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Fever Monitoring and Alert System for Children using Thermographic Camera

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ABSTRACT

As the immune system of children is weaker than adult, fever is one of the concern of the parent. The temperature measurement using thermometer is slower and not efficient for a large group of people. In this report, the face recognition technique and infrared imaging is combined to create a better fever alert system that can monitor the body temperature of the children. A raspberry pi model 3B is used to control a camera module for the face recognition and an AMG8833 infrared thermal sensor to detect the temperature of the face. The Histogram Oriented Gradient (HOG) feature is collected on the face image and each person's feature is used to train the Support Vector Machine (SVM) to perform the identity classification. The accuracy of the face recognition is evaluated using pictures of 5 different person and the result of the temperature measured and compared with infrared thermometer for analysis. The average face recognition accuracy is about 92%. The accuracy of the temperature measurement is less than 10% when the distance is between 15cm to 30cm. A pop-up will warn the user when it detects someone with temperature higher than the threshold temperature set. The face recognition algorithm is fairly accurate for this pur-pose and the temperature measured is acceptable within a few limitation such as distance and room temperature.

Key words : Temperature measurement; Face recognition.

1. INTRODUCTION

Every parent wants to make sure that their children is adequately cared for and protected from health issue and disease. The insurance industry now provides health coverage to children or baby as early as 18 weeks into pregnancy in Malaysia [1]. Fever in a child is one of the most common clinical symptoms managed by paediatricians and other health care providers and a frequent cause of parental concern [2]. Fever itself normally causes no harm but there is some disease symptom with fever. Fever happen when the brain hypothalamus malfunction and rise the body temperature above the threshold which is normally 38.3°C compared to the usual body temperature 37°C.

Most body temperature will vary according to the time of the day, the level of activity conducted also have significant effect on the body temperature. Most infection are caused by infection and other illness. A fever helps the body fight the infection by stimulating natural defence mechanism. Infants especially new-borns may get fever if they are over-bundled or in a hot environment because they cannot regulate their temperature well like the adults. Babies and kids sometimes get a low-grade fever after getting vaccinated.

Children commonly attend day care or preschool as early as 3 months since nowadays parents are working people with tight schedule. Therefore, the responsibility lays on the shoulder of the day care caretakers to take care of the children and monitor their wellbeing closely. Most of the day care centres have rules and regulations they must follow regarding the health and safety of the children in their care. Fever is a common disease among children and need quick medical attention. When the child having unusual high temperature, the caretakers must determine if the child is having fever. As for infant younger than 3 months need to go to emergency department immediately if they are having temperature higher than 38°C as they are very easily infected by bacteria [3, 4].

The child will need to be separated from other children if the cause of the fever cannot be determined. The parent of the child should be informed immediately to bring their child home so that the child can receives treatment in shortest time. This paper reports the design of fever monitoring and alert system for children in day care centre using thermographic camera. Thermographic camera has been used as the sensing temperature device because most of the children engaged in vigorous physical activity for only about 34 minutes per day [5]. Therefore, a stationary monitoring system is more convenient than to place a device on the child's body. MATLAB algorithm has been developed to differentiate and identify the face of different children. A warning pop-up will be displayed on the screen with the name of the child whose temperature exceeds a threshold value to alert the caretaker.

2. RELATED WORK

The aim of the project is to utilise thermal imaging to analyse the temperature and identify the identity of the person. This project has been using several tools from MATLAB to build up the algorithm of the image processing.

2.1 Human temperature and fever

The body temperature can vary according to several environment and biological factor such as time of the day, room temperature, level of physical activity, age, sex and race. The normal human temperature range is between 36.5 - 37.5 ℃ (97.9 - 99.5 °F). The human temperature is being regulated by the human body to sustain the optimum environment for the human organ to work in. It is regulated by feedback mechanism controlled by the centre of temperature setting in hypothalamus. If the core body temperature rises more than the body temperature limit, the hypothalamus will stimulate the body mechanism to reserve or release body heat so that the temperature can return to normal [6]. In cold environment, the heat gain mechanism is activated and prevention of heat loss by decrease firing of warm sensitive neurons and increase firing of cold sensitive neurons. While in hot environment, increase firing of warm neurons and decrease firing of cold neurons can lead to activation of heat loss mechanism and inhibition of heat gain mechanism [7]. The skin blood flow is also one of the complex mechanism to control the body heating and cooling [8].

Fever, also known as pyrexiais, is one of the most famous reason for medical consultation worldwide [9]. It is represented by the body core temperature more than the normal body temperature unnecessarily. According to guideline for management of febrile illness from WHO, the rectal temperature of ≥ 38 ℃ or axillary temperature of ≥ 37.5 ℃ is considered fever for both adult and children [10]. The three major sites that are commonly used for temperature assessment are rectal, oral and axillary. Of these three sites, rectal temperature is closer to the core temperature but the axillary temperature is more convenient to take but least accurate at the same time [11]. Fever is typically caused by pyrogen, a chemical substance that will provoke fever. Pyrogens are classified into exogenous (produced outside the host) and endogenous (produced inside the host) pyrogens based on their site of production [7]. Some exogenous pyrogens which cause fever such as those seen in gram-positive bacteria (Staphylococcus aureus enterotoxins) and the superantigens associated with Group A streptococcus and Group B streptococcus microbial infections [9]. These bacteria and fungi trigger the production and release of cytokines that can increase the hypothalamic temperature set point and thus increase the body temperature. Table 1 shows the classification of known infectious causes of fever.

Table 1: Infectious causes of fever [9]

Infectious causes of fever [9]	
Bacterial infections	Viral infections
-UTI -Turbo-ovarian abscess -Prostatitis -Meningitis -Cavernous sinus thrombosis -Brain abscess -Cholangitis -Appendicitis -Cholecystitis -Diverticulitis -Cellulitis -Necrotizing fasciitis -Osteomyelitis -Pneumonia -Retropharyngeal abscess -Otitis media -Sinusitis -Endocarditis -Pericarditis -Myocarditis	-Pharyngitis -Gastroenteritis -Aseptic meningitis -HIV -Influenza **Parasitic infections** -Malaria -Toxoplasmosis -Giardiasis **Arthropod infections** -Lyme -Rocky Mountain Spotted fever -Babesiosis **Fungal infections** -Candidiasis -Blastomycosis -Histoplasmosis

2.2 Thermographic camera and thermal imaging

All object above 0 Kelvin temperature will emit electromagnetic radiation in the infrared region of the electromagnetic spectrum. Thermographic camera detected infrared radiation (wavelength in the range of 0.75–1000μm) in a non-contact way by an infrared detector [12]. Surface of different temperature will emit radiation of different frequency and the detector will be able to capture and differentiate the object captured. Table 2 shows the wavelength and position of infrared spectrum in the light spectrum. The thermographic camera is widely used now as surveillance camera because it can provide clearer view at low light. The usage is also constantly increases in firefighting field as it can detect the source of ignition and search for fire victim effectively.

Table 2: Three group of infrared light [14]

Types of infrared light	Wavelength
Near infrared	0.7 – 1.3 µm
Mid infrared	1.3 – 3 µm
Thermal infrared	3 – 30 µm

As the correlation between body temperature and disease has been known by the hospitals. Medical infrared thermal imaging has been used to study the flow of blood, the detection of breast cancer, and muscular performance of the human body [15]. The thermal image acquired by the thermographic camera can be analysed to measure the surface temperature of the object captured or pointed. The thermographic camera also called as infrared camera and the images from the camera tend to have only single colour channel because of the camera uses a sensor that does not distinguish different wavelength.

The first generation of infrared camera only consist of a single element detector and two scanning mirrors. For the second generation, two similar scanning mirrors along with array detector were used. Large two-dimensional array detectors replaced the mirrors for the modern camera now [12]. Colour thermographic camera required complex construction and therefore is more expensive compared to the regular infrared camera that is used as the surveillance camera. Sometimes the camera will display the monochromatic image in pseudo-colour, where changes in colour is used instead of changes in intensity to display changes in the signal.

The main advantage of infrared camera is that they require minimal instrumentations. For condition monitoring system, the system only need to be setup using an infrared camera, a camera stand and computer for video output. They are also light weight and portable. Figure 1 shows a condition monitoring experiment using thermographic camera.

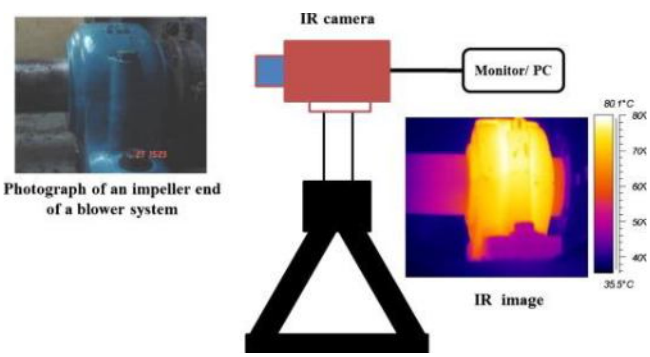


Figure 1: Typical experimental setup for infrared thermography (IRT) based condition monitoring experiments. [12]

There are several parameters must be considered when choosing an infrared camera for the project. The performing parameter will decide the ability of the camera to produce sharp and accurate image. The important parameters are:

i. Spectral range- the portion of the infrared spectrum in which the infrared camera will be operationally active. As temperature of an object increases, the thermal radiations emitted by the object are more in the shorter wave length bands. For observing objects at ambient temperature long wave length band (7.5–14 µm) is preferable.

ii. Spatial resolutions- the ability of the camera to distinguish between two objects within the field of view. A better spatial resolution will result in superior image quality. Spatial resolution of an infrared camera primarily depends on object to camera distance, lens system and detector size. Spatial resolution decreases with increasing object to camera distance and increase with larger detectors.

iii. Temperature resolutions- the smallest difference in temperature in the field of view which can be measured by the infrared camera. Temperature resolution depends on several experimental parameters like object temperature, ambient environmental temperature, object to camera distance and presence of filters.

iv. Temperature range- Temperature range signifies the maximum and minimum temperature values which can be measured using an infrared camera.

v. Frame rate- the number of frames acquired by an infrared camera per second. Higher frame rate cameras are in general preferable for monitoring moving objects.

There are some other inherent parameters such as price, size, weight, power, storage, image processing capabilities also need to be considered when choosing the suitable thermographic camera.

2.3 Image processing using MATLAB

Image processing or usually known as digital image processing is to use computer algorithm to process or analyse the digital image. For the analysis of the thermographic video, MATLAB from MathWorks is used as the software which has high performance language for image processing. It provides wide variety of toolbox for the user to have application-specific solutions. Toolbox are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems.

2.3.1. Image processing toolbox

This toolbox provides a comprehensive set of reference-standard algorithms and workflow apps for image processing, analysis, visualization, and algorithm development. Image segmentation, image enhancement, noise reduction, geometric transformations, image registration, and 3D image processing can be carried out using this toolbox [16].

Some of the usage include deblurring the image using algorithm like blind deconvolution algorithm, Lucy-Richardson algorithm or Weiner filter, image contrast enhancement, find image rotation and scale, registering image, image segmentation and spatial transformation [16]. In this project, the footage video capture will have the colour thermal image which can be processed to determine the temperature of the object.

2.3.2. Computer vision system toolbox

The computer vision system toolbox is important in this project to perform feature detection, extraction and matching. It can provide algorithm, functions, and apps for designing and simulating computer vision and video processing system. The algorithm integrated deep learning to enable the user to detect face and even classified image categories and differentiate different faces. This is crucial to tract and detect the identity of the face recorded by the infrared camera [17].

2.3.3. Face recognition technique

There are a lot of face recognition algorithm that are already proven to work well in identifying the human face. Kernel principle component analysis (PCA) [18] is one of the algorithm proposed by Kwang In Kim which will use the polynomial kernel to map and identify the facial feature in facial recognition. The independent component analysis (ICA) [19] by the M.S. Bartlett can be performed using treated the image as random variable and the pixels as outcomes, or the vice versa. Robust face recognition via Sparse representation [20] by John Wright use new framework by sparse representation computed by C1-minimazation to properly harnessed the sparsity of the feature extraction. Another popular algorithm is using neural network to perform video-based face recognition by Mostafa Parchami [21]. It is using deep learning architecture to accurately compare the facial Region of Interest (ROIs) extracted from a still reference image extracted from the video. Face recognition using Active Appearance Model (AAM) [22] by N. Faggian can effectively normalized the face segmentation to mean shape to improve the accuracy of face recognition in the video. The Principal Component Analysis (PCA) is chosen as the face recognition in this project because of the small number of training and the simplicity.

2.3.3. Thermographic analysis

For the thermographic analysis, a thermal camera is used to record the thermal video at the monitoring region. The infrared camera with specialized lenses is able to receive the thermal radiation emitted from the object and present it using different colour. The thermal imaging technique has gone up significantly since the last decade and most of the thermal camera now can measure temperature with sensitivity less than 0.07℃ with 1m distance. Figure 2 shows the advancement of the thermogram, output of thermal camera from 1995 to 2011.

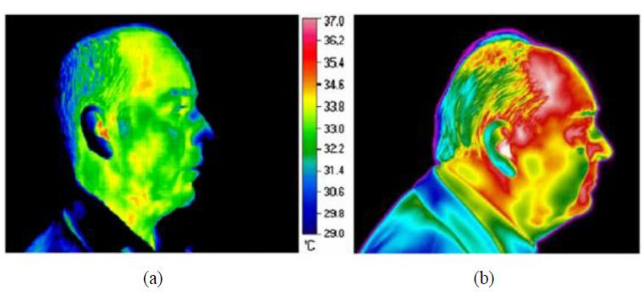


Figure 2: Thermogram of lateral face recorded in (a) 1995 and (b) 2011 [23]

The temperature of the object can be calculated by measuring the amount of infrared energy emitted by the object. Compared to ear thermometer which can only measure temperature at single spot, thermal imager can measure the temperature at tens of thousands of spots that together create a thermal image. According to an infrared camera assessment by V.Bernard [24], if the surrounding environment and temperature is calculated, the surface temperature will be an appropriate method to evaluate the present of fever in the person. A thermal camera is recommended to measuring temperature in a static and controlled environment [25].

3. METHODOLOGY

The previous chapter goes through the review on fever for human, as well as the equipment and current technology for image processing and heat analysis from previous work. The design of fever monitoring system requires a suitable thermographic camera working with MATLAB on a computer to process the thermal video by the camera. From the observation and analysis of previous project, the best method to be used in this project will be discussed in detail in this chapter.

The project flow chart shows the processes of the project in a more simple and organised way, from the start of the project until the project is finished. In this project, the project is divided into 3 stages. The first stage will be planning and hardware phase. The second stage will focus on image processing algorithm while the last phase will be emphasizing on the result verification and calibration. The project flow chart is shown is Figure 3.

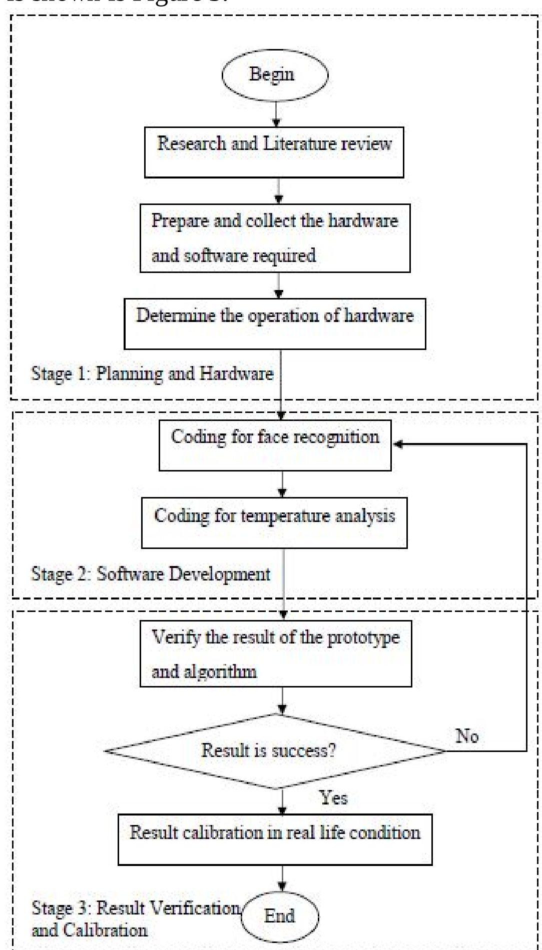


Figure 3: Flowchart of the project

3.1 Planning and hardware

The project is started with research and literature review on the previous work related to the project. By reviewing past works, suitable thermographic camera and programming algorithm for this project is determined. MATLAB is chosen as the programming language as it can provide advance tool for face recognitionand image processing. A pop-up will be shown to the caretaker when it detected a child with fever. Figure 4 shows the system block diagram of the project.

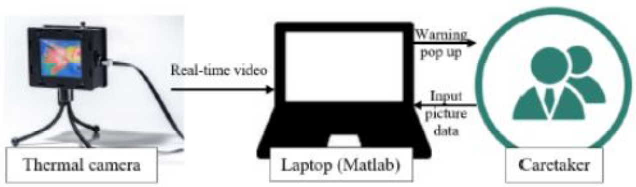


Figure 4: System level block diagram

The thermal camera will upload the real-time video footage to the laptop to be analysed from time to time. The MATLAB will pro cess the video for every frame for second. The MATLAB will identify every face appear in the frame and use the use it to match the face database in the system. The surface temperature of the person is then being analysed and if the temperature exceeds the value set by the person incharge, a warning pop up will appear to prompt the user to react immediately to inform the person in fever.

As the thermal camera in the market is usually expensive and not suitable for domestic use, an infrared thermal sensor is used to replace the thermal camera. Figure 5 shows the pictures of AMG8833 Grid-EYE Breakout from Adafruit.
The Adafruit AMG8833 is a sensor from Panasonic with 8 x 8 array of IR thermal sensors. It will return an array of 64 individual infrared temperature reading over Inter-Integrated Circuit (I2C) to the microcontrollers. It can detect human from a distance up to 7m and measure temperature from 0°C to 80°C with an accuracy of ±2.5°C. It is suitable for designing small thermal camera for this project.

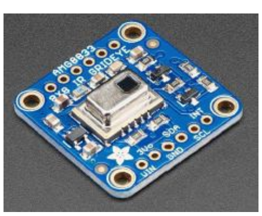


Figure 5: Adafruit AMG8833 Grid-EYE Breakout

3.2 Software development

Model-based design is used while designing the face recognition and temperature analysis algorithm using MATLAB. The model-based design is a process that enable fast and cost-effective development of dynamic system. It started with a system model with idea and requirement of the project. Simulation and prototype of the model can be done from time to time to track the design trade off and optimise the design of the system. The code of the system can be generated when the design is finish to eliminate hand coding errors. The HOG feature of the faces of different person is used to train the machine on face recognition while the MATLAB will access the thermal array sensor to acquire the face temperature.

3.2.1. Face recognition technique

The principal component analysis is chosen as the technique in this project because of its simplicity and it is suitable without large number of samples. The approach of the face recognition will be started with:

1. Detect and crop the face in the video using Viola-Jones algorithm.
2. Extract the HOG feature from the face image.
3. Compare and classify the extracted feature with the one in the database.

Figure 6 shows the overview of the face recognition system of the MATLAB proposed.

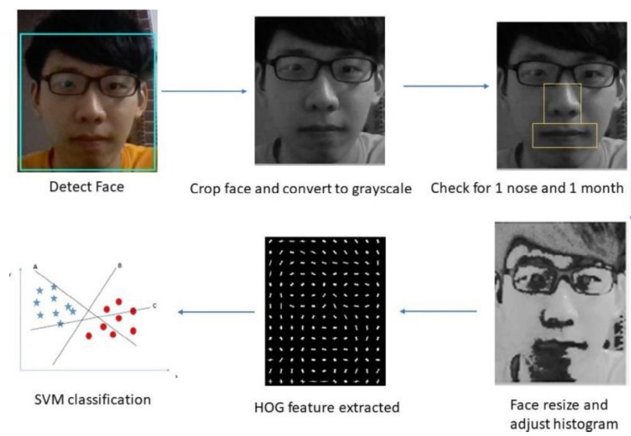


Figure 6: The overview of the face recognition system

From the live video, the system will constantly screenshot the screen and detect the present of face using the Viola-Jones algorithm by calling the CascadeObjectDetector function of MATLAB. The image is cropped and converted to grayscale for the training purpose. After that, the Histogram Oriented Gradient (HOG) feature is extracted from the face image to be used as the training. Each person is labelled for an index to store the training feature. The image will have different intensity change over the pixels, and an arrow is used to represent the direction of the intensity change of the pixels along with the magnitude of the changes using direction and size of the arrows. Figure 7 shows a pedestrian walking image and the HOG calculated and shown using arrows for the selected part.

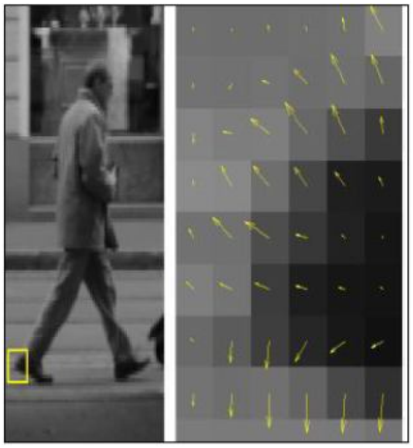


Figure 7: Pedestrian walking image and HOG of the region of interest.

The HOG feature is often used as the compressed and encoded version of the image. This is because the HOG feature is very unique for every image and can be used to differentiate different image. The feature extracted will be plotted into a histogram, the direction being divided into blocks and the feature is extracted over small parts in repetition fashion of the image. This allows the computer to have the encoded version of the image. With suitable learning algorithm and training samples, two sets of different features can be separated. One of the popular algorithm would be Support Vector Machine (SVM).

The fitcecoc function from MATLAB is used as the classifier of the Support Vector Machine (SVM). A set of training data will be supply to the SVM, each marked with their categories and a model will be built by the SVM to classify or predict new examples. It will return the full trained, multiclass, Error-Correcting Output Codes (ECOC) model using the predictors or training samples and the labels provided. When the training faces is supplied into the function, it can learn to classify the face of the image using the feature provided. Figure 8 shows the basic idea of support vector machine and how it separates the different types object using mathematical functions known as kernels.

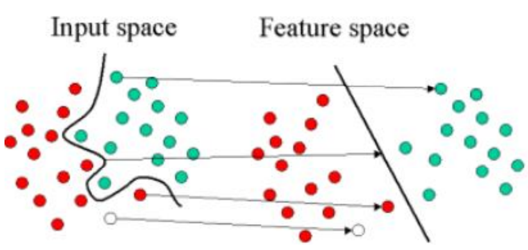


Figure 8: Support Vector Machine classification using feature.

3.2.2. Temperature analysis

The thermal camera operates in real-time at 60 frames per second by sampling the infrared energy emitted within its field-of-view. It processes the sampled data at computer and then creates and displays thermal image on the Liquid Crystal Display (LCD) monitor. A colour palette, as shown to the image below is applied to the thermal image so that each pixel in the image can represent to its temperature. Figure 9 shows the thermal image of human face from the thermal camera.
As the individual come into or pass through the field-of-view of the camera, the face recognition will trigger and it will send the thermal image for the computer to be analysed. The thermal image is analysed instantly to determine the skin temperature of the person in the image. The area of the skin that exceed the threshold value will be marked with bright colour and a warning pop-up to inform the user about the person detected and situation. The appropriate threshold value for temperature is set during the setup of the camera in a fixed position. The threshold value may be depending on the several factors such as ambient air temperature and level of activity.

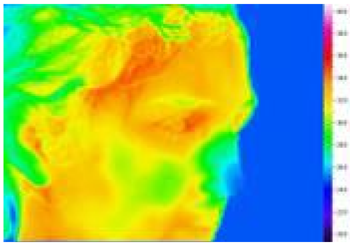
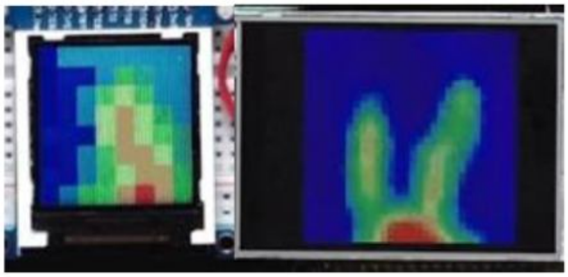


Figure 9: Thermal image of human face from thermal camera.

As the sensors used is an 8 x 8 array sensor, it will only provide 64 data to the microprocessor, each data will be decoded to each temperature represented by different degree of colours. The program then continues to interpolate the 8 x 8 array into bigger figure for better viewing. The technique of interpolation is known as 'lanczos' method. The method is basically used to increase the sample rate by mapping it to its kernel, a sinc function windows by the centre lope of the second and longer sinc function. Figure 10 shows the effect the interpolated result of the thermal data from the sensor.



(a) (b)

Figure 10: Comparison of (a) non-interpolated and (b) interpolated heat map.

The Image Processing Toolbox and Computer Vision System Toolbox is the crucial part of this project. The image processing toolbox can provide excellent 3D image processing to automate the face recognition analysis while the computer vision system toolbox is important to capture the face in the real-time video.

It started by input the thermal image of the person inside the computer. The MATLAB will be able to use the image processing toolbox to assign their face to the name. Then, the by importing the real-time video into the MATLAB, the computer vision system toolbox make the real-time face detection from the real-time video footage easier and faster. The temperature analysis is done after a face is detected using the thermal image of the face of the person. The algorithm is developed with MATLAB to use the colour intensity and distance from the camera to determine body temperature of the person. If the detected temperature is higher than 38.3 ℃, it will produce a pop-up message with warning sound to inform the system user about the name of the person in fever. The user will have to close the pop-up message and check out the situation of the person immediately. Figure 11 shows the basic work flow of the project.

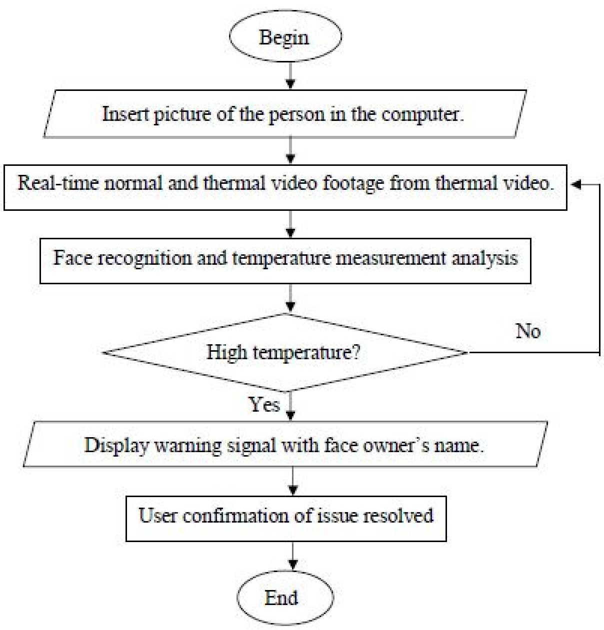


Figure 11: Flow chart of the Fever Monitoring System.

3.2.3. Graphical User Interface (GUI)

After the training is complete, the GUI of the program is designed using MATLAB. The GUI consists two figures; live video footage from the video camera and the thermal image recorded. The start detecting button will start the video streaming and thermal data acquisition and it can stop using the stop detecting button. The warning pop-up GUI is also designed using the MATLAB in which it will display the face captured together with the name of the person and detected temperature in degree Celsius. The warning pop-up will warn the person in charge about fever detected and the identity of the person prompt the person in charge to take action immediately.

3.3 Result Verification and Calibration

For the last phase of the project, the prototype is tested for the functionality and the accuracy of the result. The hardware prototypes is tested on simulated environment on real person. The real-time face detection and temperature is being tested in real-time to evaluate the accuracy and the speed of the system. The algorithm will be continuously improved to include more environmental variable such as room temperature, level of activity and room humidity.

4. RESULTS AND ANALYSIS

4.1 GUI

When the program started running, GUI only shows empty spaces with 2 buttons. Once the user pushes the 'start detect' button, it will activate the camera and AMG8833 infrared sensor and the data will be sent to the computer for analysis. Figure 12 shows the default GUI of the program.

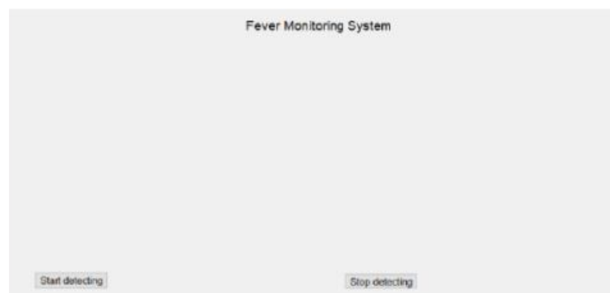


Figure 12: Default GUI of the program.

Once the 'Start detecting' button is pressed, the program will connect to raspberry pi and start receive and process data to show on the GUI. The left axes will contain the live feed video from the raspberry pi camera while the right axes will present the thermal data from the AMG8833 infrared sensor. The live feed video will be processed by the face recognition algorithm to determine the identity of the face and the 8x8 thermal data from the sensor will be presented using MATLAB colourmap. Figure 13 shows the working situation of the program GUI.

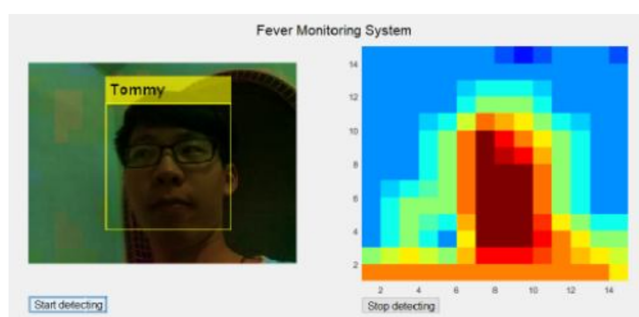


Figure 13: Program recognise people and thermal image at the same time.

The face recognition and thermal data processing run at the same time, there will be 4.5 seconds of delay for the video because it needs time to transfer from the raspberry pi to the computer. The program is able to recognise faces and track them, as well as identify the face with the faces in the database. The detected face will be marked with a box and the name of the person on the box. While the 8x8 thermal data being interpolated to 16x16 size for better view and represented it in different colour map. The colour map used in this case is the 'Jet colour map' as it has blue colour for low temperature and dark red for higher temperature.

Once the program is running, it will continue to detect and recognise face using the camera and determine skin temperature by the sensor. If the program detected a face, it will compare the temperature with the threshold and a warning pop-up will appear if the temperature is higher than the threshold value. The program will not compare the temperature again if the detected face is the same with the compared just now.

4.2 Face Recognition

The speed and the accuracy of the face recognition is very important for an alert program to be able to act in the shortest time. Therefore, the speed and the accuracy of the face recognition system is evaluated for the program. The program identifies the face image using the HOG feature and classifies them using the multiclass SVM classifier. This method allows the program to train the machine using the face image and using the classifier in a very short time. This method uses about 1.4 seconds to train the image in the database, which is consisted of 84 pictures. It uses some time to declare the file path and training feature, the classification and fitcecoc function which train the machine using SVM only uses about 0.9 second to train the machine.

With deep learning toolbox, MATLAB also offer the user the ability to train a neural network from scratch. The user will need to provide more than 500 training data to the machine and this process take more than 44 seconds on a professional computer. Figure 14 shows the screenshot of time elapsed to train a neural network by MathWork. In addition, computer without a decent Graphics Processing Unit (GPU) cannot used to train the neural network. The comparison between neural network and SVM is presented in the Table 3.

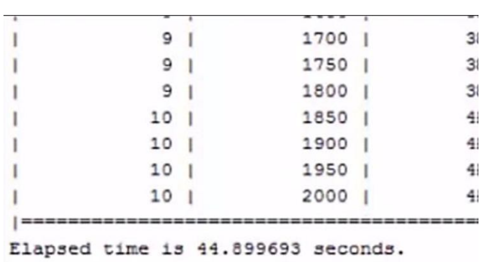


Figure 14: Time elapsed to train a neural network from scratch [26].

Table 3: Comparison between neural network and SVM

Method	Time Elapse (s)	Machine Requirement	Accuracy
SVM	1.374	Low	Fair
Neural Network	44.899	High	High

The MATLAB uses the CascasdeObjectDetector of the Computer Vision Toolbox to detect and track the faces easily. The program can detect face very fast and it can track the face and draw a box to indicate the face almost instantly. The face detection works well even in only sufficient light but it cannot detect tilted face. Some blurry face will still be detected by the program but it affects the accuracy of the face recognition. Figure 15 shows the face detection result of different position.

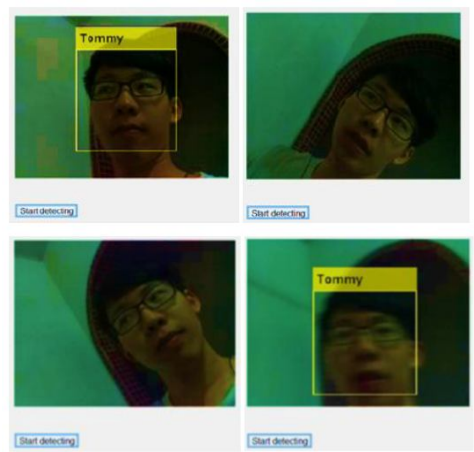


Figure 15: Face recognition in different position.

The accuracy of the face recognition is evaluated using the face of 5 different people. The machine is trained using 100 pictures of the person's face and test using another 5 new face. All the picture is in grayscale format when it is saved because the HOG feature extraction method will only work on grayscale image. The histogram of the face image will be adjusted so that it can post-process the image properly. Figure 16 shows the montage of the face database of the first person while Figure 17 shows the classification result of the 3 persons using another face image.
For the classification result of 5 persons using total of 25 image, 23 faces are successfully matched. The face recognition accuracy is 92% with almost no delay of recognition speed on the stream. It can recognise some faces even the environment is not so bright and the person's face is moving. However, the machine has troublerecognise face in low light and when the face is not straight.

4.3 Thermal

In order for the fever monitoring and alert system to work, the accuracy of the temperature measurement is very important. There are a lot of environmental variable that can affect the accuracy of the reading. Therefore, it is important to have good sensor for the temperature reading. The AMG8833 infrared offer a very low cost alternative to the engineer and developer that wanted to use thermal imaging. However, the sensor has limitation on its own. According to the datasheet of the sensor, the temperature reading has a ±2.5°C accuracy. It read the temperature in front of the sensor and display it using 8x8 matrix value. Figure 18 shows the heat map of the head detected in the raspberry pi using AMG8833 python controlled.

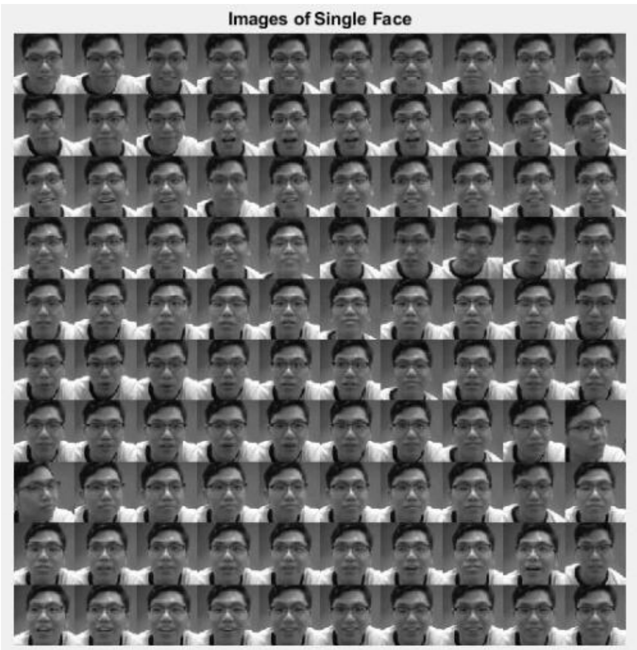


Figure 16: Montage of the face database of the first person.

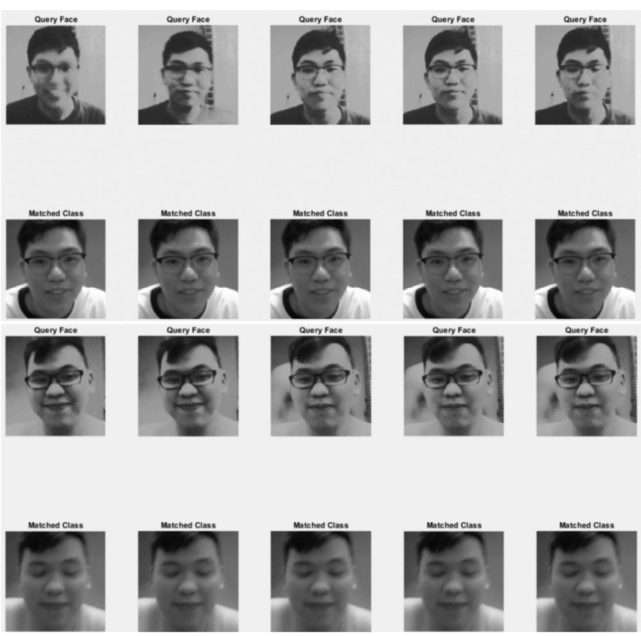


Figure 17: Test of the face recognition classification of 3 different person.

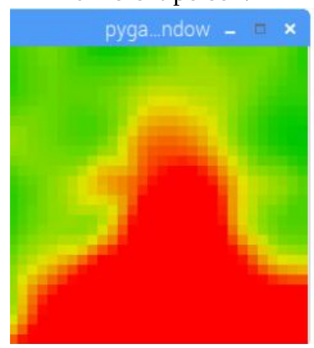
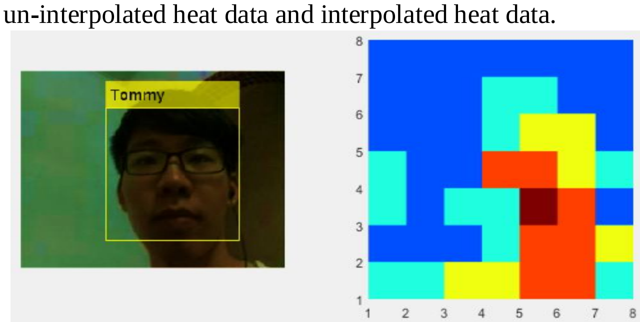
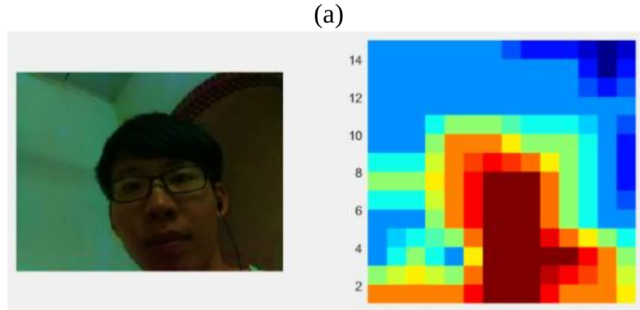


Figure 18: Heat map of the head detected using Raspberry Pi.

The result of the heat map is from the interpolation of the 8x8 heat data from the AMG8833. It uses 'lanczos' method to create matrix of 200x200 so that it will look like thermal image from thermal camera. The MATLAB is able to read the data collected from the sensor using I2Cread function of the MATLAB raspberry pi support library. The interpolation is carried out at the MATLAB after it reads the data from the sensor. The 8x8 heat data is interpolated into 16x16 heat data because too much interpolation unit will create more delay of the program. Figure 19 shows the comparison between un-interpolated heat data and interpolated heat data.



(a)



(b)

Figure 19: Un-interpolated data (a) versus interpolated data (b).

The limitation of the infrared sensor included with the measurement distance. It is important to know to which extend the infrared sensor can measures temperature accurately. Therefore, the accuracy of temperature measurement is measured with different distance from the sensor. Figure 20 until Figure 23 show the heat map and their temperature values for different distance between face and AMG8833 sensor.

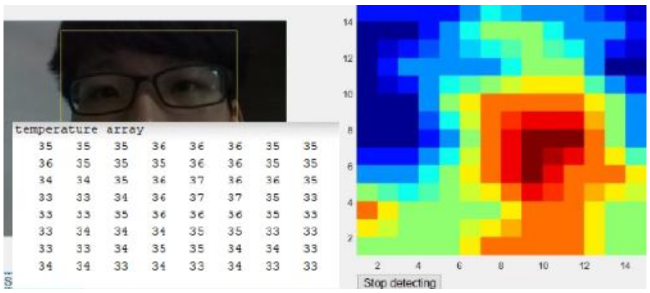


Figure 20: Heat map with 15cm distance.

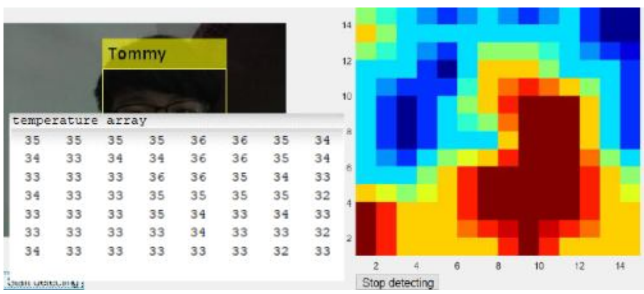


Figure 21: Heat map with 30cm distance.

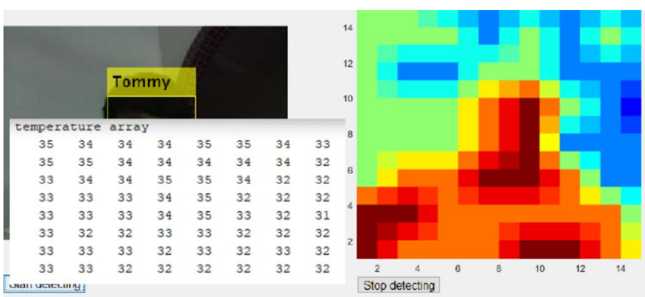


Figure 22: Heat map with 50cm distance.

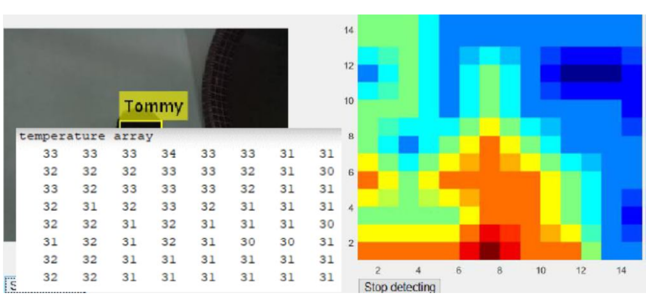


Figure 23: Heat map with 1m distance.

The accuracy of the temperature measurement is measured by compared the sensor collected value with another thermometer. As the face surface temperature is measured in this case, a non-contact infrared thermometer is used for comparison purpose. At the time of data collection, the forehead temperature which is the highest temperature of the face is 36.3°C. Figure 24 shows the measured temperature of the forehead using non-contact infrared thermometer while Table 4 shows the accuracy of the temperature measurement at different distance.

Figure 24: Forehead temperature reading using infrared thermometer.

The accuracy for the temperature is acceptable just for a domestic fever monitoring program. The accuracy of the measured value will get lower with the increasing distance. It is suggested to measure the temperature with 10cm - 1m distance because of the accuracy more than 90%. When the detected temperature reach 38°C which is the threshold temperature in this case, the system will trigger a warning pop-up with the face image, name and the temperature captured. Figure 25 shows the warning pop-up when fever is detected.

Table 4: Accuracy of the temperature measured at different distance.

Distance	Sensor Value (ºC)	Thermometer Value (ºC)	Difference	Accuracy
15cm	34 - 37	36.3	0.8	97.8%
30cm	34 - 36	36.3	1.3	96.4%
50cm	33 -35	36.3	2.3	93.7%
1m	32 -34	36.3	3.3	90.9%

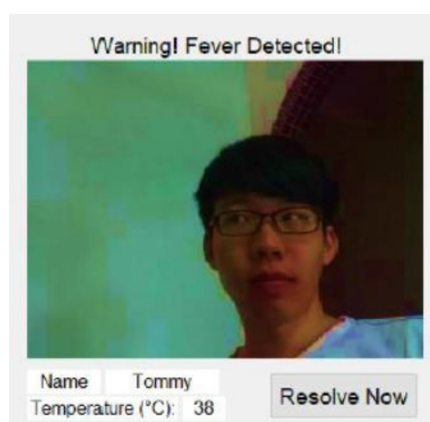


Figure 25: Warning Pop-up when fever is detected

5. CONCLUSION

For the face recognition, HOG feature extraction and Support Vector Machine (SVM) is used together at MATLAB. MATLAB supported both function and this decrease the burden of the programmer to develop everything from scratch. The advantage of this method is it is easy and fast to implement. The HOG feature extraction works well on extraction feature from the grayscale face image and the SVM successfully classify the feature of different faces within a small period of time. Although the accuracy of the face recognition can easily be affected by external cause such as low lighting, human hair, orientation of the head and facial expression, this method can be accurate in the most scenario and even with low quality video camera. This is useful in small scale of face recognition application where the feedback of the program will not be affected greatly by the inaccurate face recognition.

The thermal analysis of the faces using infrared array sensor is used to determine the temperature of the person. The AMG8833 infrared array sensor is the cheapest choice in the market. It is a very fast infrared sensor that can provide noncontact thermal measurement. However, the measurement accuracy is greatly dependent on the surrounding environment such as room temperature and distance of measurement. Within 15- 1m of distance, the sensor can provide reliable temperature measurement with less than 10% of error percentage. However, there are noticeable variation of the temperature recorded by the sensor that can cause problem when the threshold temperature set is near to the measured temperature. It may cause false alarm to the user as it has noticeable temperature variation.

The combination of the face recognition and thermal analysis create a very convenient way of detecting fever for multiple people in an instant. This is suitable for healthcare or childcare centre with more people to take care off. The system will be able to read multiple temperature reading and assign it according to the faces it detected. The caretakers will be able to monitor the wellbeing of the children once they are inside the view of the camera. This system will save time for the caretakers as well as cease the worry of the parent if implemented correctly and accurately.

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