ECE 445

SENIOR DESIGN PROJECT

PROJECT PROPOSAL

Laser System to Shoot Down Mosquitos

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Contents

1 Introduction

1.1 Problem

Mosquito bites and blood feeding can cause itchy bumps and possibly a horrible infection. Mosquitoes cause at least 2.7 million deaths every year and about 500 million cases of mosquito-borne diseases occur annually. [1] Mosquito-borne diseases and illnesses are caused by bacteria, viruses, or parasites transmitted by mosquitoes. The most prominent mosquito-borne diseases include malaria, West Nile virus, yellow fever, dengue, chikungunya, and Zika virus. Therefore, an effective method of protection against mosquitoes is necessary. Since traditional methods like nets, incense, traps, and lotions are not autonomous, tracking the mosquito and using a laser to kill it may be a feasible solution. We hope to design a system to detect mosquitoes based on vision and attack them using a laser.

1.2 Solution

The design can be divided into a positioning system, an attacking system, and a power system. The main task of the positioning system is to detect a mosquito in the environment from a camera and locate its position. The main task of the attacking system is to move the laser and switch the laser to kill the mosquito by emitting a high-power laser. The power subsystem supplies voltage to enable the components in positioning system and attacking system.

Firstly, the laser gun attached to the camera will emit a low-power laser to indicate the drop point, which is the position that can be attacked. We employ the yolov5s on our computation platform to do real-time detection with the input from the camera. Then, we move the camera to diminish the distance between the drop point and the mosquito until they coincide. The laser gun then emits a high-power laser to destroy the mosquito.

After a preliminary selection and comparison of components, we decide to use an imaging sensor like the Sony IMX219 camera to detect the mosquito. For the computing platform, the embedded development board like RK3399pro with NPU support may be capable to run yolov5. Cloud Computing is another solution, but it possibly has high latency and low stability. For the moving system, robot arms or steering engines can be used to change the position of the camera and the laser. We need more research to determine whether the control of the moving system requires another development board like Arduino.

1.3 Visual Aid

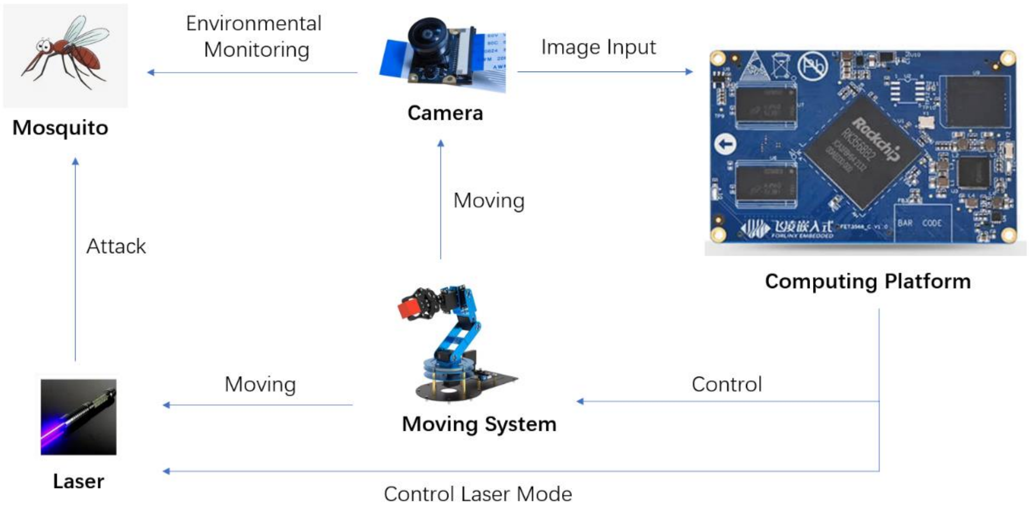

Figure 1. Visual Aid

1.4High-level requirements list

1. The laser we choose should not harm people, which means the power of the high-power laser should be larger enough to kill mosquitoes but not harm people, so 1 W power laser are considered.
2. The environment with mosquitoes may be complex, our systems are expected to detect mosquitoes not just in a blank background.
3. The speed of the data processing based on the computing platform in the positioning system, as well as moving and shooting in the attacking system should be as fast as possible.

2. Design and Requirements

2.1 Block Diagram

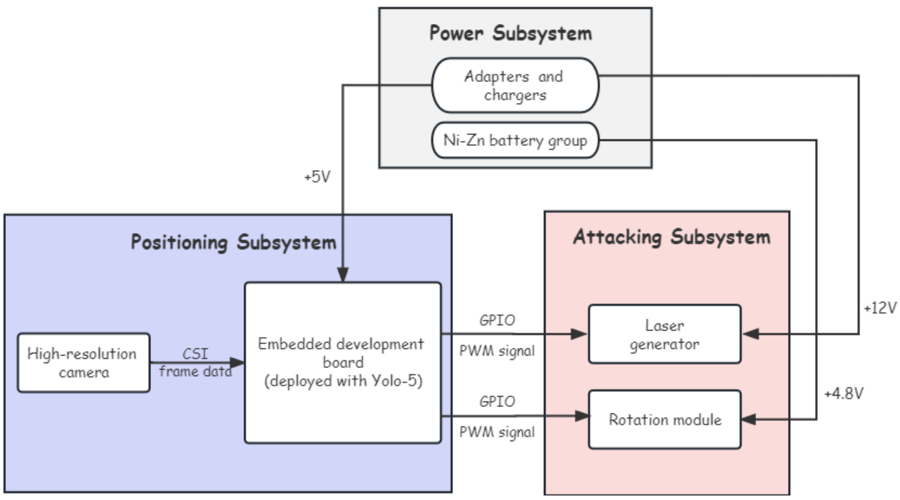

Figure 2. The block diagram

2.2 Subsystem Overview

2.2.1 Positioning Subsystem

The purpose of this subsystem is to capture the mosquito, analyze the coordinates of the mosquito and the laser, and command the attacking system. The positioning subsystem is composed of a high-resolution camera and an embedded development board. The high-resolution camera captures the surroundings that may include mosquitos and sends frames to the embedded development board.

Yolo5 is deployed on the embedded development board to detect the location of mosquitos and the laser drop point in each frame. Then it will send the corresponding pulse signal to attacking subsystem to control the rotation speed and direction. Also, if the laser and the mosquito overlap each other, it will send an attack-mode signal to attacking subsystem to emit the kill laser.

2.2.2 Attacking Subsystem

The purpose of this subsystem is to let the laser aim at the mosquito and fire a high-intensity laser to kill mosquitoes. The attacking subsystem includes the rotation module and the laser generator. The rotation module rotates horizontally or vertically according to the pulse signal from the positioning subsystem, so that the drop point of the laser can overlap with the target. The laser generator chooses different power according to the mode signal from positioning subsystem. In the positioning mode, it emits a lower-power laser to illustrate the drop point for the positioning system. In the attacking mode, the laser generator will release a kill laser to attack the target.

2.2.3 Power Subsystem

The power subsystem supplies stable voltage to the components in positioning subsystem and attacking subsystem according to their nominal voltages. The power source is the 220v AC. There are official adapters and chargers for the embedded development board and the laser generator, which can transform 220v AC to 5v DC and 12v DC accordingly to use. Also, there are 4 Ni-Zn batteries supplying 4.8v voltage for each servo in rotation module in attacking subsystem.

2.3 Subsystem Requirements

2.3.1 Positioning Subsystem

Yolov5 model is a large deep learning model, requiring sufficient computing capability to run smoothly. Based on the online data [2], a 3-TOPS NPU can support yolov5 processing up to about 6 frames per second (FPS), which is just acceptable. Therefore, an embedded development board with the NPU that performs more than 3 Teta operations is preferred. The board needs to have the MIPI CSI interface to receive the signal from the camera. Also, it should be capable of modulating PWM signal and send it though GPIO pins to control the attacking subsystem.

The software is should be able to recognize the mosquito drawn by at least 205*108 pixels, and find its location with the maximum error +/-60 pixels. Also, it should recognize the drop point of the laser, the human skin, and the human eyes. If human skin or eyes are detected, it should stop emitting the kill laser and wait. The software should be able to communicate with the drivers of the camera and GPIO pins.

Given that the mosquito is tiny, the camera should have high resolution (choose 4096×2160, or 4K format) and low distortion (less than 1%). If we want the mosquito located at the best working distance to occupy 205*108 pixels (about 1/400 field of view), the chosen focal length should be (see Fig. 3 for details)

$$f = \frac{W_{CDD} D_{best}}{W_{CDD} + 20 W_{target}}$$

where D_{best} stands for the best working distance (set as 300mm), W_{target} represents the size of the mosquito (3 ~ 6mm) [3] and W_{CDD} means the size of CMOS in the camera (choose 1/4''). [4]

So, the roughly estimated minimum focal length is 11.54mm.

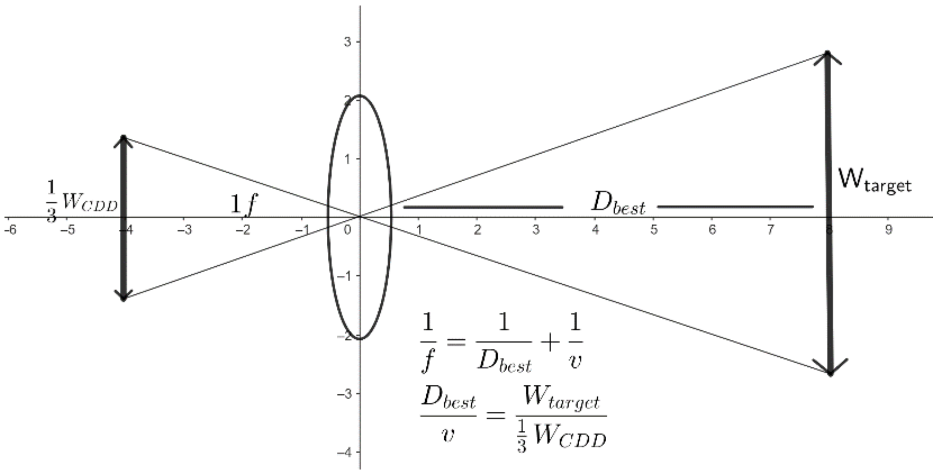

Figure 3. Derivation of proper focal length

2.2.2 Attacking Subsystem

The rotation module must have at least two degrees of freedom, allowing the laser to reach any direction in space, which is implemented by connecting two servos with rotation axes perpendicular to each other (see Fig. 4) [5]. The max rotation angle of the horizontal servo should be 360 degrees. And the vertical one should be able to rotate at least 90 degrees. To make the laser fall precisely on the target, the minimum reachable speed of the rotation module should be (see Fig. 5 for details)

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

where FPS represents the number of frames processed by the positioning subsystem per second (about $6\ s^{-1}$)

The rotation module should be able to run slower than 0.032 rad/s.

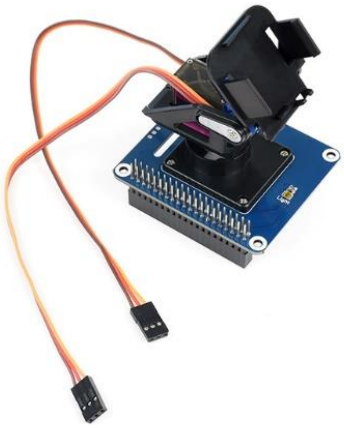

Figure 4. Two-DOF rotation module

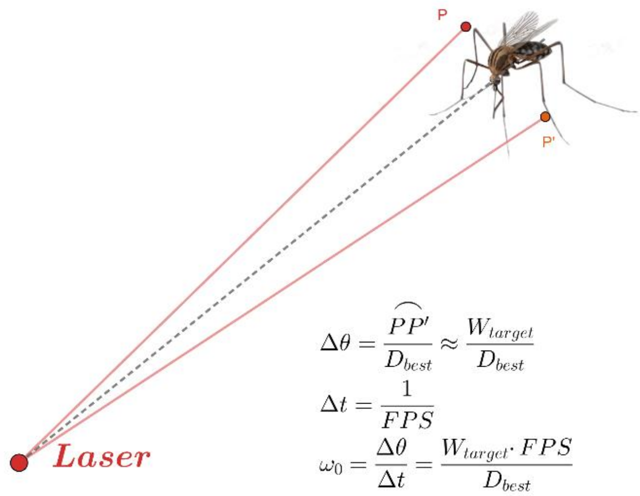

Figure 5. Derivation of ω_{min} requirement

The laser generator should be able to switch between high power and low power.
The low power should be in the range of 1mW-5mW, which is the safe range for human. The high power should be carefully selected so that it can kill mosquitos while generally doing no harm to humans (excluding sensitive parts like eyes). The preliminary set value is 1 W.

2.2.3 Power Subsystem

The power subsystem should be able to supply at least 2A to the embedded development board continuously at 5V +/- 0.2V [6], providing 4.8V DC to each servo in rotation module [5] and 12V DC to the laser generator stably.

2.4 Tolerance Analysis

The first challenge is that the mosquito is too small, making it hard to be positioned by the rotation system. To solve it, we decide to choose an appropriate focal length so that mosquitoes occupy about 1% of the image. Then, we do the calculation and select the rotation speed that is slow enough for the laser to precisely position the mosquito. Furthermore, it is difficult to consider some complex environments like killing the mosquito in the dark or in a bigger room. For the first condition, we decide to buy a night vision camera, so that it can catch the mosquito in the dark. Also, with the camera of high resolution (like 4096×2160 pixels) or a telescope, we can capture the mosquito more easily.

3.Ethics and Safety

3.1 Ethics

Our project aims to kill the mosquito with a powerful laser. It will impose a greatly positive influence on killing mosquito efficiently and widely in some area that suffered from the disease and death brought by mosquito. However, laser not only brought efficiency and a wide range of attack, it also brought some potential safety problem. For example, the laser with high power that is able to kill mosquito can also hurt people in some way.

According to IEEE Ethics term 1 [7] and ACM Ethics term 1.2[8], protecting the health of people is our first principle. Therefore, in our project, we should avoid laser out of control to hurt an item that is not mosquito by using a model with high accuracy and double check. In other words, we have to improve our accuracy of recognizing mosquito and shoot it after we make sure it is indeed a mosquito.

Another ethical issue is about privacy. Because we have to use a camera to monitor the surrounding environment to identify whether an item is a mosquito a not, it is unavoidable to identify some private item or people. IEEE Ethics [7] and ACM Ethics [8] both focus on the importance of privacy. To avoid the private data leakage, we would delete it after finishing the identifying.

3.2 Safety

3.2.1 Electrical safety

Since our device will rely on electricity, electrical safety should be considered in our project. According to basic electrical safety in university of Washington [9], we should prevent electrical shock, electrical explosions during our device work. Therefore, check the device to ensure each component is connected properly, not place it in a wet environment is the premise.

3.2.2 Environment safety

Also, during detection, the laser with a low power will move freely in the room, it may hurt people's eyes if there are people in the work area. Therefore, we want to keep people away from the work area after the device starts. It means we would use a manipulator to start and end it remotely. Just in case, we will also set up a mechanism that limits the moving trail of laser to avoid it scanning to people when detecting the mosquito.

3.2.3 Work mechanism safety

When the device detects the mosquito, it will shoot it with a laser of high power until it finds mosquito dead. It raises a concern that if the laser shoots one spot for a long time, it may cause danger. To address this problem, we will improve the accuracy or identifying the vital signs of mosquito by using multiple methods to check. We will also limit the time of continuous shoot. For example, the device can only shoot laser for 5 seconds at most. After that, it will have auto stop for 15 seconds to restart to shoot laser.

Reference

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