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Using Bimodal Gaussian Mixture Model-Based Algorithm for Background Segmentation in Thermal Fever Mass Screening

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Abstract

Since the SARS outbreak in 2003, the use of thermal imaging technology for fever mass screening in public areas becomes important. Mass screening is the first stage screening before individual screening for further verification and it is very effective to avoid congestion. In non-contact temperature measurement, the medial canthal - between the corner of the eyes and lachrymal (tear) duct - is the best area to represent the elevated body temperature for fever detection. The available thermal technology only provides the ability to detect temperature dimension of objects instead of the regions of interest. For instance, if there is similarity in temperature between regions of background and medial canthal area, thermal camera alone is unable to identify the correct region. Hitherto, in most of installed thermal imaging in airports, this problem is only solved by human operators, thus its effectiveness is influenced by human factors. In this paper, an algorithm based on Gaussian Bi-modal Mixture Models (GBMM) is proposed for background-foreground segmentation as an important feature to identify medial canthal area. To estimate the bi-modal background-foreground distribution mixture parameters, Expectation-Maximization (EM) algorithm is applied and the images are clustered statistically and linearly. The results are later multiplied with background subtraction results to get a better quality of segmentation. The 640x480 thermal resolution imagery sequences are used as input and the intensity of the pixels are collected from arriving passengers in Kuala Lumpur International Airport (KLIA) under a controlled ambient temperature. Twenty image sequences were used in the experiments and the result shown the feasibility of the proposed algorithm.

Keywords: Gaussian Bi-modal Mixture Models; Thermal Imagery; Fever Mass Screening;Background Segmentation

1. Introduction

In 2009, the world is alarmed with the new spread pandemic of Swine Influenza A (H1N1) that caused illness and death in people. By 30 May 2010, WHO has reported that more than 214 countries in have confirmed cases of the pandemic, Including over 18138 deaths. [1]Due to this, airports all around the world is placed to battle

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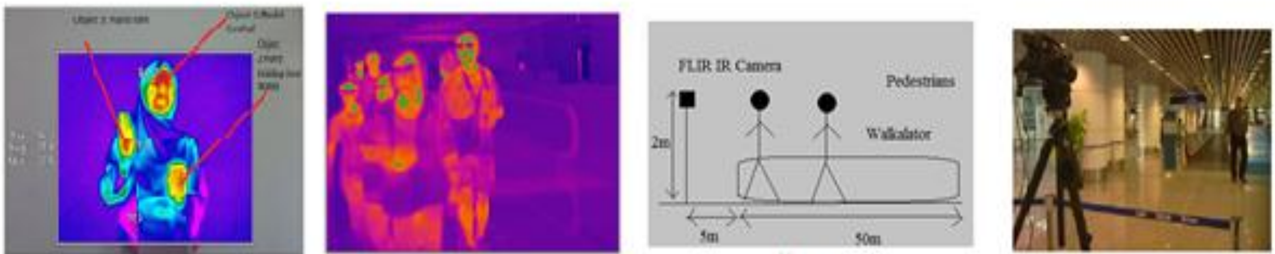
the spread of this influenza.

1.1. Mass Thermal Screening

Thermography is a recent technology used for various applications such as elevated body temperature detection, breast cancer, face recognition and video surveillance. Thermal Imaging is a process of converting invisible infrared radiation to visible image. The electronic thermal imaging exploits the nature of human body surfaces' heat exchange with environment where most of the heat transfer is in the form of infrared. Using thermal imager or thermogram, a pictorial representation is produced to represent the detected heat without visible light content. [2]American College Clinical Thermography (ACCT) proposes this technology for fever screening as it is the most effective technique for core body temperature screening. [3]The related area that best represent the core body temperature is called the medial canthal-a small area near the eyes and nose that offers the body core temperature to be measured as the area has the highest amount of light energy. [4]There are normally two steps in the thermal screening, the initial mass screening where it could screen the large group of individuals quickly and the second individual screening for potential febrile individuals found in the first screening. The real time mass screening is preferred as it is quick, noncontact, eliminate queues for fast identification. However, the thermograms alone provide the functionality to detect temperature dimension of objects and it is not sufficient to identify the regions of interest and tracking purposes. In the most installed thermal camera in airport, this functionality is supported by human operators which prone to human factors. In mass screening, whenever the temperature of medical canthal has the same temperature with other objects, adjunct analytical tools are needed for automatic identification as shown in Figure 1(a).



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

Fig. 1 (a) Three different objects with same temperature (reddish), Object 1:Medial Canthal, Object 2: Hand holding hot water, Object 3: Palm **(b)** Thermal image of free-flow arrival passengers in KLIA. **(c)** . The side view of system setup in KLIA **(d)** The IR thermal screening system setup in KLIA

2. Methodology

2.1. Background Modeling

Background-foreground segmentation is aimed to extract non-stationary objects by subtracting the new frame from background image. This is an essential step before classification stage where to identify medial canthal in the moving crowd for mass screening purpose. There are two main segmentation approaches used in visible or infrared spectrum; (i) frame differencing (ii)thresholding with their own advantages and disadvantages.Pixel's deviation or frame difference between modelled scene background and current frame is used to determine whether the pixel belongs to the background or the foreground. [5] Frame differencing approach as explained and applied in for infrared spectrum manage to deal in summer situation and discard the background hot spot as foreground. However one of its drawbacks is the requirement substantial computational and memory resources[6]. Thresholding on the other hand is inefficient if the pedestrians are not warmer than background (i.e winter). Although it is fast and require less memory resources, it needs more involved classification steps and a complex classifications which normally suffer from problem with low amount of texture information [7]. Charoenpong et al. [8]proposed a novel method based on the mixture of Gaussian method and K-Means Clustering for visible data. The intensity of the pixels in the same position is analysed by Gaussian mixture model and K-means algorithm clustering is used to define the number of clusters in Gaussian distribution. In [9],bimodal temperature distribution is created and using Bayesian framework is used to delineate the facial tissues from the background based on known priori knowledge from bimodal nature of scene for face recognition purposes.

2.2. System Design

Input of the system is the form of sequence image of temperature values, X^0 Celcius degree as the intensity level is captured using FLIR Infrared ,P640 with powerful detector resolution 640x480 under controlled and fixed ambient temperature (25-26 ^{0}Celcius**)** in arrival area of Kuala Lumpur International Airport (KLIA) as in Figure 1(c) and 1 (d) . The camera is placed 2.0 meter high and fixedly mounted to view at static angle to capture the flow of moving subjects on the walkalator. In this paper, a novel approach based on combination of classifiers is introduced. There are basically three different techniques used ; (i) Frame Differencing (ii) Bimodal Gaussian Mixture Model (iii) Thresholding based on parameters of Bimodal Gaussian Mixture Model and (iv) the novel approach based on multiplication of technique (i) and (ii), and multiplication of technique (i) and (iii).

2.3. Frame Differencing (FD) Method

The basic frame differencing tecnique could be simply done by subtracting the current frame from the previous frame or from the average image of a number of frames. Taking average of the 180 frames of background frames is costly in memory allocation. Histogram of number of pixels for temperature distribution of 180 frames is plotted as shown in the Figure 3(a) and an assumption is derived based on the observation that the temperature of the background frames is relatively the same.

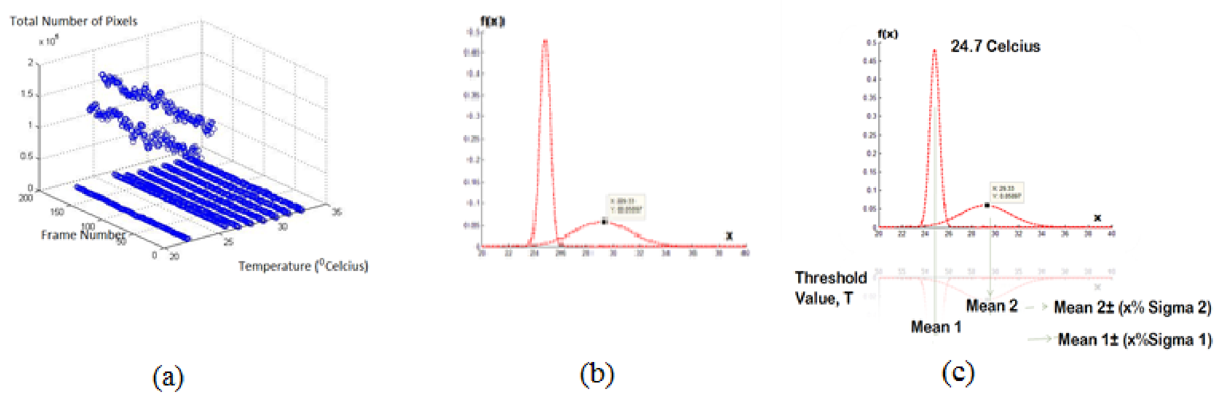


Fig. 3.(a) Histogram for temperature distribution and corresponding total pixel frequency throughout 180 frames. **(b)** Bimodal Gaussian Mixture distribution function**. (c)** Threshold values are derived from the Bimodal Gaussian Distribution parameters

, I (x,y). The current frame with pedestrians , F(x,y) is subtracted
fference is D (x,y) as in equation (1) . D(x,y) depend on threshold
is greater than threshold, T, the image is converted to binary value

(1)

(2)

2.4 Bimodal Gaussian Mixture Model (BGMM) Method

As in thermal image, it is consist of mixture of temperature distribution and as in equation (3), they are modeled using Bimodal Gaussian Distribution to represent the likelihood of pedestrians' temperature and background as in Figure 3(b).

$$P(G_t) = \sum_{i=1}^{K} \omega_{i,t} * \eta(\mu^2, \sigma^2) \quad (3)$$

Where K is the number of distribution, as bimodal distribution is selected, therefore K=2, $\omega_{i,t}$ is a estimate of weight of i th cluster of the Gaussian distribution at time t, μ is the mean value and σ is the variance of i th cluster of Gaussian distribution at time *t*.The value of the parameters are estimated by the maximum likelihood criterion using Expectation-Maximization (EM) algorithm technique as shown in equation (4). EM algorithm provides an iterative computation estimation based when the observed data are incomplete. In this case, it is given that the distribution of temperature data without knowing the weights, variances, and means for the bimodal clusters. Initial crude estimates of the parameters are randomly guessed and applied to the following loop for k=0,1…, where i=1,2 (representing the number of clusters- foreground and background) and *j* = 1, . . . ,*N*s. (*N* is the total number of samples) until the condition for the terminating the loop as shown in equation (5).[8]

$$z_{ij}^{(k)} = \frac{w_{s_i}^{(k)} (\sigma_{s_i}^{(k)})^{-1} exp\left\{-\frac{1}{2(\sigma_{s_i}^{(k)})^2}(x_j - \mu_{s_i}^{(k)})^2\right\}}{\sum_{t=1}^{2} w_{s_t}^{(k)} (\sigma_{s_t}^{(k)})^{-1} \exp\left\{-\frac{1}{2(\sigma_{s_t}^{(k)})^2}(x_j - \mu_{s_t}^{(k)})^2\right\}} \quad (4)$$

$$w_{si}^{(k+1)} - w_{si}^{(k)} < \in \;,\; i = 1,2 \quad (5)$$

2.5 Thresholding from BGMM Parameters (TBGMM) Method

Thresholding is the common approach in background substraction for thermal spectrum. As mentioned before, the drawback of this technique is when the hot spot background could not be removed. The threshold values are drawn from the bimodal gaussian distributions parameters (means, weights and variances) as shown in figure 3(c), where x % are from 10-50%, tested on the samples and qualitatively observed the results.

2.6 Multiplication of FD – BGMM and FD-TBGMM techniques

To minimise the drawbacks of the technique and maximize the benefits of the techniques. For example, the frame differencing technique will eliminate the background hot spot but produce noisy background substraction result while thresholding and Bimodal Gaussian results are less noisy but background hot spot is not removed. As shown in Figure 6, BGMM technique and TBGMM are both multiplied with result of FD to produce the better image of result A and B. Later, morphological operations are carried out on result A and B to extract the foreground from the background.

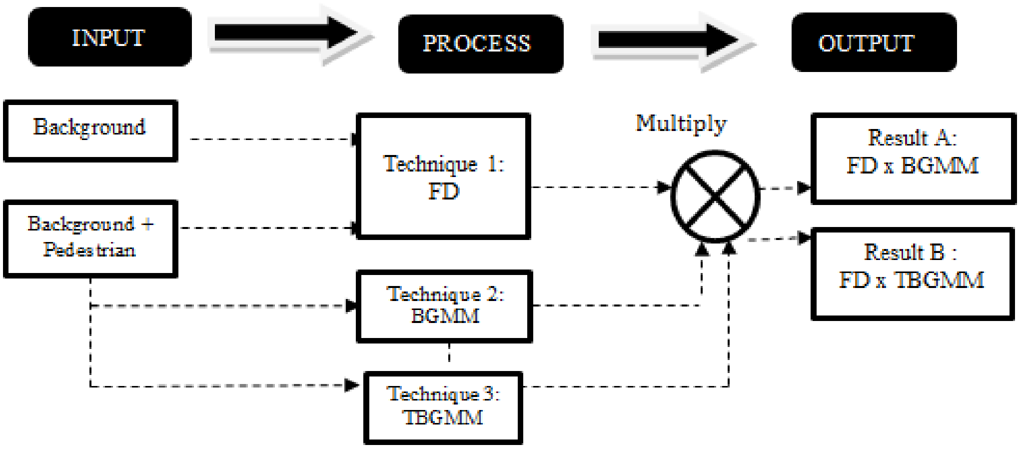


Fig 6. The summary of approach used for background-foreground segmentation.

3. Results and Discussions

In this section, the results are reported based on sequence thermal images of the flow moving subjects in the airport at the same angle. The frame rate is 180fps, and only 20 frames are used for the training data. The algorithm was implemented using the Matlab version 7.1. The results are analysed qualititatively and are shown in Figure 7.

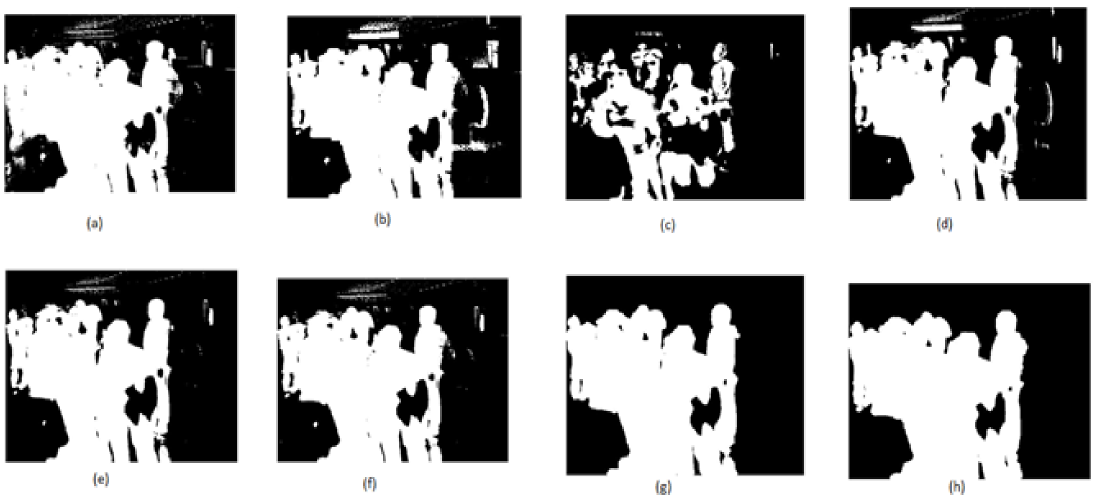


Fig 7. The binary images using different background segmentation techniques. (a) BGMM (b) FD (c) TBGMM using Threshold= Mean2 (d) TBGMM using Threshold= (Mean2 -50% Sigma2). (e) Result E (f) Result D (g) Result E after morphology (h) Result D after morphology.

The image 7(a) using BGMM is less noisy but it does not eliminate the hot spot in background as image in 7(b) where FD is able to eliminate hot spot from the background or static object. In 7(c) and (d) that used thresholding techniques,both could not eliminate hot spot in background regions. In 7(c), by using threshold of Mean2, the result is poor and discards important information compared to image in 7(d), therefore the threshold of Mean2-50%Sigma2 is selected. The selection of thresholds range is based on simple trial technique. The Figure 7(e) and 7(f) represent the results when image in 7(b) and (7d) are both multiplied with result in 7(a). This multiplication enhanced the image quality, to be less noisy and discarding static and backgroung hot spot region. After morphological process in 7(g) and 7 (h), the images are smoothed and unwanted objects outside the main foreground region are discarded. It is also shown qualitatively that the final images produced by FD-BGMM and FD-TBGMM multiplication both are equally same quality of picture. In using this algorithm,one important issue remains as to get into the multiplication process, one need to implement either FD-BGMM or FD-TBGMM where both require at least two classifiers. For larger training samples the practicality of the techniques is further to be investigated.

Summary

In this paper, a novel method for segmenting foreground from background image by using the multiplication of Frame Differencing-Bimodal Gaussian Mixture Model and Frame Differencing-Thresholding from BGMM's parameters. Twenty sequence images are used as input. The number of cluster is defined as two based on clusters of background and foreground. The algorithm developed based on common techniques; frame differencing, Bimodal Gaussian Mixture Model (BGMM) and thresholdings based on parameters in BGMM are used. For further enchancement , morphological operation is carried out Although the images produced are improved, the frame differencing technique used at the beginning require high computational memory allocation and time. This method is only appropriate for summer time or when the temperature of the foreground is greater than the background. Further improvement for the algorithm is to be further investigated to improve its robustness over large training data.

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