ECE 445

SENIOR DESIGN LABORATORY

PROPOSAL

Actions to Mosquitoes

Team #4

XIANGMEI CHEN (xc47@illinois.edu)
PEIQI CAI (peiqic3@illinois.edu)
YANG DAI (yangdai2@illinois.edu)
LUMENG XU (lumengx2@illinois.edu)

Sponsor: Said Mikki

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1 Introduction

1.1 Problem

Mosquitoes are a significant nuisance in human life, known for their irritating bites that can cause itching and discomfort. Beyond the annoyance, they are also vectors for transmitting deadly diseases, posing serious health risks to humans worldwide. Thus, how to deal with mosquitoes in our daily life and limit the harm of them to the smallest, has always been a significant problem for us.

However, due to the agility of the moving of mosquitoes, it is not easy for human to beat them accurately. The existing mosquito repellent equipment on the market, such as mosquito repellent incense and electric mosquito swatting, not only the mosquito killing effect is not ideal, but also it is likely to produce harmful chemical substances and even cause accidental injury to human beings. So, we came up with an equipment to catch mosquitoes by moving around and sucking them as soon as it discovers them.

1.2 Solution

We intend to design our project by four subsystems: a detection subsystem, a localization subsystem, an attack subsystem, and a power and control subsystem. The detection subsystem serves as the trigger, using audio cues to activate the machine when mosquitoes are present. The localization subsystem employs a 360° high resolution camera to locate the mosquito and provides real time location data to the attack subsystem, which then mobilizes to capture or eliminate the mosquitoes using a powerful suction device and CO_2 , heat, and motion based lures. The power and control subsystem is strategically divided to supply continuous energy to the detection subsystem and activated power to the localization and attack subsystems, optimizing energy usage, and ensuring sustained operations.

Our design can be implemented equipped with some subsystem requirements. Firstly, the detection subsystem requires high sensitivity and accuracy, with a minimum detection accuracy of 95% and a false positive rate below 5%. Secondly, the localization subsystem demands a 360° high resolution camera capable of identifying mosquitoes with at least 90% accuracy and providing real time data to the attack subsystem, which must possess precision mobility and an effective attractant mechanism for mosquito capture. What's more, the power and control subsystem is tasked with stable and efficient power delivery, featuring voltage regulation, surge protection, and a fail safe mechanism to ensure the seamless operation of the machine. Collectively, these subsystems form a comprehensive solution for mosquito detection, tracking, and elimination, emphasizing efficiency, accuracy, and safety.

1.3 Visual Aid

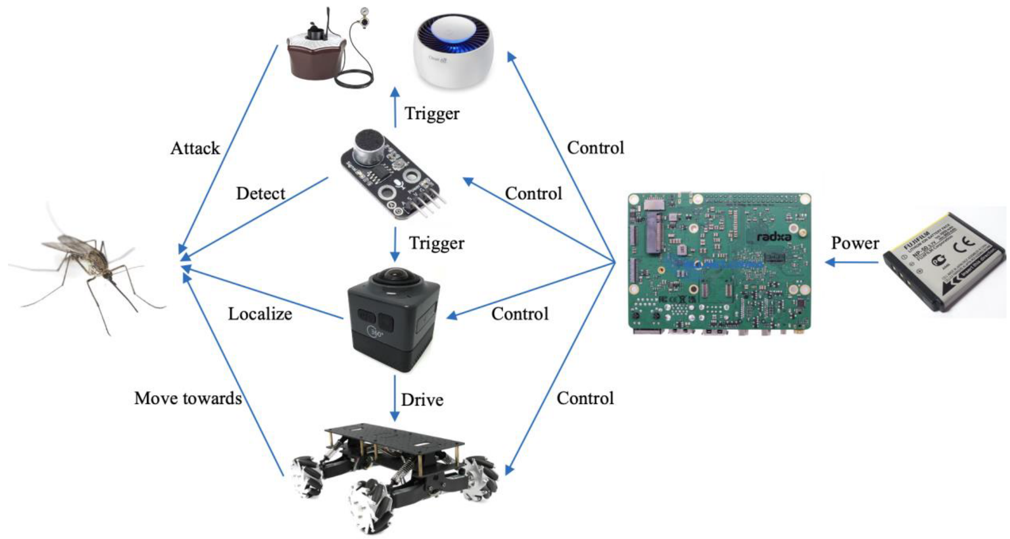

Figure 1: Visual Aid.

1.4 High-Level Requirement List

1. The microphone in the detection subsystem must be sensitive and efficient to mosquitoes' noise, which means it should trigger the machine only if there is noise caused by mosquitoes in its working area, and it should distinguish the noise of mosquitoes from other noises.

2. It is significant for the 360° camera to determine the approximate distance from the machine to the mosquito once it catches mosquito in its vision, so that the machine can adjust its moving direction according to the action of mosquitoes.

3. We design the attack subsystem only for mosquitoes, it should simulate human body's feature to attract them, as well as only sucking mosquitoes into itself to make sure the attack is accurate.

2 Design

2.1 Block Diagram

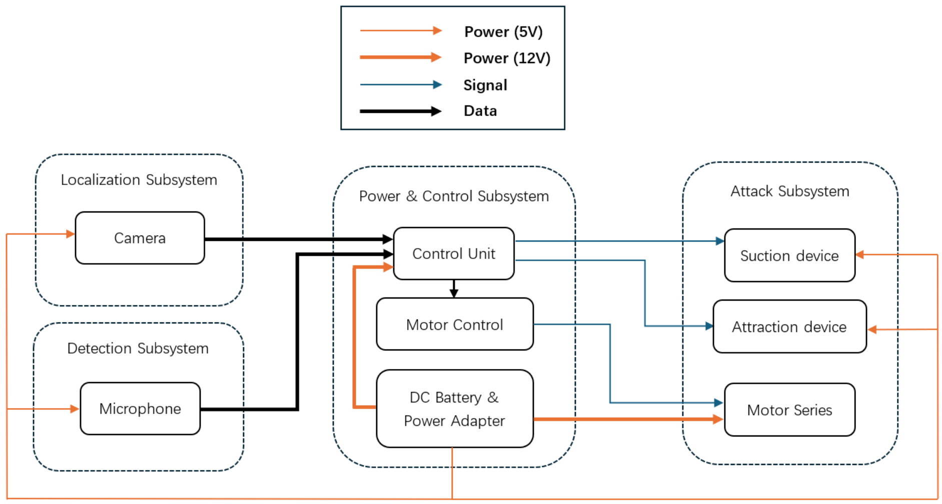

Figure 2: The block diagram.

2.2 Block Descriptions

This mosquito eradication machine is designed to detect, locate, attack, and eliminate mosquitoes autonomously. It comprises four main subsystems, each playing a crucial role in the machine's operation and interacting seamlessly with one another to achieve the goal of mosquito eradication.

2.2.1 Detection Subsystem

Description:

This subsystem, ensuring continuous surveillance, is equipped with an acoustic sensor array that captures sound waves and processes them to determine if mosquito activity is detected. The acoustic sensor is capable of distinguishing the unique wingbeat frequency of mosquitoes, which is typically between 300 to 600 Hz for most species [1]. Upon detecting a mosquito's presence, this subsystem initiate the machine's response cycle. This ensures energy efficiency by only activating the more power intensive components when necessary.

Requirement:

1. An acoustic sensor is required, capable of accurately distinguishing mosquito wingbeats from background noises.

2. The sensor must have a sensitivity range that accurately captures the frequency of mosquito wingbeats, ensuring a minimum detection accuracy of 95% within a range of at least 5 meters for extensive coverage.

3. Upon positively identifying a mosquito's presence, the sensor should activate other subsystems.

4. The false–positive rate should be kept below 5% to minimize unnecessary activations.

5. The entire subsystem must operate continuously.

6. Power consumption should not exceed 100mA at a supply voltage of 5V ± 0.1V, ensuring efficient and effective mosquito detection and subsequent elimination.

2.2.2 Localization Subsystem

Description:

It comprises a 360° high resolution camera and essential computational components to analyze captured images for mosquito presence. This subsystem integrates advanced image processing algorithms to analyze the captured images. The camera's high resolution ensures that even small targets like mosquitoes can be clearly detected. These images are then processed to identify the mosquito's presence, with subsequent adjustments made to track the mosquito's movements accurately.

We will adopt the existing YOLOv8 model for real-time coordinate detection and recognition of mosquitoes [2]. The dataset comes from public datasets online, and we will fine-tune it with data collected by ourselves. The subsystem also gauges the mosquito's altitude, adjusting the attack subsystem's height to align with the mosquito's vertical position. This subsystem's feedback loop with the attack subsystem allows for dynamic adjustment of the machine's position and orientation, optimizing the capture process.

This subsystem is integral for providing precise coordinates and ensuring the attack mechanism can engage the target effectively.

Requirement:

1. It requires a 360° high resolution camera with a minimum resolution of 4K (4096x2160 pixels) for clear mosquito imagery.

2. The camera should maintain a low distortion rate (under 1%) and have a wide dynamic range to adapt to different lighting conditions.

3. The subsystem must feature an image processing algorithm that identifies mosquitoes in images with at least 90% accuracy.

4. The algorithm should pinpoint the mosquito's position with a margin of error no greater than 2 cm.

5. The camera must interface with the attack Subsystem, facilitating real time data transmission at a rate of at least 30 frames per second (FPS).

2.2.3 Attack Subsystem

Description:

The attack subsystem, activated upon confirmation by the detection subsystem, is designed for efficient mosquito elimination. It comprises a mobile platform with wheels or tracks that navigates towards the mosquito's location, guided by the localization subsystem. Equipped with a powerful suction device resembling a fan, the subsystem traps or kills the mosquito. An attractant mechanism, utilizing a CO_2 emitter and heat source to mimic human breath and body temperature, lures mosquitoes closer. Extendable mechanics ensure proper height adjustment based on the localization subsystem's inputs, centering the mosquito before activation. The dynamic mobility of this subsystem facilitates effective mosquito capture or elimination.

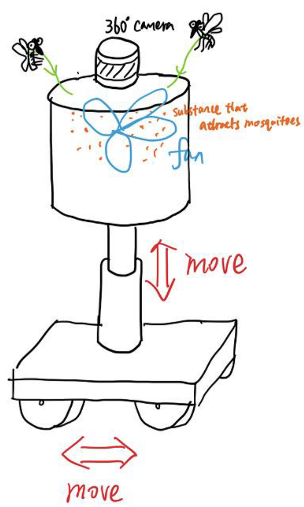

Figure 3: Design Sketch of the Attack System.

Requirement:

1. It requires a mobile platform with 1cm precision movement towards the mosquito's detected location.

2. The subsystem includes a rotation module with at least two degrees of freedom for 360° horizontal and at least 90° vertical movement, facilitating effective mosquito tracking.

3. The rotation module's minimum speed should be calibrated using formula:

$$\omega_{min} \leq \frac{FPS \times W_{target}}{D_{best}}$$

4. The subsystem must have a powerful suction device capable of capturing mosquitoes from a minimum distance of 10cm, without harming humans or pets.

5. The suction device should have a flow rate sufficient to draw mosquitoes into a containment unit and operate at a noise level below 50 decibels.

6. An attraction device that combines CO_2 and heat is essential, simulating human presence to optimize mosquito attraction.

7. The attack subsystem must receive and process position data from the localization subsystem.

2.2.4 Power and Control Subsystem

Description:

The power and control subsystem serves as the central nervous system and energy source of the mosquito eradication machine. It consists of a battery, a power adapter, a control unit, and a motor control system. This subsystem is crucial for coordinating the actions of the machine and ensuring that all components function in harmony.

The battery provides a stable 12V power supply, while the adapter ensures that all other components receive the appropriate voltage levels.

The control unit is responsible for processing data from the microphone and camera, making decisions based on this data, and sending commands to the motor control system. It also manages the activation of the attractant devices and the capture mechanism.

The motor control system, in turn, sends signals to the motor series, enabling precise movement and positioning of the machine.

Requirement:

1. The control unit must be capable of processing acoustic and visual data simultaneously, with a response time of no more than 100 milliseconds.

2. The control unit must interface with the motor control system using a communication protocol that ensures a data transfer rate of at least 1 Mbps.

3. The motor control system must be able to send control signals to the motor series with a resolution of 0.1 degrees for precise movement control.

4. The power and control subsystem must be designed to handle peak power demands of the machine, ensuring no component is subjected to voltage or current levels exceeding its rated capacity.

2.3 Tolerance Analysis

One of the greatest challenges is that mosquito wingbeat sounds are very faint and can be easily masked by background noise. Additionally, the sounds are not continuous and can be interrupted by the mosquito's flight behavior or external factors. Therefore, the microphone needs to be very sensitive and have a high signal to noise ratio. And the acceptable tolerance for the detection subsystem is that the microphone should have a frequency range of at least 20 Hz to 20 kHz, as well as a sensitivity of at least as a sensitivity of at least –40 dB and a dynamic range of at least 80 dB [3].

3 Ethics and Safety

3.1 Ethics

A qualified project must adhere to the ethics codes outlined in IEEE Policies and ACM [4], [5]. As stipulated in the team contract, the four of us will collaborate, ensuring mutual respect and fairness. We commit to upholding these codes collectively.

Our project aims to effectively manage mosquitoes, contributing to the creation of a healthier public environment. The presence of mosquitoes has been associated with the spread of diseases and unfortunate fatalities worldwide. Our goal is to mitigate these challenges for the well being of communities globally.

Our project can be divided into three main components: mosquito detection, using a camera for mosquito localization, and mosquito elimination. Regarding the detection phase, we believe there are no ethical concerns. How ever, the use of a camera for positioning raises privacy issues, as it may inadvertently capture irrelevant people and items. To address this, we propose providing advance notifications in the experimental area to inform individuals about the monitoring process.

When it comes to mosquito elimination, we acknowledge the ethical consideration of taking a life. We respect all forms of life, and our approach ensures mosquitoes are eliminated in a humane and conventional manner. It is important to note that none of our team members endorse or derive pleasure from any cruelty towards mosquitoes.

3.2 Safety

We must prioritize the safety of both electrical and mechanical components in our project. To acquire fundamental safety knowledge, all team members will complete the UIUC online safety training. During experiments, it is mandatory for at least two teammates to be present in the lab at all times.

For electrical safety, we will use batteries as the power supply. Our group fully understands and adheres to the guide lines for safe battery usage [6]. We will routinely check the device to ensure it operates in a proper environment.

Concerning mechanical safety, potential hazards include the high-speed fan designed for mosquito elimination, which can pose a risk if fingers are inserted. The moving cart also has the potential to impact individuals, and during assembly, the gear system may pose a piercing risk. To address these issues, precautions such as keeping people at a safe distance during operations and having at least two teammates present in the lab will be implemented.

There are inherent risks associated with raising mosquitoes; if they escape, there is a risk of people getting bitten and falling ill. To mitigate this, mosquitoes will be strictly controlled within the working area, and advance notifications will be provided to individuals in the vicinity.

References

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