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Human Body Temperature Detection based on Thermal Imaging and Screening using YOLO Person Detection

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***Abstract*— In addressing the worldwide Covid-19 outbreak, one of the actions to curb the spread of the virus is to keep people with Covid-19 symptoms away from others in public places. The most easily detected symptom is high body temperature due to fever, and this is one of the common symptoms of Covid-19 patients. Several methods of body temperature detection have been implemented at the entrance of the premises. One of the most common methods is to use an infrared temperature scanner. This method has some constraints including its use which is time-consuming and can lead to further spread of the virus as gun-type scanners can be a medium of virus spread as has been held by many people. Another more advanced method is the detection of body temperature through a thermal camera with imaging. Although more sophisticated, this method also has the constraint where the temperature is usually detected as a whole and does not differentiate the temperature of the human body and other nearby objects. With a focus on this problem, this study applies a combination of object detection methods through image processing with temperature detection through thermal imaging. For the object detection process, the You Only Look Once (YOLO) model and the OpenCV library have been used, especially in detecting people and non-people. While the calculation of body temperature through thermal images has been made more accurate because the scanned temperature is more specific based on the detected objects. In this way, a person's body temperature can be separated and will not be affected by the temperature of other objects. From the results and analysis obtained, an accuracy of 100% can be achieved based on a pre-trained model for human body temperature detection. With more specific and accurate detection as produced in this study, then a warning or caution will be issued only when a person actually has a high body temperature and will then not be allowed to enter the premises.**

Keywords—human, temperature, person detection, thermal, YOLO, OpenCV

I. Introduction

Covid-19 is an infectious disease caused by the coronavirus virus that was first discovered in 2019. The disease has caused a worldwide epidemic since early 2020 [1-2]. The most common symptoms experienced by infected people include mild to moderate respiratory illness and fever with abnormal body temperature. The disease can be more serious and fatal as it can impair lung function and severely disrupt the respiratory system. Thus, a new norm has been developed in every country in the world where every individual is asked to scan their body temperature before entering any premises to prevent infected people from entering the premises and spreading the virus to others.

This new norm is mostly carried out using standard infrared temperature scanners. However, there are some constraints in the implementation of this method where each person whose temperature is measured has to stand still while waiting for the temperature scanner to measure their body temperature. This method is quite time-consuming and can be annoying especially when many people are waiting in line to scan their temperature. While a large number of premises still use gun-type infrared temperature scanners where users have to hold the scanner with their hands to measure their body temperature manually. This method is worse because it can increase the risk of spreading the virus as it can spread wildly through contact with temperature scanners that have been held by many people.

There are also other more advanced methods of temperature measurement using cameras and thermal sensors. Although more sophisticated, this method also has some constraints. The main issue is that existing thermal imaging has not been able to distinguish between humans and objects. Using this method, the temperature is usually measured with a thorough temperature scan at a time. Therefore, a person's body temperature is not separated and differentiated from the temperature of a hot coffee cup held by the person (see Fig. 1). In this scenario, such a method leads to inaccurate measurements and results, as the person will be considered feverish due to having a high temperature, and in turn, will not be allowed to enter the premises. Focusing on this problem, this study explores a combination of two approaches, namely the object detection method through image processing and scanning of a person's body temperature through thermal images captured by thermal cameras (see Fig. 2). With this combined technique, then more accurate detection of a person's body temperature will be able to be made, and it will be automatically done without requiring the person to stop to measure the temperature. This way visitors can walk directly through the entrance of any premises while their body temperature is measured automatically.

Fig. 1 Thermal camera will detect the overall temperature from this view

Fig. 2 Temperature can be scanned more specifically based on the detected objects from the image

II. RESEARCH BACKGROUND

This study was held to design a temperature measuring process that can detect and scan human body temperature immediately using a thermal camera. By using a thermal camera, temperature measuring would be much easier. People do not have to measure their temperature manually by holding an infrared temperature gun. A thermal camera can measure temperature instantly and automatically since it does not need to emit an infrared signal for temperature measurement. It uses infrared light which is much faster than an infrared signal. Therefore, no time would be wasted, and human interactions could be lessened and the possibility to spread the virus would also decrease.

Another purpose for this study is to design a smart temperature scanner system that can automatically scan human body temperature only. This is done by differentiating between humans and other objects using YOLO object detection with OpenCV [3-4]. YOLO allows object detection by processing images frame by frame in motion capture. With YOLO, a visual device can recognize things such as a person, tables, chairs, and other everyday things automatically. By implementing YOLO to a thermal camera, it can distinguish a person from other objects. Thus, it can measure only the temperature of the person and not the objects. This way, the measurement would be much more precise since the desired parameter is only the person's temperature.

A. The benefits of using a thermal camera

Scanning large areas or large groups of people with multiple components and objects using an infrared temperature gun is a very time-consuming process, so users must scan each component and human being individually [5]. Thermal cameras will save time compared to IR thermometers and such systems enabled operators to screen more than a dozen subjects in just a few seconds [6]. Besides that, thermal imaging cameras measure temperatures from a long distance because of advanced optics [7]. This helps people to scan large areas easily. In addition, a thermal imaging camera does not only send the operators thousands of temperature readings, but it also converts these readings into a thermal image. Thermal cameras have an efficient solution for monitoring a person's skin temperature without any direct touch [8]. The person in charge of the device may be in another region or space and scientific studies have also proved that thermal imaging devices typically calculate surface skin temperature accurately when used correctly [9].

B. Thermal camera limitations

Despite all its advantages, thermal cameras cannot distinguish a human body from other warm items. Many companies are using thermal cameras with facial recognition tools and personal directories [9]. Since thermal cameras cannot differentiate a human body from other warmer objects, the built-in alarm will go off if a person is holding a cup of hot drink, like a cup of coffee. So in such a scenario, the person must leave the drink, get his temperature measured with the monitor, and then get his drink back after the on-duty security guard ensures that everything is in order. This leads to a time-wasting event where people must scan their temperature twice because of the incapability of the camera to detect unwanted objects for temperature measurement. This is one of the issues we want to address in this study.

III. METHODOLOGY

In this section, the flow chart and methods used to complete this project will be explained. The description will begin with an overall description of the activities carried out in the project, followed by a more detailed explanation of each component or activity.

Originally a thermal camera as in Fig. 3 was proposed and purchased for the implementation of this project. The name of this camera model is AMG8833 IR 8x8 Infrared Thermal Imager. However, the features of this camera are not sufficient for the needs of this project. This camera can record thermal images, but the captured images can only be stored in this camera without being able to stream or load to other devices. Therefore, this camera is not suitable and cannot be used to produce the data set required for the development of this system. However, this camera is used to capture a limited number of sample thermal data only for the final system testing (see subsection D). This test is made to measure the accuracy of the program output based on the images captured by an actual thermal camera. More suitable cameras have been identified, however, due to budget and time constraints for the purchasing process, other methods have been devised to allow the proposed technique to be developed as a prototype.

Due to the stated constraints, the next method of proceeding with this system development is to simulate as if the input were captured directly from two different cameras. This can be done using videos available online, e.g. [10] in the form of RGB videos along with their respective thermal imaging video. Both of these videos will be used as input streams in the program instead of streaming video from the camera.

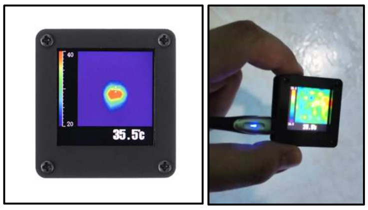

Fig. 3 The thermal camera used in this project.

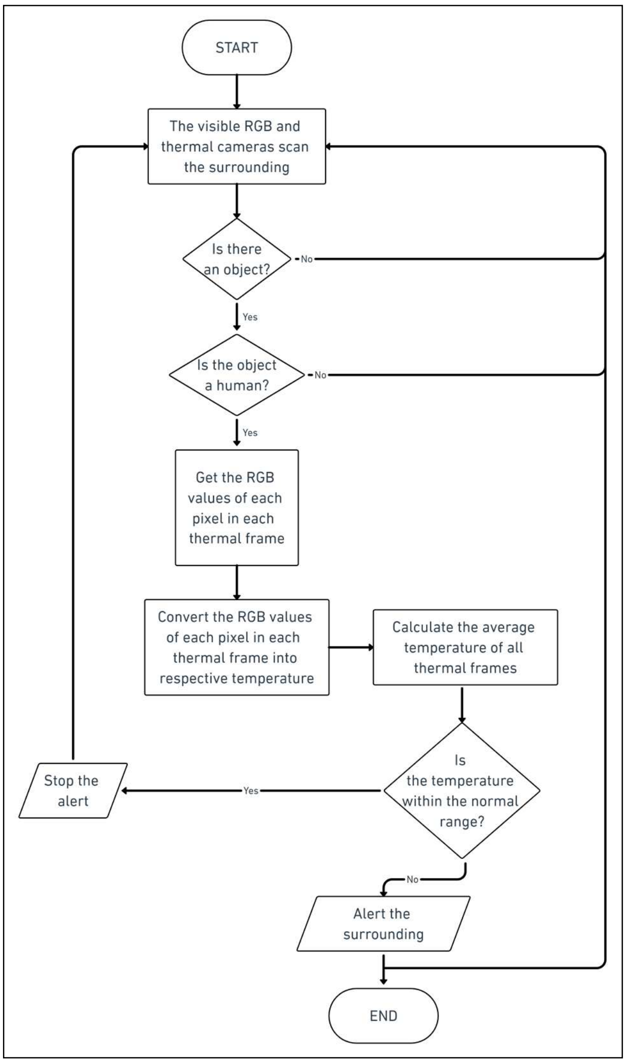

Fig. 4 The overall flowchart of the project

Fig. 4 shows a general flow chart proposed for this system. First, a camera system will be installed at the entrance of the premises. In the context of this study, the camera system includes two types of cameras, namely a camera that can capture visible views in RGB representation, while the other is a thermal camera that can capture thermal images in the form of colored images that give different temperature values for each color range. Fig. 5 shows an example of an image captured by a normal visible camera, while Fig. 6 shows a thermal image captured by a thermal camera from the same view. Whereas Fig. 7 shows an initial effort of manually combining both types of images that illustrate the same object in different representations.

Both cameras will operate continuously to capture images. Images from both cameras will be sent directly in real-time to a server that runs our codes with a combination of two methods. The image frames received by the server will be processed one by one by the program. The first method implemented in the codes is to detect objects from the RGB image, while the second method is to calculate the temperature through the thermal image by focusing only on the object that has been detected by the first method. For method 2, the main focus is only to measure the body temperature of the detected person by isolating it from the temperature of other nearby objects that may have pixels that overlap with the pixels of the person.

Fig. 5 Example of an image in RGB representation captured by a normal visible camera

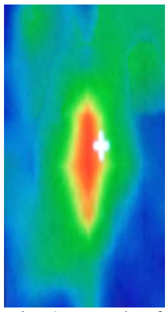

Fig. 6 Example of the thermal image taken by a thermal camera for the same view

Fig. 7 Example of a manual attempt to merge both visible and thermal images

A. Image processing over RGB frames in detecting person and other objects

This sub-section will describe the operations performed on the received RGB frame. The main operation performed on an RGB image is the detection of objects in the image. Such detection is very important in distinguishing people and non - people. With such isolation, a person's body temperature information can be distinguished from the temperature information of other objects from the same image. In this way, the image pixels that represent a person can be specifically distinguished from the image pixels that represent non -person.

To identify objects in the image, the YOLO method and OpenCV library for Python programming language are used. YOLO (You Only Look Once) is a popular method for object detection. This will be the main algorithm behind the codes for detecting objects in the image. In earlier detection methods, the algorithm employed looked at different parts of the image multiple times at different scales and repurposing image classification techniques to detect objects. This approach was slow and inefficient. Yet YOLO takes an entirely different approach. It looks at the entire image only once and goes through the network once the desired objects are detected. It is much faster than the earlier detection methods. OpenCV, on the other hand, is a cross-platform library that is commonly used in the development of real-time computer vision applications. It mainly focuses on image processing, video capture, and analysis including features like face detection and object detection.

In this project, by using the YOLO method and OpenCV library, the main program is designed to detect and scan the body temperature of humans only. Firstly, it will scan the surrounding for any objects visible. The scans will be processed as images, in a frame-by-frame manner. For each frame, if there is an object present, the camera will analyze whether the object is a human. If the identified object is a human, the program will calculate the temperature of the human body through thermal data from a group of pixels representing the human on the thermal frame. This can make the body temperature detection system work more efficiently and intelligently. Imagine a scenario where the detected object is a human, while there is also another object detected at a very close distance to the human and has a higher temperature than the human. By using the YOLO object detection method, the system will be able to distinguish the human body temperature readings from the other object.

B. Image processing over thermal images

As described above, based on the detection of a group of pixels representing a person by the YOLO method on the visible frame, the next processing is on the thermal frame based on mapping to the same group of pixels of the same coordinates. The main processing that takes place on the thermal framework is the calculation of the actual temperature value of the detected human body. This involves extracting RGB values from all the identified pixels involved (in representing humans) from the thermal frame. The conversion of RGB values into temperature was based on Table 1, taking the idea from [11], where a range of RGB values was matched with a range of temperatures. There are four important parameters involved which are r (red), g (green), b (blue) values, and temp (temperature). The minimum value of r, g, and b is 0 while the maximum is 255. The conversion values are summarized in the table below.

TABLE I: Table of conversion of RGB values to temperature

r (Red)	g (Green)	b (Blue)	temp (Temperature), °C
>=250	<=150	0	38
>=250	>=150	<=100	37
>=250	<=200	<=150	36
>=250	>=200	<=200	35
>=250	<=250	<=250	34

Based on the conversion method from the RGB value of each pixel to the temperature value it represents as described above, a person's body temperature can be detected by calculating the average temperature value of all the pixels involved. Based on this average value that represents the human body temperature, the program will then be able to identify whether a person's body temperature is in the normal range or vice versa. If the body temperature is found to be high and is outside the normal range, then an alert will be activated on the monitoring screen along with a sound notification to urgently notify the guard on duty. Based on this alert, the guard can then take appropriate action, namely by prohibiting the person from entering the premises.

C. Integrating information from both frames to the output frame

The flow chart shown in Fig. 8 illustrates in general the sequence of operations carried out by this program, including the processing that has been described in the last two subsections. During the operation, both types of input frames received by the codes will be processed separately. Based on the sequence as described, the operations performed will be summarized next and concluded with an explanation of the final result produced by the program.

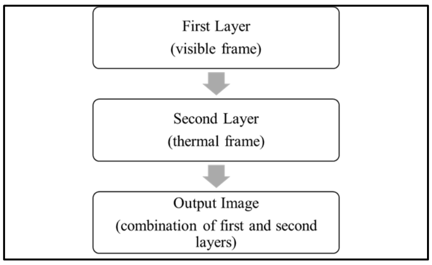

Fig. 8: Integrating outputs from both frames into one final output

Overall, by performing image processing on both the visible frame and the thermal frame, the program can detect different objects such as persons, cups, cars, and handbags from the visible frame and in turn will calculate the temperature value on the thermal frame only on the pixels that represent the detected persons only. The output produced by the program will illustrate a combination of these two frames along with an indicator in the form of bounding boxes that highlight areas in the image that represent persons and other objects. In addition, the output display will also show the body temperature information of each detected person, and along with an alert if the body temperature is found to be abnormal.

IV. Results and Discussion

In this section, the implementation of this project will be explained in detail according to the sequence of activities as specified in the methodology. Next, the outputs produced by the developed program will be shown and explained according to different scenarios and this will be followed by some analysis and discussion on the results obtained.

A. Image processing results on RGB frames in detecting people and other objects using the YOLO model

Fig. 9: An example of YOLO detects objects in an RGB frame

Fig. 10: Sample image of a thermal frame captured from the same view as in Fig. 9

Fig. 11 Sample image of the overlaying of the thermal and visible frames

The YOLO model [3] was used in this project especially for object detection on the visible frames. Fig. 9 shows a sample image where a woman is holding a hot cup. Using YOLO, the program was able to process and detect that a woman is an object that falls under the "person" class and the cup under the "cup" class.

B. Thermal image processing results in determining the actual body temperature

On a thermal image, the temperature is computed based on the colors. The brighter the color (red), the higher the temperature. Each color has its RGB values. The red color will have the value 255 which is the maximum value for the R parameter and 0 which is the minimum value for both G and B parameters. Fig. 10 shows a sample thermal image. From the image, the RGB values were obtained for each pixel within the object detection's bounding box. The values are then converted into their respective temperatures. To obtain the temperature of the person, the average temperature for all of the pixels is calculated (see Fig. 12). In a situation where multiple objects are detected being in the same bounding box as the person, the cameras can still process the image and output the most accurate temperature. This is because the camera would only obtain the RGB values from the pixels within the bounding box of the "person" class only and ignore the pixels within the "cup" class as shown in Fig. 11. Therefore, the most accurate temperature of the person would be calculated correctly.

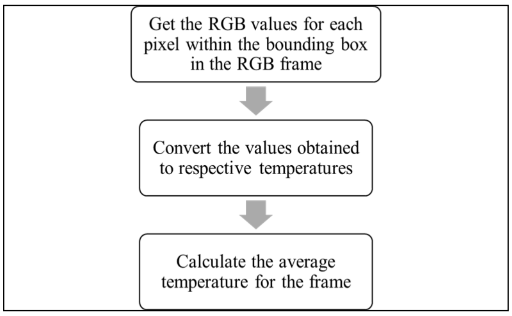

Fig. 12: The algorithm used to calculate the temperature of an object

C. Output frame with information display

To test the effectiveness of the developed program, several tests based on different scenarios were performed as follows.

1) Test 1: A person has a normal body temperature:

Fig. 13 shows the program output for test 1, in which the detected person has a normal body temperature. This output display shows a bounding box that highlights the position of the person in the frame, along with the information in the green text showing the body temperature readings and also a status that highlights this person's body temperature is in the normal range.

2) Test 2: A person has an abnormal body temperature:

Fig. 14 shows the program output for test 2, in which the detected person has an abnormal body temperature. This output display shows a bounding box that highlights the position of the person in the frame, along with the information in the red text showing the body temperature readings and also a status that highlights this person's body temperature exceeds the normal range.

3) Test 3: Someone is holding a hot cup:

Fig. 15 shows the program output for test 3, in which the detected person is holding a cup. This output display shows a bounding box that highlights the position of the person and the cup in the frame, along with the information in the red text showing the body temperature readings and also a status that highlights this person's body temperature is in the normal range.

Fig. 13: The program output when a person's body temperature is normal

Fig. 14: Program output when a person's body temperature exceeds the normal range (with alert)

4) Test 4: Several people are detected in the same image frame:

Fig. 16 shows the program output for test 4, in which there are several people detected that have normal body temperatures. This output display shows a bounding box that highlights the position of each person in the frame, along with the information in the green text showing the body temperature readings and also a status that highlights this each person's body temperature is in the normal range.

Fig. 15: Output when pixels of the person are overlapped with the hot coffee cup's pixels

Fig. 16 The program output when the body temperatures of several people entering a premise are normal

D. System testing using images from a real thermal camera

An experiment was conducted to see the effectiveness of this program on data samples captured from a real thermal camera. The camera used for this purpose is shown in Fig. 8. Due to the constraints of this camera, the dataset collected for this purpose is limited. Besides, the type of data sample taken is also limited to humans because the program will only be able to process the temperature of the detected person. To validate the outputs obtained from this program, a conventional way of measuring a person's body temperature was held to obtain the ground-truth values, namely by using a standard infrared thermometer. The temperature measured by the infrared thermometer was then compared with the temperature processed and calculated by the program and with the temperature scanned by the thermal camera. A total of five samples (see Fig. 17 – 21) were obtained to analyze the accuracy of the human body temperature detection by the program where Sample 5 was tested for a person with abnormal temperature by putting a cloth soaked with hot water on the forehead.

The comparison of the output temperatures of the samples with the temperature measured by the infrared thermometer and the temperature scanned by the thermal camera is represented in Table 2. To calculate the accuracy of the results, the equation below is used:

$$Accuracy = \frac{TP+TN}{(TP+TN+FP+FN)} \qquad (1)$$

The numbers of occurrences of TP, TN, FP, and FN with the accuracy of the temperature measurements are tabulated in Table 3.

Fig. 17 Output of Sample 1

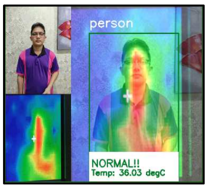

Fig. 18 Output of Sample 2

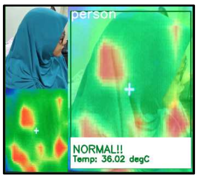

Fig. 19 Output of Sample 3

Fig. 20 Output of Sample 4

Fig. 21 Output of Sample 5

TABLE II: A comparison of captured body temperature values with three different methods

Method / Sample	**Ground-truth actual temperature measured by the infrared thermometer (°C)**	**Temperature scanned and displayed by the thermal camera (°C)**	**Output temperature computed by the program (°C)**
1	36.9	28.5	**35.47 (Normal)**
2	36.8	23.2	**36.03 (Normal)**
3	36.1	26.5	**36.02 (Normal)**
4	36.5	27.7	**35.98 (Normal)**
5	40.4	25.0	**39.06 (Abnormal)**

TABLE III: The numbers of occurrences of TP, TN, FP, and FN with the accuracy of the temperature measurements

Label	**Description**	**Occurrence Count**
TP	Normal temperature based on the samples	4
FN	Incorrectly predicted temperature based on trained samples	0
FP	Correct predicted temperature based on untrained samples	0
TN	Abnormal temperature based on the samples	1
Accuracy	$\frac{4+1}{(4+1+0+0)} x\ 100$	100%

Based on the results of the program that have been summarized in Table III, it can be concluded that the program has successfully produced the expected outcome, that is, the four samples show a normal body temperature. While the body temperature value calculated by this program is also not much different from the infrared thermometer reading. Yet we can see that the temperature detection by the thermal camera itself is not accurate. With this brief analysis, we can say that the program can work well based on images from a real thermal camera. However, further analysis needs to be done to make a more accurate assessment with more sample data. For this purpose, a more suitable thermal camera is needed.

V. Conclusion

The main objective of this project, i.e. to design a temperature measuring process that can detect and scan human body temperature immediately using a thermal camera was achieved. By using a thermal camera, temperature measuring would be much easier. People do not have to measure their temperature manually by holding an infrared temperature gun. A thermal camera can be attached to a surface and measure temperature by capturing images. They also do not have to stand still at one spot and wait for their temperature to be measured. A thermal camera can measure temperature instantly and automatically since it does not need to emit an infrared signal for temperature measurement. It uses infrared light which is much faster than an infrared signal. Therefore, no time would be wasted, and human interactions could be lessened and the possibility to spread the virus would also decrease.

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References

[1] World Health Organization, "Laboratory testing for 2019 novel coronavirus (2019-nCoV) in suspected human cases," vol. 2019, no. January, pp. 1–7, 2020.

[2] J. R. Hageman, "The Coronavirus Disease 2019 (COVID-19)", Pediatr. Ann., vol. 49, no. 3, pp. e99–e100, 2020

[3] Visiongeek.io, 2018. "YOLO Object Detection with OpenCV and Python". [online] Available at: <https://www.visiongeek.io/2018/07/yolo-object-detection-opencv-python.html>[Accessed 20 May 2021]

[4] Tutorialspoint.com 2021. "OpenCV Tutorial - Tutorialspoint,". [online] Available at <https://www.tutorialspoint.com/opencv/index.htm>[Accessed 20 May 2021]

[5] "Temperature Guns Versus Thermal Imaging Technology," Flir.asia, 2015. https://www.flir.asia/discover/rd-science/ temperature-guns-versus-thermal-imaging-technology/

[6] "Spot Thermometer vs Thermal Imaging Camera | TEquipment," Tequipment.net, 2019. https://www.tequipment.net/spot-thermometer-vs-thermal-imaging-camera/

[7] "Temperature Guns versus Thermal Imaging Technology - Imaging Tech Solutions (ITS)," Imaging Tech Solutions (ITS), Mar. 20, 2020. https://imagingtechsolutions.com/temperature-guns-versus-thermal-imaging-technology/

[8] "FLIR Thermal Cameras Improve Office Safety and Wellness Amid COVID-19 Concerns," Flir.com, 2020. https://www.flir.com/discover/public-safety/flir-thermal-camera-helps-improve-safety-and-protect-the-value-of-office-buildings-amid-covid-19-concerns

[9] "Entering a Building May Soon Involve a Thermal Scan and Facial Recognition," IEEE Spectrum: Technology, Engineering, and Science News, 2020. https://spectrum.ieee.org/the-human-os/biomedical/devices/entering-a-building-may-soon-involve-a-thermal-scan-and-facial-recognition

[10] Youtube.com 2021. "How to become invisible to Infrared Cameras". [online] Available at: <https://www.youtube.com/watch?v=fpx7hsoYEt4> [Accessed 8 June 2021].

[11] Vendian.org 2021. "What color is a blackbody? - some pixel rgb values". [online] Available at: <http://www.vendian.org/mncharity/dir3/blackbody/> [Accessed 10 June 2021].