYSTEM

Fig. 1 shows the proposed fever screening system which are consist of a thermal camera, coupled with computer installed with the MATLAB programming (version 2012a or later) and an appliance for further image processing.

(a) Thermal camera  (b) Computer  (c) Display

Fig 1: Thermal Imaging Based Fever Screening System

A. Thermal Camera
A thermal camera used in this paper is from FLIR model, Thermo Vision A-20M. It is features with a perfect resolution of 320x240 pixels with capability to measure the temperature from -20°C-150°C and with additional special lenses up to 900°C. The refresh rate is 50/60 Hz. To install multiple cameras in the network, Ethernet connectivity is an ideal option.

B. Computer and appliances
The thermal image is received from the thermal camera and processed using computer installed with MATLAB programming software.

III. FUZZY LOGIC BASED VIOLA JONES FEVER DETECTION ALGORITHM

The proposed fever detection algorithm consists of Viola Jones based eye detection, mean sample canthus region detection followed by fuzzy logic fever detection.

A. Viola Jones based eye detection
Eye detection method operates using Viola Jones method which is Haar Classifiers to rapidly detect any object and Adaboost classifier cascades that are based on Haar like features and not pixels. The steps for Viola Jones based eye localization are:

Step 1: Build training set. The input image which is the face is subdivided into patches and analyses it whether it contains target facial component or not. The patches can be represented as coefficient vector because each coefficient is from applying a filter onto the patches. The build training set for thermal image is different with rgb image since high level clutter present in the image [5]. For negative sample, instead of use random image, regions that do not contain the targeted object in human facial is used so that the clutter fully belongs to the face region, less variable and can be more easily modeled. The positive samples consist of targeted object which is right eye region and the negative samples are non-eye region in human facial. The training set consists of 1500 positive and 3000 negative patches in size 25x25. The thermal images are from captured image by thermal camera FLIR model, Thermo Vision A-20M.

Step 2: Initialize weight for positive and negative samples.

Step 3: Calculate the integral image. From this calculation, the value of mean and standard deviation is obtained. Expand the range of standard deviation and do it for fifty times. The value to expand is start with mean value and expands it little by little and analyses value of eye in the range.

Step 4: When the ranges reach three conditions which are eye detection is 100%, low non-eye detection and total error is below than 50%, the strong classifier may be obtained.

Step 5: Set a of t, a values show the value of strong classifier and the higher the number, the better it is.

Step 6: Weight of each image are updated accordingly and images that were recognized correctly will be reduced in weight.

Step 7: Final strong classifier will be obtained after training. The strong classifier will detect the right eye in the thermal image.

Fig 2: Eye detection

B. Canthus region detection
Canthus region detection is done once eye been detected. Assume that eye will be in the cropped box for detected eye; mean sample canthus region detection is applied on the detected box followed by temperature range searching for fuzzy logic fever classification.

Fig 3: Cropped eye detected

Step 1: Find a y-axis middle point of the cropped box.

\[ m = (y_T - y_b)/2 \]
Step 2: Find an x-axis quarter point of the cropped box.

\[ q = (x_2 - x_1)/4 \]

Step 3: Temperature range searching process where fever subject will be determined based on predetermined range temperature value. There are two methods tested for temperature range searching which are based on grayscale pixel value and color extraction pixel value. The pixel value for temperature range searching is manually determined using 300 thermal images for fever subjects.

a. Grayscale pixel value

The color image is converted to grayscale using MATLAB®’s build-in function. Based on canthus region from \( q \) (from \( B \), step 2), the temperature range searching is done by manually determining the grayscale pixel value from the thermal image based on indicated temperature. The grayscale pixel value is proportional to temperature (see Graph 1).

b. Color extraction pixel value

The basic concept of color extraction pixel value is extraction of red and green element from the image and the extraction color is summed up. The summation value is proportional to temperature value (see Graph 1). Temperature range searching process is done manually in canthus region in \( q \) (from \( B \), step 2) based on summation of red and green value.

Step 4: Find the average value of that region.

\[ a = \Sigma (q/\text{Total pixels}) \]

\( q \) is canthus detection (from \( B \), step 2) and Total pixels is total pixel value for detected box.

For fever detection, the value of \( a \) (from \( B \), step 4) is taken. If the value of \( a \) is above the threshold value, the subject is obtained from pixel value that indicated 38°C of temperature.

\[ \text{threshold} = \text{pixel value/temperature value} \]

For fever classification, the range of pixel value for fever classification is obtained from temperature thresholding step (at \( B \), step 3) and the fever will be classified based on value of \( a \). The fever classification described as above:

- If \( \text{pixel value} < x_1 \), the subject is non-fever;
- If \( x_1 < \text{pixel value} < x_2 \), the subject is fever;
- If \( \text{pixel value} > x_2 \), the subject is high fever.

IV. EXPERIMENTAL RESULT

The sample thermal images for patients were collected at Policlinic Gomez, Cyberjaya. 500 thermal images for patients have been collected. The disease types identified by doctor are ranging from cough, sore throat, headache, diarrhea, joint pain and others. Out of 4000 thermal images collected, 55 samples were identified as fever patients and 3945 identified as non-fever patients.

All the collected data is tested using Fuzzy Logic Based Viola Jones Fever Detection Algorithm. Among 55 collected thermal images identified by doctor as fever patients, 35 samples correctly detected as fever with an accuracy of 63%. Among 3945 collected thermal images identified by doctor as non-fever patients, 2500 correctly detected as non-fever with an accuracy of 63%.

Parameter setting for this algorithm is the threshold value of the temperature. This parameter is determined by the measured value of pixel value per temperature from the color bar that obtains from thermal camera. The pixel value that indicated as 38°C chose as threshold value. The optimum parameter for this case is 492. From data collection which are the thermal images, it was found that most stable and accurate location to measure core body temperature for infrared thermal imaging based is at the canthus region.

False positive rate is 30% and false negative rate is 40%. False positive is when non-fever subject is falsely identified as fever. Few factors may contribute to false positive such as the image taken when the subject is in stress mood or after the subject done some physical activities which may affect the temperature in the subject’s facial. The consequence is time-consuming since more works to do to reconfirm the subject is healthy. False negative is when fever subject is identified as non-fever. This case may happen if the canthus region is falsely detected and the temperature is measured at other parts of human facial which is have lower temperature.
False negative has bad consequence since if the subject have infectious disease like H1N1, the viral may infect to more people.

Table 1: SUMMARY OF FEVER DETECTION RESULT

<table>
<thead>
<tr>
<th>Age/Types</th>
<th>Child</th>
<th>Youth</th>
<th>Adult</th>
<th>Older</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever identified by doctor</td>
<td>3</td>
<td>1</td>
<td>51</td>
<td>0</td>
<td>55</td>
</tr>
<tr>
<td>Fever identified by algorithm</td>
<td>3</td>
<td>1</td>
<td>31</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>Non-fever identified by doctor</td>
<td>4</td>
<td>5</td>
<td>3936</td>
<td>0</td>
<td>3945</td>
</tr>
<tr>
<td>Non-fever identified by algorithm</td>
<td>3</td>
<td>4</td>
<td>2493</td>
<td>0</td>
<td>2500</td>
</tr>
</tbody>
</table>

Table 2: SUMMARY OF DISEASE DETECTED

<table>
<thead>
<tr>
<th>Disease/Types</th>
<th>Cough</th>
<th>Sore throat</th>
<th>Headache</th>
<th>Diarrhea</th>
<th>Joint pain</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever identify by doctor</td>
<td>13</td>
<td>16</td>
<td>15</td>
<td>2</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Fever identify by algorithm</td>
<td>10</td>
<td>11</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Non-fever identify by doctor</td>
<td>1000</td>
<td>200</td>
<td>500</td>
<td>67</td>
<td>69</td>
<td>2109</td>
</tr>
<tr>
<td>Non-fever identify by algorithm</td>
<td>800</td>
<td>100</td>
<td>450</td>
<td>60</td>
<td>60</td>
<td>1030</td>
</tr>
</tbody>
</table>

V. CONCLUSION

This paper proposed Fuzzy Logic based Viola Jones method that used thermal image for fever screening. It is found reliable with 63% accuracy. The temperature measurement is depends on eye detection algorithm which is the temperature will be measured at the detected eye box. Altering the method for eye detection method may improve the accuracy. In addition, all the images tested are human being images, if there are non-human being images tested, the algorithm will still search for wrong eye and wrong canthus region which will lead to the wrong result. In future, there is human detection method will be embedded into the fuzzy logic based Viola Jones fever detection method to confirm the existence of human being before proceed with fever detection.

REFERENCES