PROJECT PROPOSAL

COURSEWORK 1

Designing And Evaluating The Deployment Of A Mosquito Zapper Robot

Author
Silvia Aminul

Tutor
Dr. Tao Geng

M00702000

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1 Introduction

The reliance on technology surges as the population of mosquitoes increase, this is becoming a growing public health concern as mosquitoes are known to carry a vast amount of diseases and rapidly transmit amongst humans and animals leading to severe illnesses and millions of deaths every year. Mosquitoes who are carrier of diseases are life threatening to those who are immunocompromised or have weakened immune systems.

As the populations of mosquitoes increase so do the bites, their biotic interactions can especially imbalance the ecosystem as they play a major role on other species, from a holistic perspective their invasive nature can lead to drastic consequences on the environment, native species, and potentially human activities.

This project proposal aims to deliver an extensive overview on the execution of a robotic device that can eliminate high-powered mosquitoes through a laser beam upon detection using a high-resolution camera.

2 Concept Behaviour

The Robot designed for this proposal will be able to do the with the following:

- To locate a mosquito without any external interventions (ex. human) this can be done through the aid of a advanced algorithms and sensors that finds the best way to kill them.
- An imaging system can be placed above the robot to visualise its surrounding and identify mosquitoes through object recognition.
- Advanced sensors that can detect the presence of mosquitoes by their size, shape, movement, or other characteristics
- sensors to stop robot from crashing into object and preventing external damages for example stopping if an object or human is in the way
- Motors to allow the robot to move around in search of mosquitoes.
- A laser that can eliminate mosquitoes.
- to allow the camera face any direction a motor will be installed.
- to allow the laser point in any direction a motor will be installed.
- a source of power to help
- A battery will be required as the power source in order to operate the robot for a long period of time.
- For the robot to operate autonomously a control system is required whereby human input is not required.
- to gradually improve the robots performance a machine learning algorithm will be implemented

3 Background Research

In this section will review that robots in the market that are similar in concept. This section will also include examining the different approaches taken to build a mosquito zapper in research papers.

3.1 LeiShen's Mosquito Zapper

This robot has been referred to as a toy-sized autonomous mosquito zapper, designed by a company named LeiShen. Although there is not much information on this whether this robot has actually been deployed or what kind of components it uses, this robot is similar to the project's aim.

3.2 Autonomous Roomba

Although a robot vacuum is different from a mosquito zapper the concept is similar. This mosquito zapper should be able to roam around room autonomously just like the vacuum and avoid obstacles or have a hard encasing to control damage on the hardware. It

4 Challenges

4.1 OpenCV

In one similar experiment, found that using OpenCV solely to using a tracker function to track the movement of a mosquito in different methods did not give the greatest results.

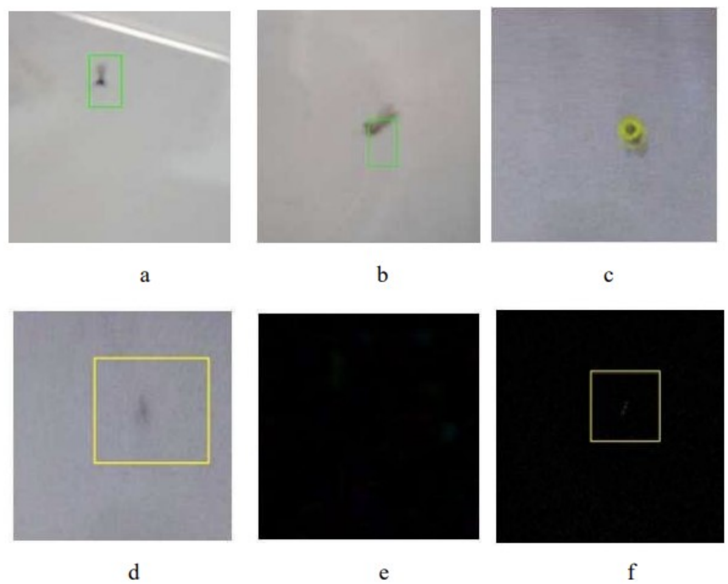
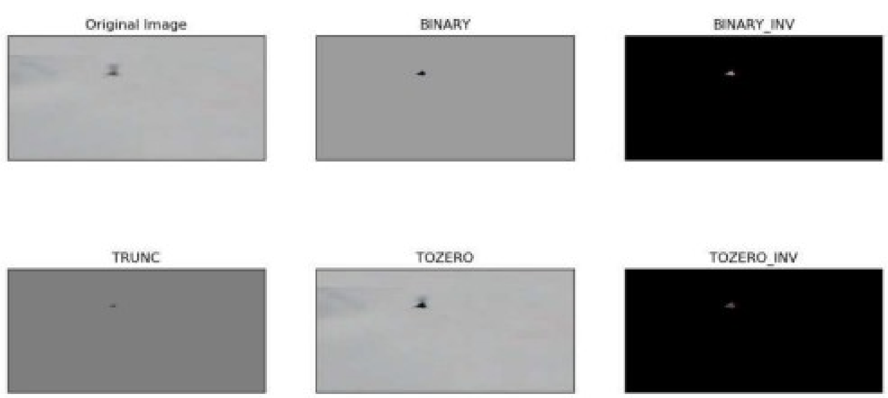


Fig.1. Using OpenCV for mosquitoes tracking: a – tracking mosquito with function cv2.TrackerCSRT_create (), b – Hara cascade, c – color tracking, d – color tracking without success, e – optical flow, f – frame difference

As seen in the figure above the mosquito in one of the methods cannot be detected at all, however by using an image processing function called Thresholding ON A 2-4mm sized mosquitoes gave drastically different results:[1]



4.2 Design

5 Hardware structure

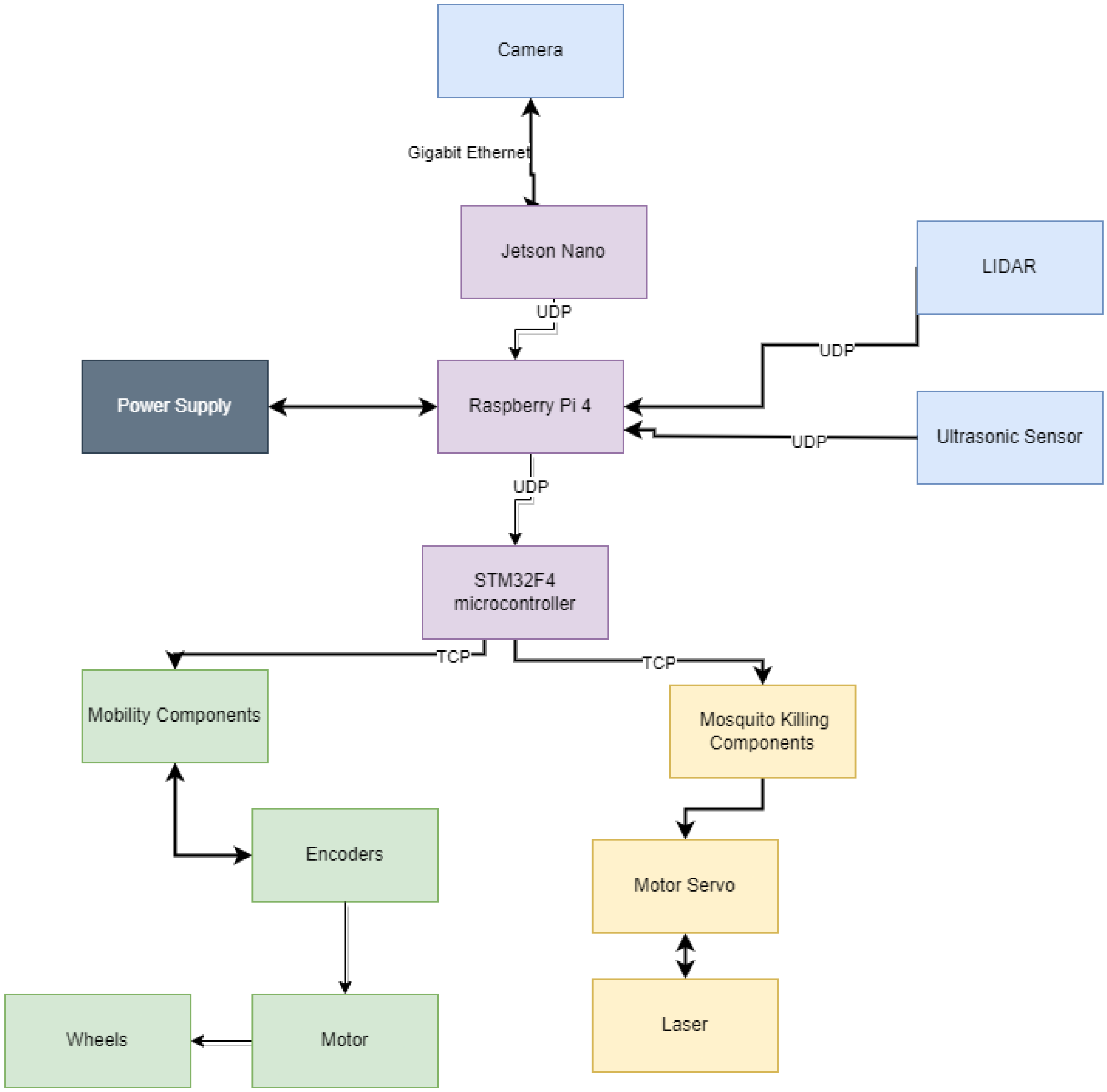


Figure 1: An autonomous mosquito zapper robot roaming

Components requiring to carry out high level task have either User Datagram Protocol (UDP) connection or Gigabit Ethernet, this is to minimise the risk of loosing importance of data due to the speed, if the perception component which is the initialising component fails to deliver the right data on time it makes the robot ineffective at detecting the mosquito hence unable to annihilating mosquitoes, however UDP allows missing packets given this is not a viable option when detection small moving mosquitoes the better option for the camera is Gigabit Ethernet. TCP on the other hand is slightly lenient as although it is a slower method of sending data it is guaranteed that the data will be received, this form of connection has been used towards the lower level tasks such a movement and eliminating mosquitoes.

In this project single boards will be used to control components. Jetson Nano can be used for the vision component (Camera), this single board has be chosen as its overall performance is better than most other computers, this is especially important if high resolution and excellent detection performance is required. The connection between the components was decided based on efficiency and requirement, Gigabit Ethernet has been used for two reasons, one of them being less latency. Reduced latency rates range from 5 to 20 ms and can stream a 4K content at a higher frame rate.

	Jetson Nano	Raspberry Pi 3A+
GPU	128-core NVIDIA Maxwell	Broadcom VideoCore IV
CPU	1.4 GHz 64-bit Quad-Core ARM Cortex-A57 MP-Core	1.4 GHz 64-bit quad-core ARM Cortex-A53
RAM	4GB LPDDR4	512MB LPDDR2 SDRAM
Video Output:	HDMI, Display-Port (4K)	HDMI, Display Serial Interface (DSI)
Camera Serial Interface (CSI)	Yes	Yes
Price (CSI)	£154.50	£54.99

For the central computer, Raspberry Pi 4 will be used as an affordable option as although its purpose is to carry out high level planning it does not require to use a lot of resources to carry out tasks.

Lastly the microcontroller, the series STM32F4, provides a range in terms of needs, it can provide sufficient memory to have excellent performance in terms of motion control.The STM32F407/417 product lines provide from 512 Kbytes to 1 MByte of Flash, 192 Kbytes of SRAM, and from 100 to 176 pins in packages as small as 10 x 10 mm. It's good performance, power efficiency and rich connectivity is the reason for choosing this microcontroller.

5.1 Simultaneous localization and mapping

There are three steps in making a model functioning when implementing Simultaneous localization and mapping (SLAM) :

- Perception - To achieve a model of the environment in which the robot will navigate in sensory components such as Lidar can be used, to do detect the mosquito a camera can be used with openCV. An ultrasonic sensor will be used in the case that the Lidar fails, this type of sensor is deemed useful if the object's vicinity is close.
- Planning - consist planning how the autonomous interaction between the computers are going to take place without human interaction, to achieve this a high level central computer is going to be used to do high level planning and receive interfaces from the implementation of perception (Lidar and Camera).
- Action - Low level controllers is going to be used to control the encoders to move around the mapped environment and change the angle as well as direction of the laser.

5.2 Key Hardware Components

- A high resolution camera is required to detect the size of a mosquito averaging the size of 2 to 4 mm, to configure this camera it must be ensured that the view from where the camera is placed is clear and allows a wide view of the field where mosquitoes are most likely to be. The preferred frame rate per second should be 60, meaning the roughly one image per every 16 ms should be coming through. Given only one computer is invested to solely receive data from the camera to process the image, a fast and high quality computer such as the Jetson Nano Computer should be fast enough to process the frames.
- A laser strong enough to neutralise a mosquito however weak enough to not harm the human eye is required to make this robot safer, to configure the laser according the camera's coordinates the laser can be attached to a Servo motor before it is fixed on the robot.
- A motor servo would be controlled though the microcontroller (STM32F4) which receives information from the main control system (Raspberry Pi 4),using the location and movement provided by the Jetson Nano.To make the laser move according to the camera, a servo can be used or in a scaled up project robotic arm to aim the laser. In this case the servo motor can be controlled by the robot's control system, using the location and movement information of the detected mosquitoes provided by the camera and image processing algorithms.

5.3 Steps in Connecting the Hardware

The camera and sensors (Ultrasonic sensor for obstacle avoidance) can be connected to the control system with the right cables, upon receiving a location and movement information input the control system can use the data to adjust the robots movement and adjust the laser's aim.

When executing this project a decision must be made on what type component should be used to reposition the laser's aim when a mosquito is detected. One can use a servo motor or a robotic arm, in this project the proposed component is a servo motor.

The laser connected to the servo motor or robotic arm should then be connected to the control system with the right cables, the purpose of the laser is aim and kill mosquitoes detected from a calculated direction from the coordinates received from the camera.

To ensure the system is working the circuit should be tested at this point and make further adjustments. One adjustment required will be the calculation of the laser's's aim when pointing at the mosquito, this is going to be dependant on the robot's design in terms of size and distance from the camera. To detect mosquitoes the camera is going to use image processing function, given the placement of the laser and the camera on the chassis is going to be different from each other, the camera's coordinates on the detected mosquitoes is not going to allow the laser to aim correctly, therefore an angle direction will be need to be adjusted in the servo motor to point the laser correctly.

To calculate this, the angle at which the servo motor needs to move the laser is required. This can be done using basic trigonometry, by calculating the angles formed by the lines connecting the center of the camera's field of view, the location of the detected mosquito, and the servo motor axis.

Alternatively, if the robot uses a robotic arm to aim the laser, the location of the detected mosquito in three-dimensional space can be used to calculate the position and orientation of the end effector (the part of the robotic arm that holds the laser) that is required to point the laser at the mosquito. This can be done using inverse kinematics algorithms, which calculate the joint angles of the robotic arm that are necessary to achieve a desired end effector position and orientation.

6 Software

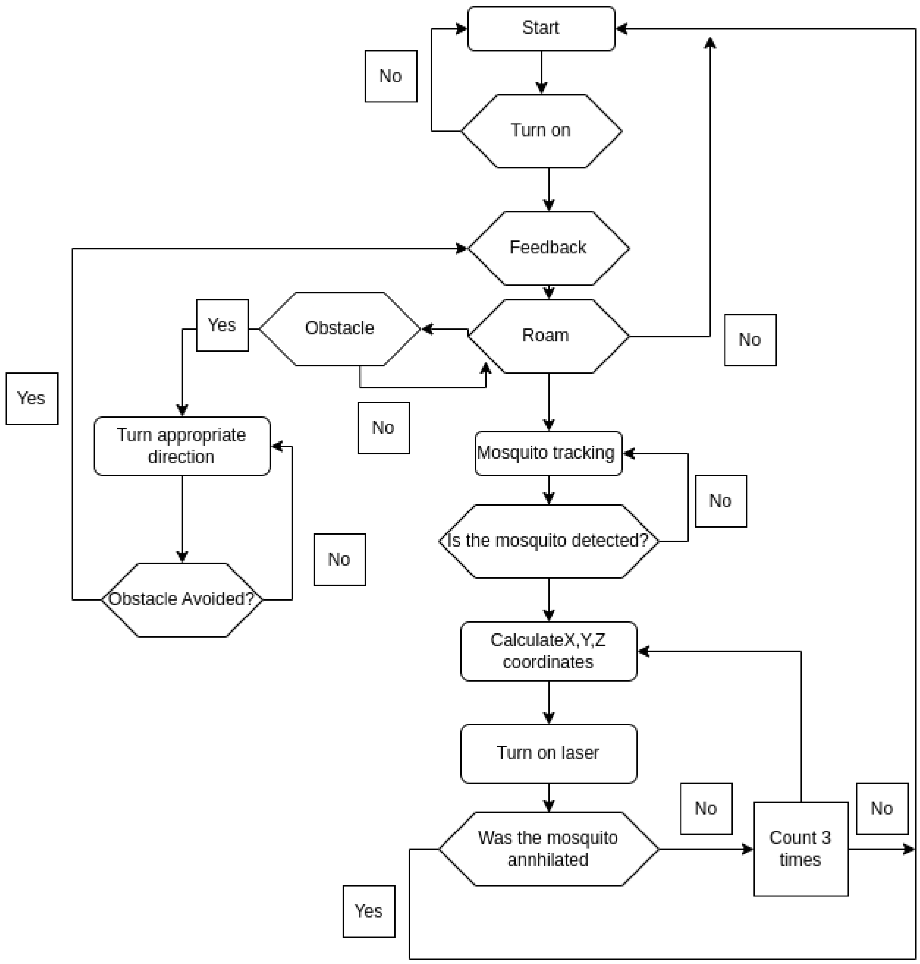


Figure 2: A flowchart

Use image processing algorithms to automatically detect and track mosquitoes in the camera's field of view. This can be done using techniques such as thresholding, edge detection, and object recognition algorithms.

Use the detected mosquitoes to identify their location and movement direction, and use this information to control the robot's movements and aim the laser.

Fire the laser at the detected mosquitoes, using the robot's aiming mechanism, to kill them on contact.

To make the laser move according to the camera, a servo can be used or in a scaled up project robotic arm to aim the laser. In this case the servo motor can be controlled by the robot's control system, using the location and movement information of the detected mosquitoes provided by the camera and image processing algorithms.

For example, the control system can use the location of the detected mosquitoes to calculate the necessary angle and direction for the servo motor or robotic arm to move the laser. This information can then be sent to the servo motor or robotic arm, which will move the laser to the desired position.

Alternatively, a fixed laser and position the camera and servo motor or robotic arm in such a way that the laser is always aimed at the center of the camera's field of view. In this case, the control system can use the movement of the detected mosquitoes to adjust the pan and tilt angles of the camera and servo motor or robotic arm, to keep the laser pointed at the mosquitoes as they move.

Overall, the key to making the laser move according to the camera is to use a control system that can process the location and movement information of the detected mosquitoes, and use this information to control the servo motor or robotic arm that aims the laser.

7 Component List

High-resolution cameras or a specialized sensor that can detect the presence of mosquitoes. A camera with a high frame rate and good resolution can be used to capture images of mosquitoes and identify them based on their shape and size. This can be combined with image processing algorithms to automatically detect and track mosquitoes in real-time.

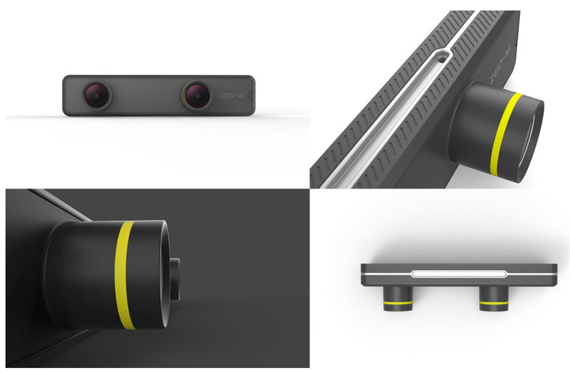


Figure 3: High-resolution camera: A Stereo Camera such as the Zed Mini can be used to detect and track mosquitoes in the robot's field of view.

Servo motor or robotic arm: A servo motor, such as the Tower Pro SG90 or the DYNAMIXEL AX-12A, can be used to aim the laser at the detected mosquitoes.

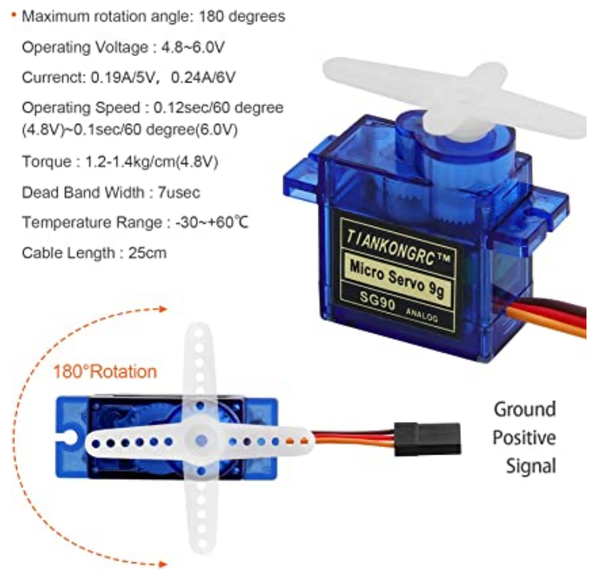


Figure 4: SG90 9g Micro Servos for RC Robot Helicopter Airplane Controls Car Boat

Laser: A laser, such as the 445nm Blue Laser Module or the 532nm Green Laser Module, can be used to kill the detected mosquitoes on contact. A laser, or other high-intensity light source, that is capable of killing mosquitoes on contact.

Figure 5: High Power 445nm Focusing Blue Laser Module Laser Engraving

Control system: A control system, such as a Raspberry Pi 4, can be used to process the input from the camera and other sensors, and control the servo motor or robotic arm and the laser. A control system, such as a microcontroller or a computer, to process the input from the mosquito detection system and control the laser firing mechanism.

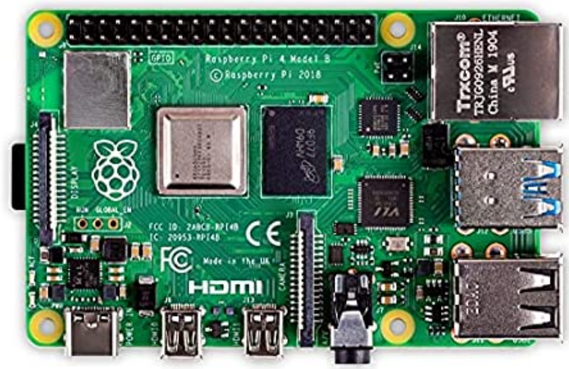


Figure 6: Raspberry Pi 4 Model B 8GB

The decision of using following computers have been explained in the hardware section.

Figure 7: Jetson Nano Developer Kit

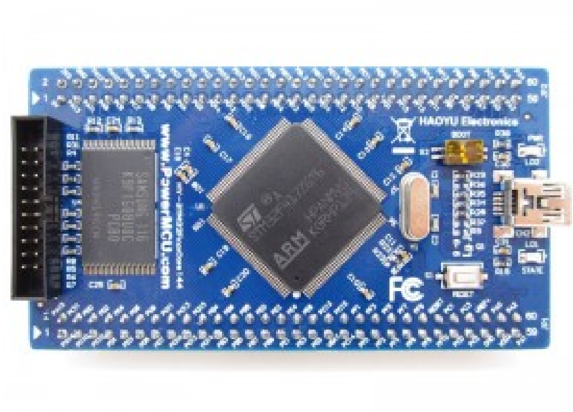


Figure 8: ST STM32F407/417

Power supply: A power supply, such as a battery or a plug-in power supply, can be used to provide the necessary electrical energy for the circuit. A power source, such as a battery or a plug-in power supply, to provide the necessary energy for the laser and the other components.

A housing or chassis to hold and protect the other components, and provide a way for the robot to move around and access areas where mosquitoes may be present.

In addition to these core components, additional hardware and software components, such as sensors will be required for navigation and obstacle avoidance (SLAM), and software for image processing and control algorithms.

8 Safety Protocol

To ensure that your mosquito-detecting robot circuit is connected safely, the following steps can be followed:

Use appropriate wiring and connectors for the circuit. This will ensure that the connections are secure and able to withstand the current and voltage levels in the circuit.

Use fuses or circuit breakers to protect the circuit from excessive current. This will prevent damage and potential hazards if there is a short circuit or other electrical malfunction in the circuit.

Use appropriate power supplies and voltage regulators to ensure that the voltage applied to the circuit is within the rated voltages of the components. This will prevent damage and ensure that the components are operating at their optimal levels.

Use appropriate heat sinks and other cooling measures to prevent overheating of the components in the circuit. This will ensure that the components are able to dissipate heat effectively and operate within their safe temperature limits.

Test the circuit before using it, to ensure that it is functioning properly and safely. This can be done using a multimeter or other test equipment to measure the current, voltage, and resistance in the circuit, and verify that the values are within the safe limits for the components.

Overall, by following these steps and using appropriate wiring, connectors, and protective measures, to ensure that the mosquito-detecting robot circuit is connected safely and functions properly.

9 Further Development

There are several sensors that can be used to detect mosquitoes, depending on the specific requirements of your robot. Some possible options include:

Developing more advanced algorithms for mosquito detection and tracking. This could involve using machine learning algorithms to improve the accuracy and efficiency of the detection and tracking process, and enable the robot to adapt to different types of mosquitoes and environments.

Enhancing the robot's ability to navigate and avoid obstacles. This could involve using additional sensors, such as lidar or ultrasonic sensors, to enable the robot to map its surroundings and avoid collisions with objects and people.

Improving the robot's power efficiency and battery life. This could involve using more efficient components and algorithms, and implementing power management strategies, to enable the robot to operate for longer periods without needing to be recharged.

Expanding the robot's capabilities to include other functions, such as insecticide application or air quality monitoring. This could involve adding additional sensors and mechanisms to the robot, and developing new algorithms and control systems to support these additional functions.

Acoustic sensors: Mosquitoes make distinctive buzzing sounds when they fly, which can be detected using microphones or other acoustic sensors. This type of sensor can be used to detect the presence of mosquitoes, but may not be able to provide precise location information.

Heat sensors: Mosquitoes are attracted to the heat and carbon dioxide produced by warm-blooded animals, including humans. A heat sensor, such as a thermal imaging camera, can be used to detect the presence of mosquitoes by detecting their heat signature.

Chemical sensors: Mosquitoes are attracted to certain chemicals, such as lactic acid and other human perspiration compounds. A chemical sensor, such as a gas chromatograph, can be used to detect the presence of these chemicals and infer the presence of mosquitoes in the area.

10 Conclusion

To conclude this proposal many things have been considered, this robot may become a project that is scalable and put and end to the millions of death.

11 References

[1] Ildar Rakhmatulin. Raspberry pi for kill mosquitoes by laser. *Available at SSRN 3772579*, 2021.