CST3590 COMPUTER ENGINEERING PROJECT

Faculty of Science and Technology

Thermal imaging camera programmed using machine learning

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Project Title

Thermal camera imaging for home automation using machine learning.

Abstract

With the increase in population which causes a high demand of electrical power, has led to an all-time high production of electricity which results in global warming/climate change which in-turn causes numerous problems to the environment. These problems include, rise in the maximum temperature, rise in the minimum temperature, rise in sea levels, higher ocean temperatures, increase in natural disasters such as droughts, aridity, violent tropical cyclones, flooding and wildfires, and finally reduces agriculture yields and health impacts due to the high temperatures. In order to reduce these levels, humans should be more considerate and responsible for electricity wastage and should try and save electricity in any way possible. The go-to option available right now are the motion sensor cameras that use an infrared camera to capture movement, but these have many drawbacks such as, delayed response time or the results can be altered due to the surrounding temperature. Whereas, the proposed idea in this report overcomes all those drawbacks by using machine learning and is made more efficient to reduce electricity wastage through light bulbs. This report brings light upon an approach of using internet of things and machine learning to help reduce these levels. The report demonstrates a technique of using thermal imaging to automatically turn lights off and on depending on human presence in the room by the help of machine learning. The project orbits around the concepts of internet of things and machine learning. The prototype is constructed using a raspberry pi 4 model B and a thermal camera mlx90640. The camera is connected to the raspberry pi using the I2C pins on the raspberry pi and then uses a python script to function accordingly. If implemented in schools, universities, offices or homes, can help reduce electricity consumption massively.

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1.0 Introduction

Thermal imaging using machine learning to control led

1.1 Keywords

- Machine learning
- Deep learning
- Thermal imaging
- Global warming
- Internet of Things (IOT)

1.2 Background and context description

Global warming is among the most major consequences of human activity, with the excessive usage of fossil fuels as energy resources which in-turn increases the concentration of greenhouse gases (GHGs) such as nitrogen oxide, methane, carbon dioxide, and water vapor in the atmosphere, leading to a rise in the earth's average surface temperature. The greenhouse effect is the prime reason that the earth is a suitable environment to live for the humans, without greenhouse gasses the earth’s temperature would be too high for human life to exist on. However, a rise in the number of greenhouse gases in the atmosphere cause this disastrous phenomenon, known as global warming.

1.2.1 The main causes of global warming include:

Natural Events: The world's climate has been changing numerous times over the years owing to natural reasons such as volcanic eruptions, changes in incident solar radiation due to the Milankovitch cycle and fluctuations in the solar radiation emitted by the sun [15]. Volcanic eruptions have a substantial impact on the earth's temperature. The eruptions deploy ashes and harmful gasses such as sulfur dioxide, carbon dioxide and water vapor into the upper atmosphere. These gasses contribute to the increase in the global temperature casing global warming. Nevertheless, the quantity of carbon dioxide emitted by volcanoes is negligible in comparison to human emissions [16]. Volcanos only produce 130-230 million tons of carbon dioxide where as human causes are responsible for 26 billion tons of carbon dioxide annually, which is 100x more than that caused by volcanoes. Natural phenomena continue to have an impact on the climate, but they have a much smaller and slower impact when compared to the impact of human activities. Scientists used climate models based on information from satellites and ground stations to reproduce temperature simulations for the past 150 years in order to demonstrate that human activities are the primary effect on the climate. The model simulations were able to fit the global temperature records by simply considering solar natural variability and volcanic emissions between 1750 and 1950, yet after 1950, the global temperature patterns cannot be justified without incorporating greenhouse gasses produced by humans. [17]

Water vapor**:** Water vapor is the most common gas in the atmosphere, and it has been acknowledged as the most crucial element in providing feedback regarding climate change. Moreover, water vapor causes two-thirds of global warming. Furthermore, the amount of extra heat entering the atmosphere is dictated by the amount of water vapor in the atmosphere. Due to the short lifetime of water vapor, the atmosphere maintains a steady balance between water vapor concentration and the temperature. However, when temperatures rise, the balance will be disrupted, contributing to global warming as water vapors are capable of increasing the warmth 2x as much as carbon dioxide can cause.[18]

Carbon Dioxide: Carbon dioxide concentrations in the atmosphere have grown by 30% since 1950, which is a considerable increase. This increase was most likely driven by human activity. Humanity relies mostly on fossil fuels to generate energy, and the quantity of nitrous oxide, water vapor and carbon dioxide produced by burning these fuels varies depending on the kind of fossil fuel. Coal, natural gas, and oil are the most frequent forms of fossil fuels used by humans, with coal accounting for 45 percent of CO2 emissions in 2015, oil accounting for 35 percent, and natural gas accounting for 20 percent [19]. Mankind is not only responsible for the increase in the proportion of carbon dioxide in the atmosphere, but also interrupted the carbon dioxide cycle by overcutting the trees. Deforestation prevents trees from absorbing carbon, causing carbon dioxide concentrations to rise in the atmosphere, where deforestation itself accounts for 25%-30% of yearly Greenhouse gasses emissions [20].

Methane**:** Methane emissions are the second greatest contributors of causing global warming, the volume of methane emissions has more than doubled over the previous 150 years, with human activities accounting for about 60% of these harmful emissions [21]. This harmful gas is emitted into the atmosphere by a lot of different means that include refining, distribution, extraction, production and transportation of natural gas. Furthermore, considerable volumes of methane are produced by human waste, livestock, agriculture and landfills.

Sources	Percentage (%)
Agriculture and Waste	37.08
Wetlands	34.83
Oil and Natural gas	16.61
Coal	7.87
Biomass burning	5.62

Methane Emissions Globally between 2003 and 2012 [22].

The data above shows methane emissions globally between the years 2003 and 2012. According to the table, agriculture and waste seem to be the biggest contributors of methane into the atmosphere followed by Wetlands and the least being biomass burning.

Nitrous Oxide: Activities such as burning of fossil fuels, industrial operations, agriculture and wastewater treatment account for around 40% of the overall nitrous oxide emissions. If current trends continue, N2O emissions are expected to reach 25.7 N2O/year by 2100, resulting in a 0.37°C increase in the average surface temperatures. Nitrous oxide remains in the atmosphere for roughly 114 years before being eliminated as part of the nitrogen cycle by a particular bacteria or eliminated by chemical reactions or by UV light. More importantly, this particular gas has the power to warm the atmosphere almost 300x more than carbon dioxide, however nitrous oxide concentrations are substantially lower than that of carbon dioxide concentrations [23][24].

1.2.2. The consequences of global warming include:

The earth's surface temperature has been increasing steadily since the industrial revolution. Studies show that the earth's temperature has increased by 0.8 degree since 1880. Big research institutes such as NOAA, The Japan Meteorological Agency, NASA and the Met office Hadley Centre observed the annual temperature between 1880 till 2014, and all came up with similar patterns but different values. Moreover, scientists have predicted an increase of 2-6 degree in the earths temperature till the end of the 21st century if the current harmful activities keep happening at the current rate, especially the burning of fossil fuels to produce energy. This increase in temperature effects all the living organisms on the planet. Crops, animals and plants need specific temperatures to survive and if those requirements aren't met, a disturbance will be engendered in the growth and population of certain species. Furthermore, the increase in temperature will also cause the spread of extreme weather conditions such as floods,

heat waves, droughts and hurricanes causing damage to human life and other materialistic resources. Additionally, the rise in temperature will also be responsible for the melting of ice glaciers causing an increase in the sea levels which in-turn will trap more heat from the atmosphere [25]. As the water bodies are known to trap the heat energy from the atmosphere, which increases the water temperature affecting the marine life. Warmer oceans result in a lower percentage of dissolved oxygen which will cause difficulties for many species in the ocean. Coral bleaching is one of the most visible symptoms of how global warming is affecting the marine life [26]. With all these restraints on the environment, people should start changing their old habits to an eco-friendlier attitude to help reduce these levels. There are many ways to do so, but the easiest way around this issue is if people start saving electricity at homes using various sensors.

1.3. Internet of Things

With the current advancements in technology, home automation is being implemented my many big companies to help the consumer in many ways such as saving money by reducing electricity usage which results in lower electricity bills and helps save the environment. The Internet of Things (IoT) is a phrase that has recently been used to describe objects that can interact via the internet [27][28]. Considering all devices have digital capabilities and can be identified and tracked automatically, IoT has the potential to significantly simplify how industrial and commercial systems can operate and be maintained. It furthermore allows the objects to be controlled remotely over the network/wifi interface. The most important requirement of IOT is that all the computers involved should be connected over the network. As a result, IoT is emerging as an internet-based industrial information architecture that may be used to enhance industrial information integration [29]. The importance of IoT in industrial and commercial systems has been acknowledged, since IoT will have an influence on the global economy. Many new prospects for applying IoT to many industrial sectors exist today or might be anticipated in the near future [30][31].

IoT plays a role in almost every field of the industry including industrial, commercial and consumer. moreover, consumer-oriented IoT products such as linked automobiles, wearable technology, health, home automation and appliances with remote monitoring capabilities are becoming more prevalent.

IoT computers are a subset of the broader notion of smart homes which includes light sources, security system, media and cooling and heating [32]. Furthermore, consumers can benefit by saving electricity by automatically turning off unwanted electric appliances or by keeping a track of the energy consumption by the electric devices at home [33]. For instance, an automated house can be based on a platform that connects all the electric appliances together so they could be easily monitored or controlled by the consumer. With the increasing demand, many manufacturers have shifted dynamics to a more IoT based products such as the Lenovo's Smart Home Essentials, Apple's HomePod, Amazon echo, Google Home and many more. All these lineups have smart electrical home appliances that share resources with each other over the WIFI resulting in an easier and more automated lifestyle [34].

1.4. Deep learning

Deep learning comes under machine learning, and is a simple neural network that has three or more layers to function efficiently. These networks seek to replicate the functioning of a human brain, allowing the computer to learn from enormous volumes of data. Even though a neural network with a 1 layer may still produce approximate predictions, more hidden layers can assist to refine and tune the model to achieve higher yields of accuracy. They layers are interconnected nodes, with each layer improving and optimizing the prediction or grouping of data. This movement of calculations via a network is known as forward propagation. The visible layers of deep learning are the output and input layers. The deep learning model receives information that needs processing in the input layer, and the final classification or prediction is performed in the output layer. Backpropagation is another approach that employs

algorithms such as gradient descent to compute errors in projections and then modifies the biases and weights of the function by descending backwards through the different layers in order to train the model. Forward and backward propagation operate together to allow a neural network to predict outcomes and adject accordingly for faults. The algorithm continuously improves in accuracy over time. In the most basic terms, the above-mentioned algorithms describe the most basic sort of deep neural networks. Deep learning techniques, on the other hand, are extremely sophisticated and many types of neural networks exist to solve specific issues or datasets [40]. A few examples include:

- Convolutional neural networks (CNNs): is an algorithm which is commonly used for computer image and vision classification applications, as they it is programmed to recognize characteristics and patterns with an image, allowing tasks such as object reorganization and detection to be performed.
- Recurrent neural network (RNNS): is an algorithm commonly used in natural speech and language recognition applications because they utilize time series or sequential data.

Applications

Deep mining applications are part of our everyday lives but many of these applications are so well-integrated into goods and services that consumers are oblivious of the intricate data processing that is going on in the background. Among these examples include, being used in law enforcement, financial services, customer service and healthcare [40].

As deep mining and machine learning are products of AI and share a few characteristics but listed below are the 5 main differences between then [41]:

Human Factor: To produce outcomes, machine learning may require more continuing human engagement, whereas deep learning requires less intervention but is comparatively more difficult to set up.

Hardware: Machine learning algorithms are often less sophisticated compared to deep learning algorithms and can be executed on standard computers, whereas deep

learning requires significantly more powerful resources and hardware. Due to this, there is a rise in demand for graphics processing units as they are handy when it comes to their high bandwidth memory and the ability to disguise memory transfer delays with the help of thread parallelism (the ability to run multiple processes at the same time).

Time: The time needed to put up and start operating for machine learning is quick but comparatively less accuracy in their results, whereas deep learning requires more effort to setup but may produce results instantly (even though the quality of the results will improve as more data is made available over time).

Approach: Machine learning often necessitates organized data for processing and use older techniques such as linear regression where as deep learning makes use of neural networks and is built to accommodate large volumes of unstructured data.

Applications: Machine learning is already being used in places like banks, doctor's office and even your personal email inbox. Deep learning on the other hand, is employed where increasingly complicated and autonomous algorithms are used such as a self-driving automobile or surgical robots.

1.5 Machine Learning

Why is machine learning necessary?

Machine learning is a growing field of computering algorithms that aim to mimic human intelligence by learning from the surrounds. Machine learning techniques have been effectively employed in a wide range of industries including computer vision, entertainment, pattern recognition, aerospace engineering, finance and as well as biological and medical applications. In Broder terms, machine learning is a wide term that refers to computer approaches that use previously obtained knowledge to enhance performance or generate accurate predictions. The information or data provided to the machine is often in the form of electronic data gathered and made available for analysis.

This data might be digitalized human-labeled training sets or other sorts of information received through contact with the environment. In all circumstances, its scale and quality are critical to the success of the machine's predictions. Moreover, machine learning is the process of creating accurate and efficient algorithms. Space and time complexity are key metrics of the quality of these algorithms. Unlike all the other fields, in machine learning a concept of sample complexity to analyze the sample size is necessary for the algorithm to learn. furthermore, theoretical learning for an algorithm is determined by the complexity of the logic functions and the quality of the training sample.[35]

Machine learning admits a very broad set of practical applications which include the following [35]:

- Document or Text classifications: The algorithm used in this application is to detect whether the data on the website is too explicit or inappropriate. This is mainly used by web browsers such as Google or Safari. Moreover, it can also help assigning a topic to a document by reading the data present in the document.
- Speech processing applications: this application helps with problems involving speaker identification, speech recognition or where speaker verification is needed. With this algorithm, there won't be a need of human intervention for decision making avoiding human errors and making these tasks much easier and automated.
- Computer vision applications: applications in this field include face detection, object recognition, Optical Character recognition (OCR), or pose estimation. The most common use for this application can be found in the latest smart phones to unlock them.
- Computational Biology applications: machine learning plays a huge role in treating cancer patients through radiotherapy. It can also be used for analysis of protein and gene networks.

- Moreover, machine learning can be used for many other applications as well such as, learning to play video games that require decision making, or for cyber security to stop hackers from corrupting or stealing sensitive data, or for controlling a car using machine learning and various sensors to avoid obstacles and follow a path and take decisions without the intervention of a human.

Machine learning can be classified into 4 main methods:

Supervised learning: Supervised learning methods are used for applications in which the training set provided consists of instances of the input vectors and their associated target vectors. These models are trained to make predictions only based on the inputs provided and then the outputs are compared to the data provided to estimate the accuracy and skill of the trained model. Supervised learning is usually used for categorization/classification learning methods as it aims to frequently persuade the computer system to learn from the categorized data samples provided. Once again, digital recognition is a common example of categorized learning. Moreover, classification learning is applicable to any situation in which deducing a classification is advantageous and the classification is simple to ascertain. The probability of inputs is frequently left unspecified in supervised learning. These models are not required as long as the inputs are provided but if part of the provided input values are incorrect or missing then the output will be incorrect [36].

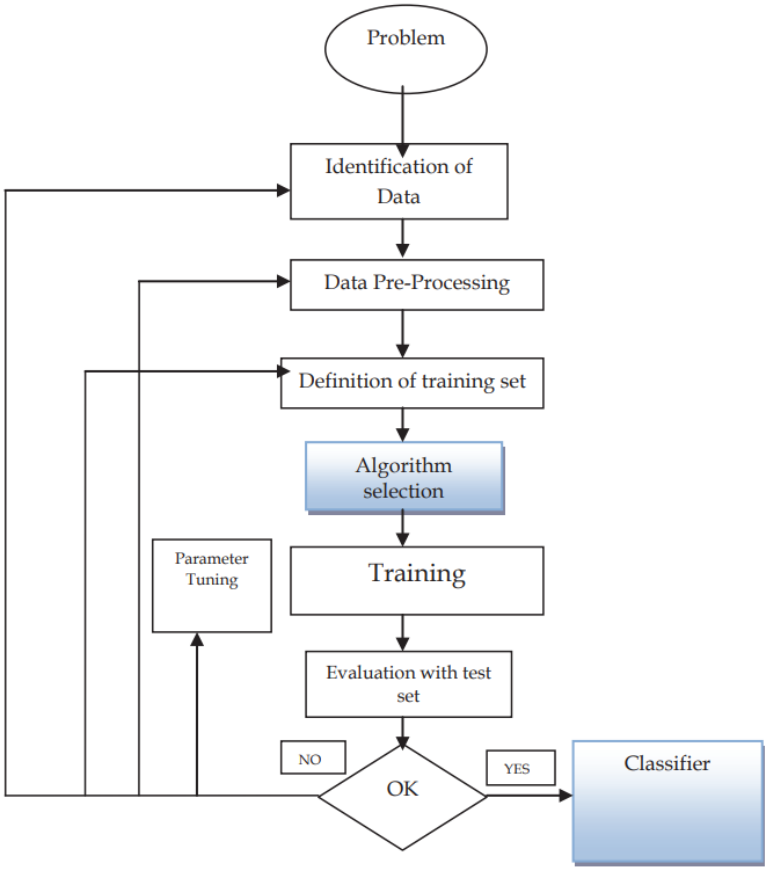


Fig. 1. Machine Learning, Supervised method flowchart

unsupervised learning: unsupervised learning is a sort of algorithm that discovers patterns in unlabeled data. The goal is to imitate, which is also a key wat of learning in humans, would compel the machine to compact internal picture of its's reality and then generate useful material from it. Unlike supervised learning, in which data is labelled by a human, unsupervised approaches display self-organization, which captures patterns depending on the probability densities. This learning approach appears to be considerably more difficult than supervised learning, as the aim of the computer is to learn how to perform a task is based on its own set of instructions without being instructed by humans specifically. Unsupervised learning cab be approached in two

ways, the first strategy is to train the computer by employing a reward system to signify success rather than by providing explicit categorization of the sample data given as input. It is important to note that this form of learning will typically fit into the decision-making framework since the aim is to make judgments that maximize rewards rather than to cerate a categorization. Learning via trial and error can be time consuming, however because there is no pre-existing classification of samples, this type of learning can be quite effective as there will be errors bases on human errors or the data not being grouped properly. Moving on, the second form of supervised learning is known as clustering. The purpose of this sort of learning is to detect similarities in the sample data provided rather than using an objective function. the assumption is typically that the found clusters would fit relatively well with a logical categorization. This type of technique is only useful and effective if there is enough sample data provided. For example, filtering algorithms that are used by Amazon to recommend books, are based on the notion identifying similar groups of individuals and then assigning new members to these groups. In some circumstances, knowledge about other cluster members may be sufficient for the algorithm to provide relevant results but in some cases the clustered data may not be sufficient for a human analyst. Unfortunately, just like all the other learning methods, unsupervised is also plagued by the issue of overloading the training data provided. There is no one-size-fits-all solution to the problem since any algorithm that learns from its input data set provided must be fairly strong [36].

Semi-supervised learning: Semi-supervised learning is a similar to supervised learning but it only uses a small number of labeled instances and a large number of uncategorized data for the training purpose. The purpose of a semi-supervised learning algorithm is to make good use of all accessible data, rather than just the labelled data, as in the case with supervised learning. Using unlabeled set of data effectively may necessitate the use of unsupervised approaches such as density estimate and clustering. Once patterns have been established, supervised ideas from supervised learning can be utilized to label the uncategorized instances or assign labels to

unlabeled data representations that will subsequently be used for prediction. Given the computational burden and cost of labelling instances, many real-world supervised learning issues are also examples of semi supervised learning problems. Classifying pictures, for instance, necessitates a collection containing photographs that have previously been tagged human operators. Many issues in natural language processing, automatic speech recognition and computer vision all fall within this category and are difficult to solve using traditional supervised learning approaches [37].

Reinforced learning: Reinforced learning is a branch of machine learning concerned with how AI algorithms should behave in a given environment in order to maximize the concepts of cumulative rewards. Reinforced learning, along with unsupervised and supervised learning, is one of three fundamental machine learning paradigms. Unlike supervised learning, reinforced learning does not need the presentation of labeled output/input pairings, as well as the explicit correction of suboptimal actions. Instead, the emphasis is on striking a balance between exploitation (of current data) and exploration (of previously unexplored region). In similar words, Reinforcement learning refers to a class of issues in which a computer agent operates in a given environment and must adapt to function based on feedback through different variables such as a sensor. The usage of the environment implies that there is no present training data available, but rather a goal or collection of objectives that a computer agent must attain, they may execute and get feedback on performance toward achieving the set goal. It is comparable to supervised learning as in that the AI system has some kind of response to learn from, but the feedback might be slow and statistically unpredictable, making it difficult for the model to link effect and cause. Playing a game where the model's aim is to achieve a high score and may take actions in the game and receive feedback in the form of rewards and punishments is a great example of reinforcement algorithm [37].

The proposed prototype will automatically detect human presence in a snapshot taken by the camera using machine learning and turn on the LED or turn off the LED accordingly (implementation technique and details will be provided later in the document).

1.6 Recourses required

The software resources required include:

- Raspbian OS
- Tensorflow with keras library
- OpenCV library
- Platypush platform
- Jupyter notebook

The hardware resources required include:

- Raspberry pi 4 model B
- Mlx90640 thermal camera
- LED
- 330-ohm resistor
- Breadboard
- Jumper wires

2.0 Literature review

This section will breakdown the problem in hand and provide critically analyzes of other projects done to achieve a similar outcome and utilizes that information in developing a better prototype.

2.1 Introduction

With the emerging technology and population growth, energy is needed more than ever. Due to this demand, there is a high increase in electricity production and thus people should be more considerate and try and reduce usage of excessive electricity at homes, offices and educational institutes because of the huge amount of greenhouse gasses being released into the atmosphere causing global warming/climate change. Climate change is one of the most urgent challenges of our day, putting tremendous strain on our communities and the surroundings. The repercussions of climate change are worldwide in scope and unprecedented in scale, ranging from changing weather patterns that jeopardize food production to increasing sea levels that increase the risk of catastrophic flooding. The fast-increasing global energy use has already sparked worries in regards to supply issues, severe environmental consequences and energy resource depletion. Studies done by The International Energy Agency reveal that energy consumption have grown by 49 percent and carbon dioxide emissions by 43 percent in the last two decades. Further studies suggest, buildings including offices, houses educational institutes and hospitals are responsible for 43 percent of the total energy conception. [1] In order to bring these levels low, we need to take greener decisions in our everyday life, starting with saving electricity at homes, office and educational institutes. In addition to that, this report will discuss how using thermal cameras for sensing human presence and turning the lights on and off accordingly is the most reliable and achievable strategy to reduce energy wastage at homes, offices and educational institutes and it can also be used for surveillance purposes to increase security at homes. Moreover, we have brough light upon different approaches suggested by different authors and how our approach might be more efficient and feasible for tackling the problem in hand. [3][4]

2.2 How sensors can help in global warming

Due to the current climate change situation, energy management has become mandatory and a solution to this could be using automated systems that use sensors and detectors to manage all the electrical appliances at homes, offices and educational institutions (RAMYA, RAO. and RAGHAVA 2020). Research done by [2] states that, with the help of these automated systems the total energy consumption in a building can be decreased by 30% resulting in a healthier environment. For a consumer to implement such changes, there should be a motivating factor. These factors might include awareness, realization, positive attitude or social influence. For individuals to alter their consumption habits, they should first be made aware of the amount of electricity being used and know of the consequences accordingly [14].

2.3 Different approaches used

(Vatin and Gamayunova, 2016) State in their research that a solution to saving energy is by installing an intelligent meter to keep track of the electricity being used. This approach will help the consumer to keep note of the electricity being used and act accordingly. In addition, the research paper also includes that, people should install energy-saving bulbs as they are very useful for a long run even though they might be expensive comparatively. Whereas [2] mentions that, a consumer needs motivation to plan a strategy for saving electricity after being aware of where it is being used by the smart meter and disagrees with (Vatin and Gamayunova, 2016) [5]'s idea of saving electricity. Measuring and keeping track of the electricity being used might be a good idea only if an action is taken afterwards, for instance if the light bulbs are using excessive amount of energy than they should be replaced with more efficient bulbs or have sensors help automatically turn on or off lights depending on different factors that

suit the situation best. Finally, smart meters might not be the best option as it all depends on the intentions and nature of the consumer to act accordingly.

Moving on, [6](Lundberg, Tang, Attari, 2019) research on the similar topic shows surveys done from 1989-2010 regarding different approaches to saving electricity, and the most popular answer chosen was that turning the lights off when not being used was the most effective way of saving energy. Their plan towards saving energy was kind of similar to the strategy suggested by [2]. The research paper demonstrates two approaches, one was turning the lights off when not in use and the other solution was to install more efficient light bulbs. The efficiency of a light bulb can be calculated by the amount of visible light given out by a certain amount of energy. For example, incandescent bulbs produce 10lm to 18lm per wat, whereas compact fluorescent light bulbs produce approximately 35lm to 60lm per wat and finally Light Emitting Diode (LEDs) which are the most efficient light bulbs that produce around 60lm to 100lm per wat. Furthermore, Lundberg, Tang and Attari (2019) show how changing light bulb is a way more efficient than the traditional way which is just turning the lights off for instance, a 100w incandescent bulb produces visible light equal to that of a 14w LED bulb. Now if you were to calculate the energy used by these two bulbs in 2 hours, LED = 28Wh and the incandescent bulb uses 200Wh of energy which is still more than the LED if it were to stay on for 8hrs(112Wh). Whereas the Autor of the book (Meredith, 2009) Disagrees with this approach as it is not efficient enough and instead people should focus on a more reliable and systematic outcome. Moreover, the report successfully demonstrates how using a more efficient bulb would reduce energy consumption, but a withdraw of this strategy is that it only focuses on one alternative which is turning the lights off. For example, if a user were to install a 14w LED bulb and have a 2-hour session with lights on, the energy used would be 28Wh but if the lights were left on for 8 hours, 112Wh of energy would be used meaning 84Wh (112 – 28) of energy would be wasted by a single bulb. End of the day we would still be wasting energy but compared to the incandescent bulbs, it would be less but our objective is to not waste electricity overall. Thus, making this approach not as effective.

Furthermore, [7] proposed an idea of using a smart Arduino micro-controller equipped with various sensors to detect light intensity, temperature and human presence. The proposed system automatically controlled the brightness of light bulbs, speed of fans and power supply of that specific room depending on the results captured by the sensors installed. The system proposed depends on a lot of factors to function thus making it complex and prone to many system errors. The proposed idea helps reduce electricity usage but the idea itself is complex and has a high maintenance cost making it less effective as planned.

Meanwhile, [8] projects an idea of using PIR sensors with a REAL TIME CLOCK(RTC). The author combines the PIR sensor with a RTC to obtain maximum results. Moreover, the sensor is used to capture movement and turn the lights on accordingly whereas the clock is used to keep the lights on during specific intervals depending on the consumers daily activity. The main component in a PIR sensor is the pyroelectric sensor, this sensor is responsible for detecting the amount of IR radiations from the surroundings. The pyroelectric sensor is divided into two halves. When there is a movement, the reading on one of the halves increase creating a positive differential after which the lights are turned on for a short amount of time. The overall idea is good as it helps in reducing wastage of electricity but there are still areas that need improvement. For instance, having the lights on at a specific time during the day is not accurate as human activity can differ every other day. Furthermore, a few drawbacks of using a PIR sensor include, they aren't accurate if the person is wearing bright colors, many layers of clothing, cover a small area and the results can be inaccurate if the room temperature is similar to the human body temperature causing false signals or might even cause complete system failure. These flaws could immensely decrease the efficiency of the project, leaving many areas for improvement.

Moreover, [9] demonstrates a similar idea of using PIR sensors that could turn the lights off and on depending on any movement captured by the sensor. Studies show using

sensors reduced energy usage by 30%. However, few of these sensors have a user adjustable time delay (TD). If the TD was kept short, that would cause the lights to turn off quicker (from when the motion was last captured) even if the person is still in the room. Whereas, if the TD was increased the lights would stay on for long time (from when the last motion was captured) even if there is no motion captured at that time. Furthermore, a universal TD cannot be used for everyone on this planet because, research show that human activity differs a lot throughout the day and in addition to that, all humans differ in activity even if it is during the same time of the day. The paper suggests a new solution which is a smart occupancy sensor that adapts to the human activity for the best results. The idea suggested by the author can be beneficial in two ways, first is that it saves unwanted energy and second benefit is it increases the bulb life thus reducing on the replacement and maintenance charges. Moving on, the author mentioned that the sensor will take time adapting itself with the human activity in a day and they didn't take into account that human activity may differ every day [10]. Thus, proving it may not be that accurate but will do the job and reduce energy consumption efficiently compared to PIR sensors with universal TD. The idea could be improved as there are loop holes such as, If the TD isn't accurate, lights will stay on even if no motion is captured or the lights might turn off quick in spite of someone already being in the room but idle. Finally, the author only compares the proposed idea with PIR sensors having universal TD and not as a complete solution to saving electricity in the most efficient way.

Furthermore, [11] illustrates a similar idea of using sensors but instead of monitoring the daily human activity, the sensors are used to monitor the natural light available. In broader terms, the author makes use of sensors that monitor natural light in a specified area and accordingly turn lights on or off depending on these readings. In order to activate this system, a small adjustment is made to the switching point. Additionally, a filter is also attached to this system which helps with increasing or decreasing the delay time of the light switches. The proposed idea is very helpful during the day but will fail in dark rooms/area where there is no natural light as the lights will stay on the whole time

until not turned off explicitly. Moreover, the results may vary on cloudy days making this idea not as efficient as planned.

Unlike the previous approaches, [12] came up with a different idea as it uses the cloud and wifi facilities. The idea discussed by this paper is, to automatically turn of lights using your phone. These lights are required to connect to a stable wifi connection and so does the user's phone in order to control them. They use the idea of receiving and transmitting requests to the cloud. Basically, the user sends a request to the cloud to check the lights status, the cloud then confirms if the lights are turned off or if they are left on and from there the user can change the setting by changing the code saved on the cloud, which is read by the lights and change status accordingly. This system does not only help reduce energy usage but also helps with controlling the lights from anywhere. For the hardware design, an ESP8266 chip was used as this chip is comparatively cheaper and consists of a small processor for it to function independently without needing an external Arduino board. For the software part, as discussed earlier the project makes use of clouding with wifi to achieve the desired goal. Additionally, it uses the MQTT protocol for communication over the usual HTTP protocol as MQTT was initially created for machine-to-machine communication. Furthermore, the protocol also produces comparatively smaller code footprints and provides low bandwidth with high frequency. A drawback in this approach is that the user and the lights need to be connected to the wifi at all times for the system to operate. In addition to this, the system should include a system to turn off the lights automatically after a set period of time as leaving the lights on would still be accounted for energy wastage.

Moving on, [13] came up with a new approach of using voice control assistance to turn of lights or other electrical appliances at home. The proposed system makes use of the IFTTT platform, NodeMCU, Real-Time database and a raspberry pi. IFTTT platform is a software used to connect different applications and services together, the database is used for storing information regarding the appliances whether a particular electrical

device is on or off and finally the raspberry pi is used for enabling voice assistance which is then converted to signals sent to the relay for enabling or disabling current in the specified device. A web application is also designed for the user to view the current appliances connected to the system with the status by retrieving data from the database. This approach helps save electricity and brings ease and comfort to the consumer. Additionally, the user is able to turn off or on the appliances remotely. With all the benefits the system brings, it is still venerable because of weak security measures and voice assistant only recognizes English as the primary language making it hard for people that can't speak fluent English hard to communicate or make use of such a system. Thus, not making it as efficient as portrayed.

Concludingly, the approaches mentioned above have their strengths and weaknesses but the main focus here is to save electricity in the most efficient way and these ideas are effective but
can be made better with further dept of research. Furthermore, none of these approaches made used of machine learning or deep learning to help assist the process of automatically turning lights off to provide more accurate results.

3.0 Proposed prototype design

This section will go through the development methodology and implementation of the proposed model and explain how the proposed model might provide more efficient results then the different approaches mention in section 2.3.

3.1 Why the proposed model is more efficient

As discussed above, all the different approaches used for saving electricity by turning of lights when not in use had some kind of a drawback making it not as efficient as required. Most of them used PIR sensors, light sensors or used the cloud, whereas we will be using a thermal camera and machine learning to capture thermal radiation from humans to turn on or off the lights automatically for saving electricity.

To solve the problem of excessive usage of electricity, we can use thermal imaging to capture thermal radiation emitted from the human body and accordingly keep the lights on or off automatically. In broader terms, we will be using a raspberry pi, a thermal camera which in our case will be MLX90460 breakout camera, a breadboard and a few wires. The camera will take pictures within short intervals and check for human presence and if the results are positive (human is present) it will turn on the lights until a negative (human isn't present) result is recognized by the system.

The reason we used thermal cameras for this approach is because they do not relay on a source of light to provide results and can function efficiently in complete darkness as well unlike the usual cameras. Furthermore, the functionality of thermal cameras is not affected by wearing bright color clothes or weather conditions as that of PIR sensors. Moreover, thermal cameras have long range of detection compared to the PIR sensors. Additionally, unlike other sensors, thermal cameras don't have a TD making it more efficient as there won't be unwanted delays while turning the lights on or off. Furthermore, machine learning is proven to have help projects with the need of

automation improve and provide more accurate results. The system will not be needing a lot of human participation.

3.2 Which machine learning is most suitable?

For this specific thermal imaging project, Machine learning using neural network algorithm with supervised learning approach was used. The reason for going with this approach was because this algorithm has three hidden layers that work together in analyzing and finding patterns in a given set of data. Each layer is responsible in detecting a pattern and when it does so, the next layer is activated. This project focuses on identifying presence of a human in the pictures taken by the camera every minute. 500 grey scale images were taken by the mlx90640 and were grouped into two separate files. One file was for positive results (human present in the picture) and a file to store negative results (no human in the picture). And then the model is trained upon these images to produce results. 3 layers of neuro networks were used in identifying patterns in the images taken to train the model to achieve high accuracy and efficiency.

3.3 Development Methodology

To effectively manage a project, the management or development team must select the project development technique that is most suited to the project at hand. Every methodology has its own set of advantages and disadvantages, and it exists for a variety of reasons. For this project, the waterfall method has been used in order to construct the prototype. The waterfall technique is a rigid linear model comprised of consecutive phases that include requirements, design, implementation, verification and maintenance, each concentrating on a specific objective. Before the following step may begin, each phase must be completed completely. There is generally no way to go back and change the project or direction [48]. This approach is making the project easy to understand and manage. All the aims and procedures are outlined in the beginning of

the process for the stakeholders to agree and once agreed no further changes are done during the process and it also helps in reducing the chances of errors. Below is a visual presentation of the complete process.

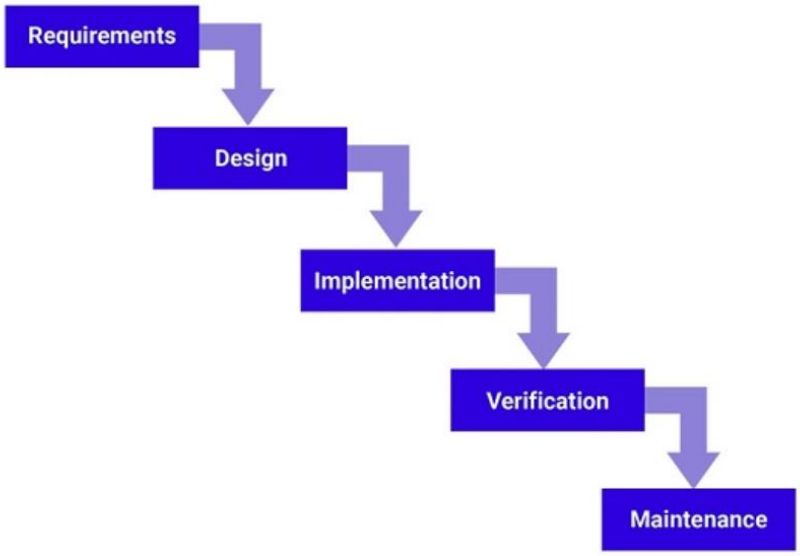


Fig. 2. Waterfall Methodology

3.4 Requirements

Hardware components used:

Raspberry pi

Fig. 3. Raspberry pi 4b

A raspberry pi is a credit card sized processing unit that is capable of doing all the tasks a normal desktop would do. For example, stream high quality videos, learn programming languages, write a word document, browsing the internet or just playing video games. Moreover, a raspberry pi can be used to interact with the world outside and is being used for many different applications ranging from weather stations to security and surveillance [31]. A raspberry pi comes in many different specs, whereas this project will be using the Raspberry pi 4 Model B. This specific raspberry pi comes with a 1.5 GHz 64-bit quad core ARM Cortex-A72 processor, 802.11ac on board WIFI module, Bluetooth, Ethernet port, 2 USB 2.0 ports, 2 USB 3.0 ports, 8 GB RAM, and a dual monitor support with the help of 2 micro-HDMI ports for up to 4K resolution.

Another common option available was the Arduino but a raspberry pi was better suitable for a task like this as it has far more memory and processing power than the Arduino [42].

- MLX90640 (Thermal Camera)

fig. 4. MLX90640 thermal camera

This camera uses a 24x32 array of infrared thermal sensors and returns 786 individual infrared temperature measurements. There are 2 versions of this camera available, but the project uses the wide angle 110x70 field of view as both the cameras provide the same results and only differ in the field of view. It is connected to the raspberry pi using the I2C module. It is similar to those costly thermal cameras except its much smaller and simpler to integrate [43].

- An LED

- A Breadboard

This is used to connect the led to the raspberry pi safely and neatly.

- A 330-ohm resistor

A resistor is used to limit the flow of current in a circuit. This will allow the led to only use sufficient amount of current without damaging the raspberry pi.

- Jumper Wires

Software Requirements:

- Raspbian OS

The Raspbian Operating System is commonly used operating system used in a raspberry pi. It's a Debian based operating system first released in July 15, 2012 and was used as the primary OS for the raspberry pi. Later in 2020, Raspbian announced a 64-bit version of the same operating system for the raspberry pi. The Raspbian OS is an operating system best optimized for the single board cpus. Moreover, this OS is compatible with all models of the raspberry pi except the Pico microcontroller. There are mainly three versions of the Raspbian operating system:

- Raspberry Pi OS Lite (32 & 64 bit)
- Raspberry Pi OS with desktop (32 & 64 bit)
- Raspberry Pi OS with desktop and recommended software (32-bit)

For this specific project, the raspberry pi was booted with the Raspberry Pi OS with desktop and recommended software (32-bit) version. The features include, user friendly interface based on LXDE similar to that of a windows or mac making it easy for user to interact with the system. Furthermore, the Raspbian uses APT for downloading or

deleting packages onto the raspberry pi. Moreover, the operating system comes with many ready to use software including beginner IDEs such as Mu Editor, Thornny Python IDE and Greenfoot.

- Platypush platform

It's an open-source module used to help automate one's house. Unlike the other home automation, platypush allows the user to install any type of plugin and use different home appliances all together in one application. It was published in 28 July, 2019 by a few developers to ease the process of home automation and over-come many drawbacks of the previous home automation options such as Alexa. Furthermore, the open-source module a light weight application that is compatible with many devices and can be executed in a Python-virtual environment, Docker container or in a virtual machine [44]. Platypush is used to interact with the thermal camera mlx90640 from the raspberry pi as the camera isn't compatible with just the raspberry pi libraries.

- TensorFlow Library

TensorFlow is a Google-developed open-source library aimed towards deep learning applications. Basically, TensorFlow is used to create machine learning models for mobile, desktop or the cloud. Furthermore, it provides the user with many benefits such as easy model building using advanced APIs such as Keras, Robust machine learning production anywhere like on a device, web and cloud with the choice of using any programming language preferred [45]. TensorFlow is used for training and deploying the trained model in our raspberry pi.

- Jupyter-notebook

Project Jupyter is an open-source application that can be used to create and share computer science projects. Furthermore, Jupyter supports more than 40 different programming languages and it also produces interactive outputs like images, HTML, videos, Latex and many more. The project will be using Jupyter-notebook as an ide for the training and deploying of the prototype as TensorFlow can be used for exploring the data and producing results [46].

- OpenCV

OpenCv is an open-source library that is used for machine learning, computer vision and image processing. It can be used to process images and videos and identify objects or patterns within those processed images. This library is used in this project for image processing to help the training process of the model.

System design

In order to construct the prototype, a series of processes need to be completed first. Once all the processes are taken care of, the prototype will be able to detect if there is a person in the view of area and act accordingly. One of the main processes is using machine learning/deep learning to train the model so it can operate without any human intervention. The camera will take a snapshot every minute and check if there is a human present, if yes it will turn on the led and wait till the human isn't detected by the camera anymore and the LED will turn off. Below are two diagrams used to describe the design of the model to further help understand the working of the prototype.

3.5 Activity Diagram

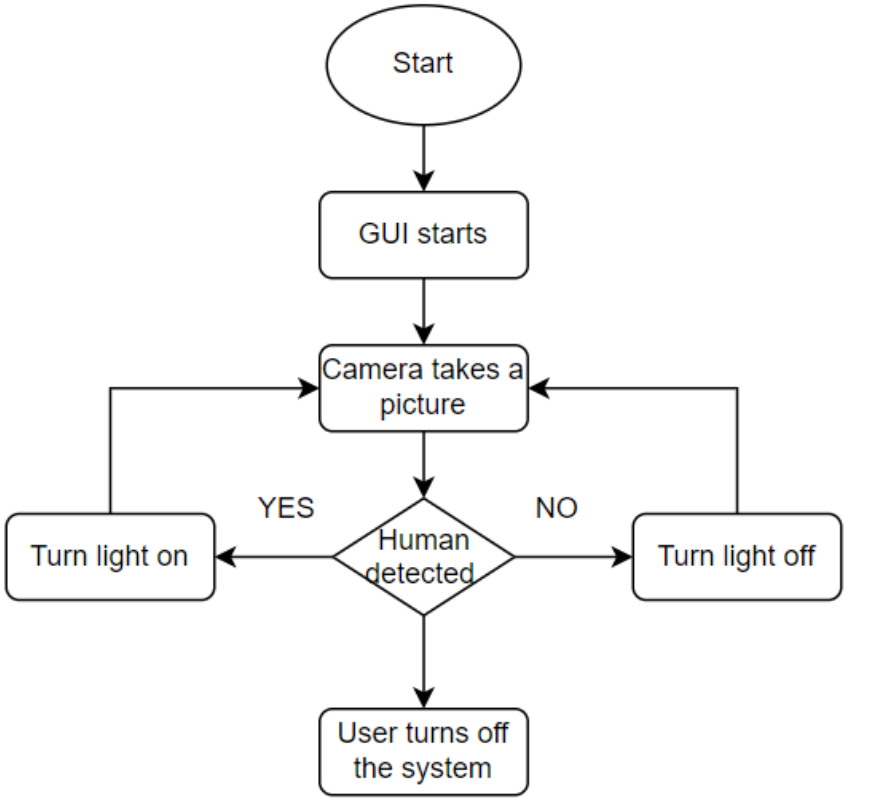


Fig. 5. Activity diagram thermal camera deduction system

The above activity diagram demonstrates a simple outline of how the prototype will function. once the user starts the program, the camera will start taking pictures with a minute interval and every picture taken is comprehended by the machine learning logic and if human is deducted the lights are turned on and if not then the lights are turned off.

3.6 Use case diagrams

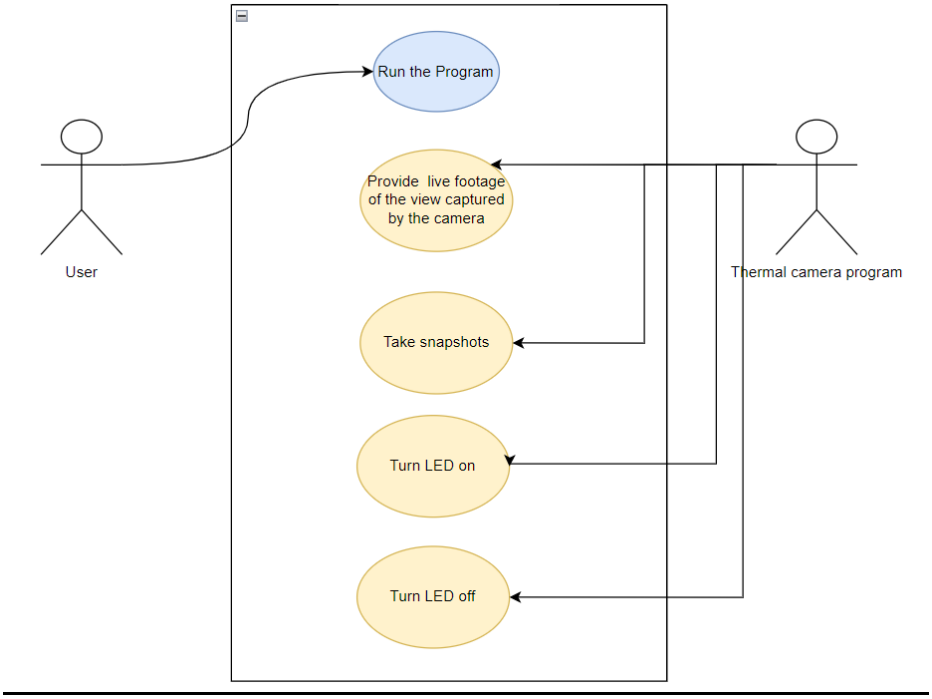


Fig. 6. Use-Case diagram for thermal camera application

The above use-case diagram displays a visual representation of the relation between the user and the thermal camera program. As shown above, there are two actors, one is the user and the other is the thermal camera program that is responsible for detecting if there is a human present in the picture captured and turn on or off the LED accordingly and also provides a live footage of the camera through the html page. Whereas, the human is responsible for running the program.

3.7 Circuit design

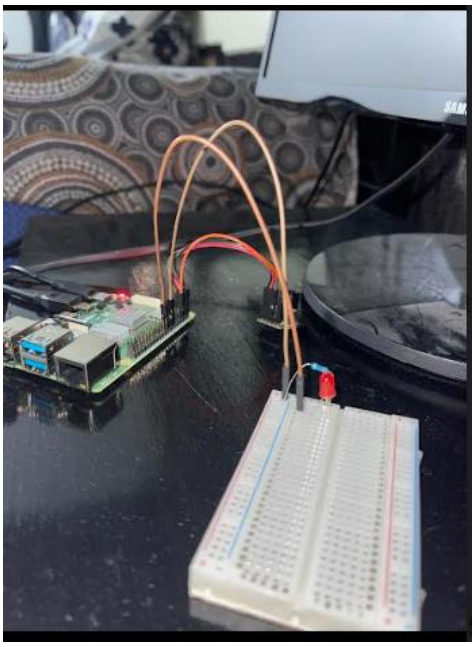


Fig. 7. Final circuit design

4.0 Implementation

In order to make the prototype, all the required processes are mapped out in an order in fig 4 below. Fig 4 provides a brief visual of all the processes needed step by step in order to complete the prototype.

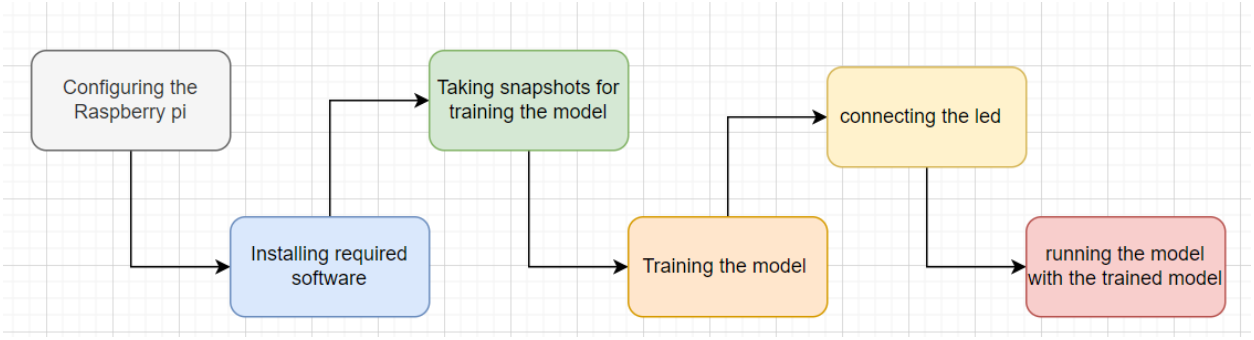
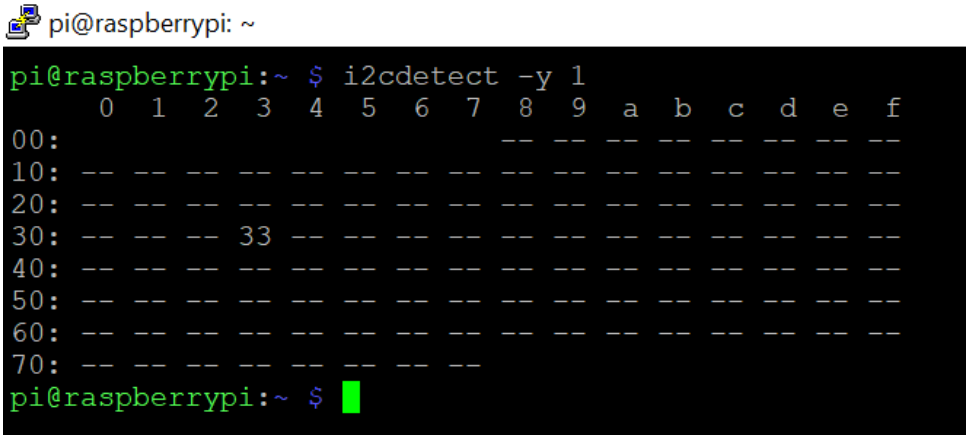


Fig. 8. Block diagram

Next, as the block diagram just tells the basic steps, this part will focus on each separate process and explain the implementation of these processes in dept.

4.1 Configuring the Raspberry pi and wiring the camera

Before anything the raspberry pi needs an OS to start functioning and, in this project, will be using the Raspbian OS 32-bit. The next step is to enable the I2C module through the **boot/config.txt**, so the thermal camera can be wired and connected to the raspberry pi. The bandwidth rate of the spi bus is set to 40000Hz to support the camera. Moving on, the camera is connected to the raspberry pi through the SCL and SDA pins number 3 and 5 and the power is connected to the pin number 2 which is the 5v power supply as shown in fig 5 below. Once the camera is wired up, the i2cdeduct function should be able to deduct the camera and show 33 in the grid as shown in the fig below.



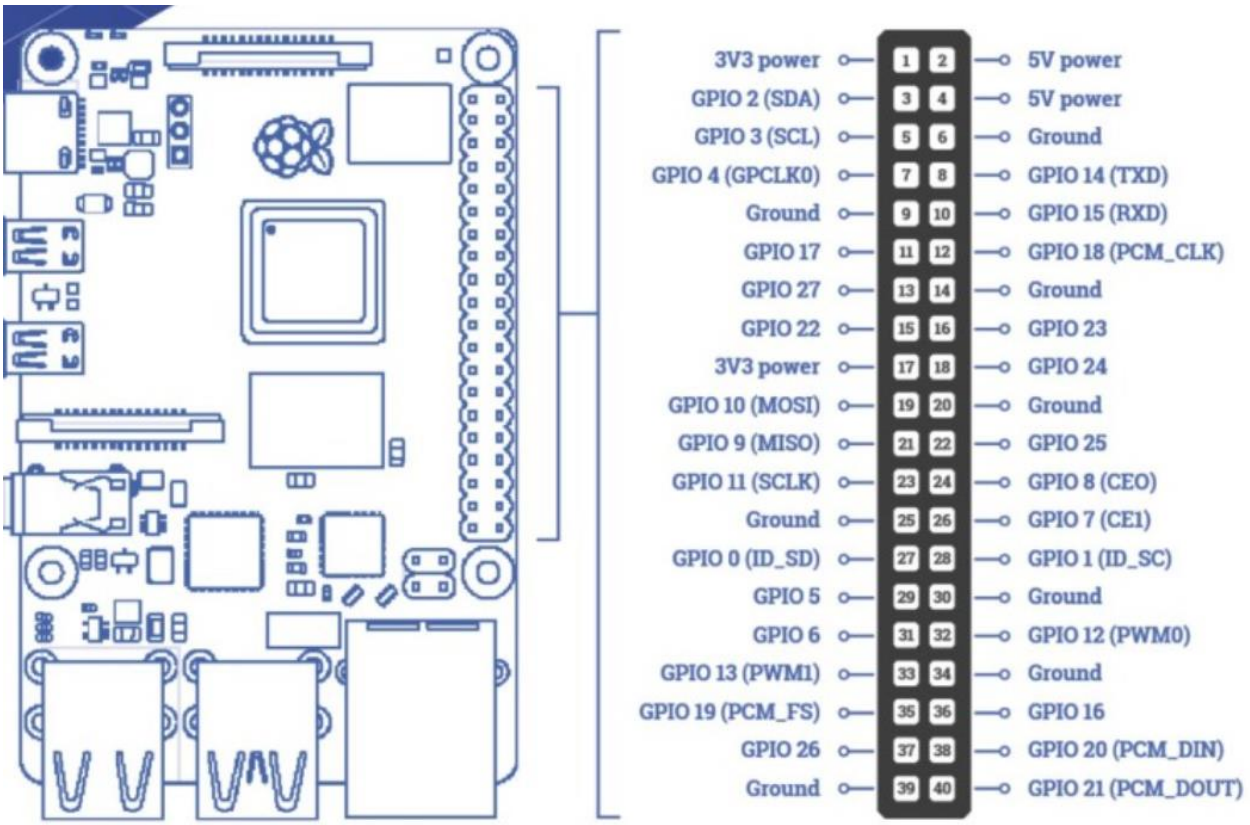


Fig. 9. Raspberry pi Pin layout

4.2 Installing required software

Once the raspberry pi is configured the next step is to install all the required software for the camera to function. The first package installed is a GitHub repository that consists of an executable file called rawrgb. This file is used to display the raw binary data captured by the camera. This is important for configuring the camera later as the mlx90640 isn't compatible with the raspberry pi yet and thus need a third-party software for it to function accordingly. Once the raw.rgb is ready, next the third-party software used in order to run the mlx90640 is the PLATYPUSH. For this to function a server is needed to display the results captured by the camera on a link, if the user wants to monitor the camera at any given time for safety. The Server used is the Redis.Server. its installed using a GitHub library. Once installed, the server should be able to listen to any requests made by the server and help connect the server to the link for surveillance. Moving forward, once the server is up and running, the PLATYPUSH can be installed

using the GitHub repository. Next a few plugins are installed which are “http, mlx90640, TensorFlow”. The http plugin is used for accepting and opening the html page for the user to interact with, the mlx90640 library is used to configure the mlx90640 camera and use its functions in order to take pictures or display results for the user to monitor and finally the TensorFlow library is used for running the trained model with the PLAYPUSH software to achieve the final product. Once that’s done, the http and mlx90640 need to be configured in the config.yaml file inside the platypush library.

Fig. 10. Config.yaml file

Fig 4 is a visual display of how the http and mlx90640 plugins are configured. The documentation of each of these plugins explain how to use them for example, The default port for the http server is 8008 and the default port for WebSockets is 8009. In this scenario the default ports are used. Next, we have the mlx90640, the fps is set to 16, the rotate is set to 270 and finally the path for the rawrgb file (The file responsible for the capturing the raw binary data captured by the camera) is specified. The default resolution is set to 32x24.

4.3 Taking Snapshots for training purposes

Once the camera is configured, the next task is to take snapshots that will be used for training the model to achieve accuracy. For the snapshots a simple python script is written as shown below.

Fig. 11. Python Script for taking snapshots

First the necessary packages are imported which are datetime and time. Then from the documantation of mlx90640 camera, the .capture function is used. This function takes the output file location for the snapshots that will be taken. The range is set to 500 pictures and a delay of 1 sec between each snapshot taken. All the pictures are taken from different angels to cover as many posobilities as possible to improve the accuracy of the model. Furthermore the grayscale is set to true as it will make the neural network much lighter and accurate because it will only rely on one variable per pixel without being decived by the RGB cobinations. Once the function is executed, every second a new image is store under the folder mentioned in the formate jpg.x(number of picture).

```
mash@raspberrypi: ~/mlx90640
mash@raspberrypi:~ $ cd mlx90640
mash@raspberrypi:~/mlx90640 $ ls
0.jpg    164.jpg                  230.jpg  295.jpg  359.jpg  422.jpg  487.jpg
100.jpg  165.jpg                  231.jpg  296.jpg  35.jpg   423.jpg  488.jpg
101.jpg  166.jpg                  232.jpg  297.jpg  360.jpg  424.jpg  489.jpg
102.jpg  167.jpg                  233.jpg  298.jpg  361.jpg  425.jpg  48.jpg
103.jpg  168.jpg                  234.jpg  299.jpg  362.jpg  426.jpg  490.jpg
104.jpg  169.jpg                  235.jpg  29.jpg   363.jpg  427.jpg  491.jpg
105.jpg  170.jpg                  236.jpg  2.jpg    364.jpg  428.jpg  492.jpg
106.jpg  171.jpg                  237.jpg  300.jpg  365.jpg  429.jpg  493.jpg
107.jpg  172.jpg                  238.jpg  301.jpg  366.jpg  42.jpg   494.jpg
108.jpg  173.jpg                  239.jpg  302.jpg  367.jpg  430.jpg  495.jpg
109.jpg  174.jpg                  23.jpg   303.jpg  368.jpg  431.jpg  496.jpg
10.jpg   175.jpg                  240.jpg  304.jpg  369.jpg  432.jpg  497.jpg
110.jpg  176.jpg                  241.jpg  305.jpg  36.jpg   433.jpg  498.jpg
111.jpg  177.jpg                  242.jpg  306.jpg  370.jpg  434.jpg  499.jpg
112.jpg  178.jpg                  243.jpg  307.jpg  371.jpg  435.jpg  49.jpg
113.jpg  179.jpg                  244.jpg  308.jpg  372.jpg  436.jpg  4.jpg
114.jpg  180.jpg                  245.jpg  309.jpg  373.jpg  437.jpg  50.jpg
115.jpg  181.jpg                  246.jpg  30.jpg   374.jpg  438.jpg  51.jpg
116.jpg  182.jpg                  247.jpg  310.jpg  375.jpg  439.jpg  52.jpg
117.jpg  183.jpg                  248.jpg  311.jpg  376.jpg  43.jpg   53.jpg
118.jpg  184.jpg                  249.jpg  312.jpg  377.jpg  440.jpg  54.jpg
119.jpg  185.jpg                  24.jpg   313.jpg  378.jpg  441.jpg  55.jpg
11.jpg   186.jpg                  250.jpg  314.jpg  379.jpg  442.jpg  56.jpg
120.jpg  187.jpg                  251.jpg  315.jpg  37.jpg   443.jpg  57.jpg
121.jpg  188.jpg                  252.jpg  316.jpg  380.jpg  444.jpg  58.jpg
122.jpg  189.jpg                  253.jpg  317.jpg  381.jpg  445.jpg  59.jpg
123.jpg  190.jpg                  254.jpg  318.jpg  382.jpg  446.jpg  5.jpg
124.jpg  191.jpg                  255.jpg  319.jpg  383.jpg  447.jpg  60.jpg
125.jpg  192.jpg                  256.jpg  31.jpg   384.jpg  448.jpg  61.jpg
126.jpg  193.jpg                  257.jpg  320.jpg  385.jpg  449.jpg  62.jpg
127.jpg  194.jpg                  258.jpg  321.jpg  386.jpg  44.jpg   63.jpg
128.jpg  195.jpg                  259.jpg  322.jpg  387.jpg  450.jpg  64.jpg
129.jpg  196.jpg                  25.jpg   323.jpg  388.jpg  451.jpg  65.jpg
12.jpg   197.jpg                  260.jpg  324.jpg  389.jpg  452.jpg  66.jpg
130.jpg  198.jpg                  261.jpg  325.jpg  38.jpg   453.jpg  67.jpg
131.jpg  199.jpg                  262.jpg  326.jpg  390.jpg  454.jpg  68.jpg
132.jpg  1.jpg                    263.jpg  327.jpg  391.jpg  455.jpg  69.jpg
133.jpg  200.jpg                  264.jpg  328.jpg  392.jpg  456.jpg  6.jpg
134.jpg  201.jpg                  265.jpg  329.jpg  393.jpg  457.jpg  70.jpg
135.jpg  2022-04-19_01-04-00.jpg  266.jpg  32.jpg   394.jpg  458.jpg  71.jpg
136.jpg  202.jpg                  267.jpg  330.jpg  395.jpg  459.jpg  72.jpg
137.jpg  203.jpg                  268.jpg  331.jpg  396.jpg  45.jpg   73.jpg
```

Fig. 12. Snapshots taken by camera

```
137.jpg  203.jpg                  268.jpg  331.jpg  396.jpg  45.jpg   73.jpg
138.jpg  204.jpg                  269.jpg  332.jpg  397.jpg  460.jpg  74.jpg
139.jpg  205.jpg                  26.jpg   333.jpg  398.jpg  461.jpg  75.jpg
13.jpg   206.jpg                  270.jpg  334.jpg  399.jpg  462.jpg  76.jpg
140.jpg  207.jpg                  271.jpg  335.jpg  39.jpg   463.jpg  77.jpg
141.jpg  208.jpg                  272.jpg  336.jpg  3.jpg    464.jpg  78.jpg
142.jpg  209.jpg                  273.jpg  337.jpg  400.jpg  465.jpg  79.jpg
143.jpg  20.jpg                   274.jpg  338.jpg  401.jpg  466.jpg  7.jpg
144.jpg  210.jpg                  275.jpg  339.jpg  402.jpg  467.jpg  80.jpg
145.jpg  211.jpg                  276.jpg  33.jpg   403.jpg  468.jpg  81.jpg
146.jpg  212.jpg                  277.jpg  340.jpg  404.jpg  469.jpg  82.jpg
147.jpg  213.jpg                  278.jpg  341.jpg  405.jpg  46.jpg   83.jpg
148.jpg  214.jpg                  279.jpg  342.jpg  406.jpg  470.jpg  84.jpg
149.jpg  215.jpg                  27.jpg   343.jpg  407.jpg  471.jpg  85.jpg
14.jpg   216.jpg                  280.jpg  344.jpg  408.jpg  472.jpg  86.jpg
150.jpg  217.jpg                  281.jpg  345.jpg  409.jpg  473.jpg  87.jpg
151.jpg  218.jpg                  282.jpg  346.jpg  40.jpg   474.jpg  88.jpg
152.jpg  219.jpg                  283.jpg  347.jpg  410.jpg  475.jpg  89.jpg
153.jpg  21.jpg                   284.jpg  348.jpg  411.jpg  476.jpg  8.jpg
154.jpg  220.jpg                  285.jpg  349.jpg  412.jpg  477.jpg  90.jpg
155.jpg  221.jpg                  286.jpg  34.jpg   413.jpg  478.jpg  91.jpg
156.jpg  222.jpg                  287.jpg  350.jpg  414.jpg  479.jpg  92.jpg
157.jpg  223.jpg                  288.jpg  351.jpg  415.jpg  47.jpg   93.jpg
158.jpg  224.jpg                  289.jpg  352.jpg  416.jpg  480.jpg  94.jpg
159.jpg  225.jpg                  28.jpg   353.jpg  417.jpg  481.jpg  95.jpg
15.jpg   226.jpg                  290.jpg  354.jpg  418.jpg  482.jpg  96.jpg
160.jpg  227.jpg                  291.jpg  355.jpg  419.jpg  483.jpg  97.jpg
161.jpg  228.jpg                  292.jpg  356.jpg  41.jpg   484.jpg  98.jpg
162.jpg  229.jpg                  293.jpg  357.jpg  420.jpg  485.jpg  99.jpg
163.jpg  22.jpg                   294.jpg  358.jpg  421.jpg  486.jpg  9.jpg
mash@raspberrypi:~/mlx90640 $
```

4.4 Training The model

For the training phase, a more stronger processing power is needed so the images taken by the raspberry pi are transferred to a virtual box installed in the laptop to further train the model. Before the training phase begins, the pictures taken by the camera need to be grouped into two separate folders. One folder for the negative response which is if there is no human present and the other folder for the positive response where a human is present in the frames captured.

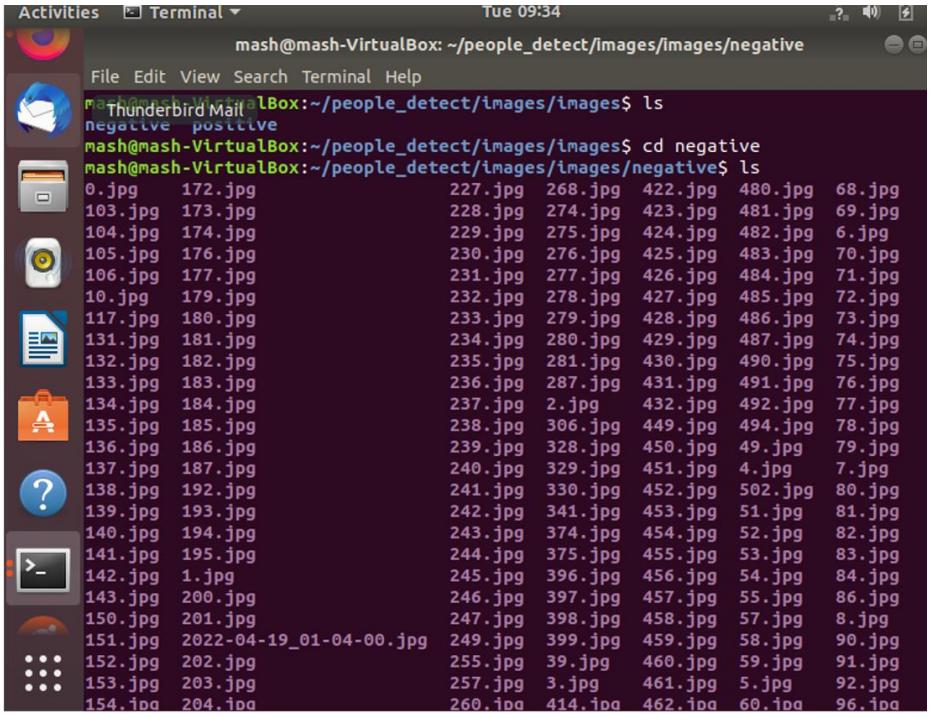


Fig. 13.1. Folder containing all the negative snapshots

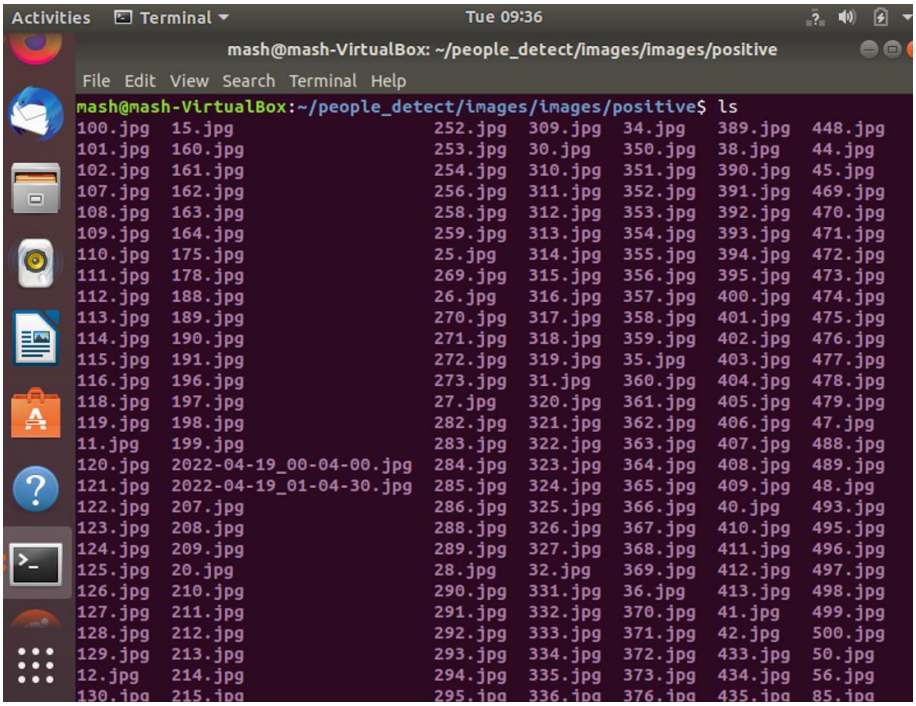


Fig. 13.2. Folder containing all the positive snapshots

Once that's done, the model is trained using jupyter notebook, tensorflow, keras, OpenCV and matplotlib libraries. The model is composed of three neuro layers, first the input image is flattened and then the three layers work together in detecting the image and producing an output.

Once the model is declared, it is trained using the model. With the 5 iterations, the model is able to produce top accuracy using the 500 images taken by the thermal camera. Finally, when the model is ready, its exported as a tensorflow model to be used by the raspberry pi for predictions.

4.5 Connecting the LED

For connecting the led, a few hardware components are used such as:

- A breadboard
- A 330 Ohm resistor
- Jumper cables
- Red LED

The resistor should always be used with a led that is connected to the raspberry pi because the raspberry pi only supplies a small amount of current which is around 60 mA and this would result in the LED wanting more supply and if allowed it might damage/burn out the raspberry pi. the resistor is used to control the flow of current keeping the raspberry pi safe. The LED is connected to the GPIO pin 24 of the raspberry pi. below is the basic setup of the led which will later be implemented to the main python script.

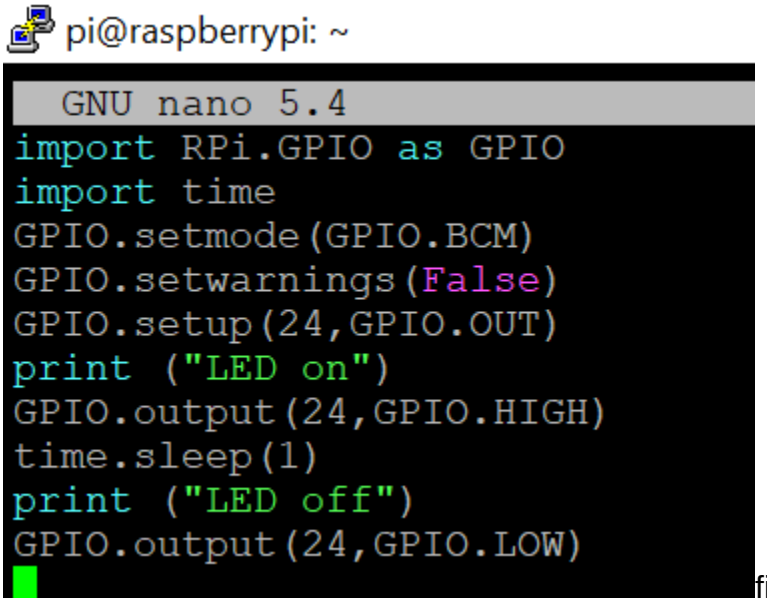


fig. 14. Basic led setup script

4.6 Running the trained model

Finally, after the exporting of the trained model and configuring the led, it's time to run the program and test it in different scenarios to confirm if the model is able to live up to the expectations. Before running the main script, the server needs to start in a different terminal to enable the http page for the user to view the live footage being captured by the camera.

5.0 Testing

The model is tested with different scenarios, such as:

- Lights turned off
- Lights turned on
- Wearing bright colors

The model is tested with all these above scenarios and it worked perfectly by turning the small led on when a human was captured by the camera and turn the led off if no human presence was captured.

6.0 Evaluation and improvement cycles

After completion of the prototype, it was tested with the scenarios above to check if it was meeting the requirements. Fortunately, the prototype was able to work accurately in all the different setups mentioned.

Lights turned on

As shown in the snapshots below, the camera is able to identify the presence of a human and turn on and off the LED accordingly. In one figure a human is present Infront of the camera thus the LED is turned on whereas in the snapshot the camera is pointed in a different direction so no human is captured resulting in the LED turning off.

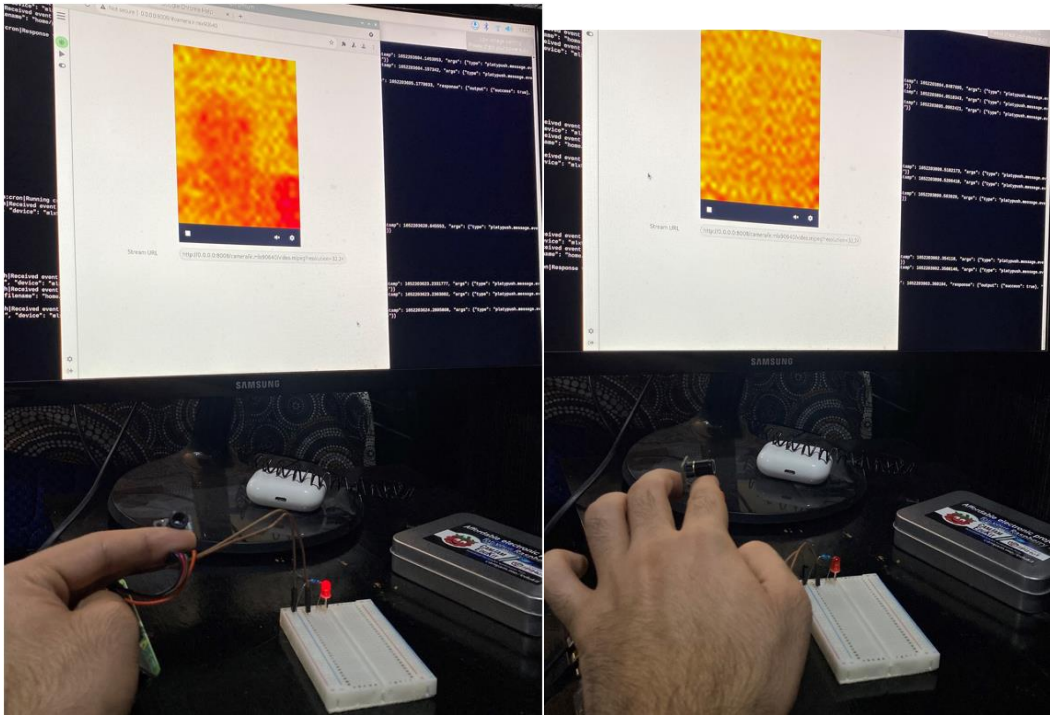


fig. 15.1. LED turned on and LED turned off with the room lights turned on

Lights turned off

In this scenario, the room lights are turned off. As shown below, the image on the left demonstrates the LED being turned off while there is no human detected by the camera and the image on the right demonstrates the LED being turned on when a human is recognized by the camera.

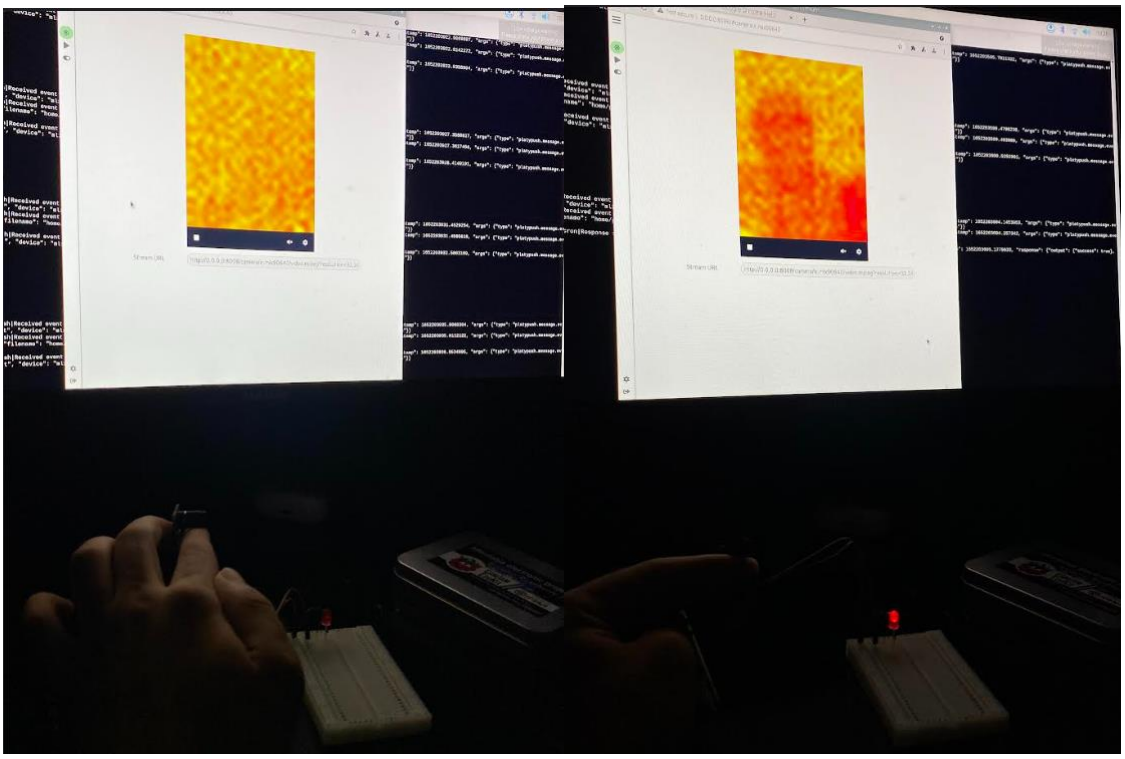


fig. 15.2. LED turned on and off with the room lights turned off

Wearing dark clothes

Finally, the user is wearing dark color cloths i.e., black, and as shown in the fig below and the camera is still able to identify me which results in the LED turning on.

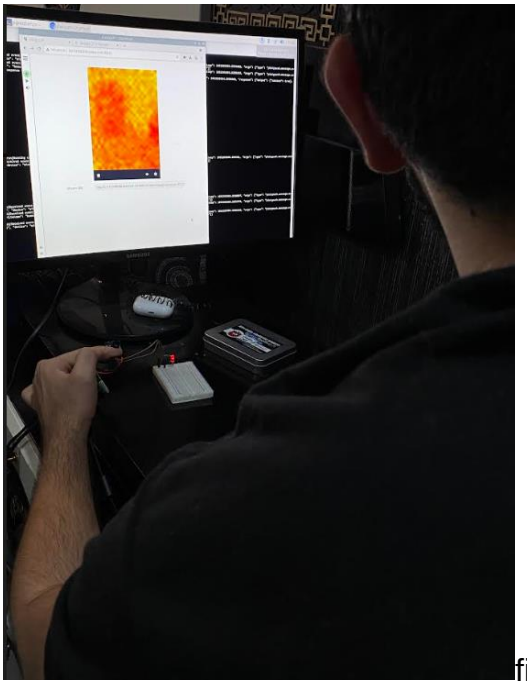


fig. 15.3. LED turned on with wearing dark clothes

Although while the building process of the prototype many obstacles were faced such as:

- Difficulty of downloading all the different packages as they all had to be compatible with each other to function without failure. The most difficult package to download on the raspberry pi was the tensorflow library as the newer versions needed python 3.6+ and the remaining packages downloaded were using python 3.6 so instead of upgrading the python version, the tensorflow version was downgraded to 1.5.0 version. And working with the older version had many

problems. Next time to avoid this issue, python 3.9 will be used with all the latest versions of the libraries being used.

- Overheating of the raspberry pi once the camera and the LED were connected at the same time. Raspberry pi is a small device and doesn't have a lot of power to provide power to two different electrical components. In the future, the same logic will be applied to an Arduino board to check if it performs any better than the raspberry pi.
- The thermal camera used which was the mlx90640 isn't compatible with the raspberry pi yet resulted in using a third-party package platypush. Downloading and understanding this package was time consuming instead next time a thermal camera that is compatible with the raspberry pi will be used.

7.0 Future advancements

The current prototype is able to recognize a human and turn on the led accordingly using machine learning. With more time given, the camera can also be used for security purposes. The same logic can be used in identifying any trespassers after a certain time and notify the owner with a text message or an email with the image and time attached. Furthermore, a more advanced thermal camera can be used that has comparatively lesser lag and better quality resulting in more accuracy for the model while functioning. Moreover, with more training, the model can also help to identify the number of people present in a room and let the owner know.

8.0 Conclusion

Concludingly, taking electricity for granted can cause huge negative impacts on the planet such has increased levels of greenhouse gases can lead to devastating natural disasters, destroying many ecosystems and putting both human and animal lives in danger. Thus, people should be more considerate and save electricity whenever and wherever it is possible. There are many ways of saving electricity as mentioned above but the most effective and universal approach would be using thermal imaging with machine learning to capture presence of human and turn on lights accordingly. With thermal imaging combined with machine learning we do not need to worry about factors such as speed of the human, TD, type or color of clothes, weather conditions and wifi connectivity proving it more efficient than the ideas proposed earlier.

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Appendices

Research Ethics Screening Form for Students

Middlesex University is concerned with protecting the rights, health, safety, dignity, and privacy of its research participants. It is also concerned with protecting the health, safety, rights, and academic freedom of its students and with safeguarding its own reputation for conducting high quality, ethical research.

This Research Ethics Screening Form will enable students to self-assess and determine whether the research requires ethical review and approval via the Middlesex Online Research Ethics (MORE) form before commencing the study. Supervisors must approve this form after consultation with students.

Student Name:	Mashal Tareen	Email: tm914@live.mdx.ac.uk
Research project title:	Thermal camera imaging using machine learning	
Programme of study/module:	Individual Project	
Supervisor Name:	Dr Xiaochun Cheng	Email: X.Cheng@mdx.ac.uk

Please answer whether your research/study involves any of the following given below:		
1. [H]ANIMALS or animal parts.	☐ Yes	☒ No
2. [M]CELL LINES (established and commercially available cells - biological research).	☐ Yes	☒ No
3. [H]CELL CULTURE (Primary: from animal/human cells- biological research).	☐ Yes	☒ No
4. [H]CLINICAL Audits or Assessments (e.g. in medical settings).	☐ Yes	☒ No
5. [X]CONFLICT of INTEREST or lack of IMPARTIALITY. If unsure see "Code of Practice for Research" (Sec 3.5) at: https://unihub.mdx.ac.uk/study/spotlights/types/research-at-middlesex/research-ethics	☐ Yes	☒ No
6. [X]DATA to be used that is not freely available (e.g. secondary data needing permission for access or use).	☐ Yes	☒ No
7. [X]DAMAGE (e.g., to precious artefacts or to the environment) or present a significant risk to society).	☐ Yes	☒ No
8. [X]EXTERNAL ORGANISATION – research carried out within an external organisation or your reseach is commissioned by a government (or government body).	☐ Yes	☒ No
9. [M]FIELDWORK (e.g biological research, ethnography studies).	☐ Yes	☒ No
10. [H]GENETICALLTY MODIFIED ORGANISMS (GMOs) (biological research).	☐ Yes	☒ No
11. [H]GENE THERAPY including DNA sequenced data (biological research).	☐ Yes	☒ No

12. [M]HUMAN PARTICIPANTS – ANONYMOUS Questionnaires (participants not identified or identifiable).	☐ Yes	☒ No
13. [X]HUMAN PARTICIPANTS – IDENTIFIABLE (participants are identified or can be identified): survey questionnaire/ INTERVIEWS / focus groups / experiments / observation studies.	☐ Yes	☒ No
14. [H]HUMAN TISSUE (e.g., human relevant material, e.g., blood, saliva, urine, breast milk, faecal material).	☐ Yes	☒ No
15. [H]ILLEGAL/HARMFUL activities research (e.g., development of technology intended to be used in an illegal/harmful context or to breach security systems, searching the internet for information on highly sensitive topics such as child and extreme pornography, terrorism, use of the DARK WEB, research harmful to national security).	☐ Yes	☒ No
16. [X]PERMISSION is required to access premises or research participants.	☐ Yes	☒ No
17. [X]PERSONAL DATA PROCESSING (Any activity with data that can directly or indirectly identify a living person). For example data gathered from interviews, databases, digital devices such as mobile phones, social media or internet platforms or apps with or without individuals'/owners' knowledge or consent, and/or could lead to individuals/owners being IDENTIFIED or SPECIAL CATEGORY DATA (GDPR[1]) or CRIMINAL OFFENCE DATA. [1]Special category data (GDPR- Art.9): "personal data revealing racial or ethnic origin, political opinions, religious or philosophical beliefs, or trade union membership, and the processing of genetic data, biometric data for the purpose of uniquely identifying a natural person, data concerning health or data concerning a natural person's sex life or sexual orientation".	☐ Yes	☒ No
18. [X]PUBLIC WORKS DOCTORATES: Evidence of permission is required for use of works/artifacts (that are protected by Intellectual Property (IP) Rights, e.g. copyright, design right) in a doctoral critical commentary when the IP in the work/artifactis jointly prepared/produced or is owned by another body	☐ Yes	☒ No
19. [H]RISK OF PHYSICAL OR PSYCHOLOGICAL HARM (e.g., TRAVEL to dangerous places in your own country or in a foreign country (see https://www.gov.uk/foreign-travel-advice), research with NGOs/humanitarian groups in conflict/dangerous zones, development of technology/agent/chemical that may be harmful to others, any other foreseeable dangerous risks).	☐ Yes	☒ No
20. [X]SECURITY CLEARANCE – required for research.	☐ Yes	☒ No
21. [X]SENSITIVE TOPICS (e.g., anything deeply personal and distressing, taboo, intrusive, stigmatising, sexual in nature, potentially dangerous, etc).	☐ Yes	☒ No

M – Minimal Risk; X – More than Minimal Risk. H – High Risk

If you have answered 'Yes' to ANY of the items in the table, your application REQUIRES ethical review and approval using the MOREform **BEFORE commencing your research**. Please apply for ethical approval using the MOREform (https://moreform.mdx.ac.uk/). Consult your supervisor for guidance. Also see *Middlesex Online Research Ethics (*MyLearning area*) and* *www.tiny.cc/mdx-ethics* (CS students).

If you have answered 'No' to ALL of the items in the table, your application is Low Risk and you may NOT require ethical review and approval using the MOREform before commencing your research. Your research supervisor will confirm this below.

Student Signature: **MK** Date: 22/10/2021

To be completed by the supervisor:

Based on the details provided in the self-assesment form, I confirm that:	Insert Y or N
The study is Low Risk and *does not require* ethical review & approval using the MOREform	
The study *requires* ethical review and approval using the MOREform.	

Superivsor Signature:……..…….. Date:……