Mosquito Trapping Device Through Combination of Artificial Wing-Beat Sound and Yeast Generator

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Abstract

Disease causing mosquitoes has been a big problem encountered by the Department of Health (DOH) of the Philippines due to the rising cases of dengue-infected virus to humans that causes death. One of the solutions by the DOH to possibly decrease the dengue-carrying mosquito is to culture a Wolbachia-infected mosquito and release it to the wild. However, eliminating mosquitoes prior to the deployment of their Wolbachia-infected mosquitoes in the wild is beneficial for them for it to effectively work. The proposed method used is a soundwave with 400-600Hz sound frequency to lure mosquitoes to the zapper and eliminate/kill them along with Carbon Dioxide (CO2) generated from yeast. The system automatically counts the killed mosquitoes along with the CO2 reading and is presented by a real-time data monitoring using a graphical user interface (GUI). This study addresses the challenges encountered by the DOH in eliminating wild mosquitoes and their way of manual counting of the killed mosquitoes.

Keywords: Mosquito attraction, sound-based trap, wing-beat frequency, monitoring, electric zapper

1 Introduction

Mosquitoes belong to a group of blood-feeding insects that contribute to transmission of serious infectious diseases like dengue, malaria, chikungunya, zika, and Rift Valley fever [1, 4]. Mosquitoes also affects and carry diseases to animals mostly dogs and horses. Dengue is one of the most important infection of humans, with an estimated 100 million clinically apparent infections annually. These insects cause more disease and death than any other animal on the planet. In the Philippines, dengue is considered as endemic disease that resulted to a considerable economic burden [7]. Hence, eliminating disease-carrying mosquitoes would save lives and prevent suffering around the world.

There are existing researches that sound plays an important role in the mating behavior of mosquitoes, including Aedes aegypti. Males of the said specie orient to the fundamental wing beat frequency of females, and both sexes actively modulate their flight tone before mating to converge at harmonic frequencies [5]. Aedes aegypti are gathered in swarms in response to host signals where these swarms are composed predominantly of competing males, with females entering singly to be mated[12, 11]. Mating occurs on the wing, with males approaching the female from behind and then rotating 180 degree to position themselves venter-to-venter[15]. The male's fundamental frequency is 600 Hz while the female is at 400 Hz and their shared harmonic frequency when matchmaking is at 1200 Hz[14]. Male mosquitoes are phono tactically attracted by the flight tones of females, whereas females are not attracted to the flight tones of males.

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A sine wave is an effective substitute as a harmonic laden natural sound of a female for attraction[13, 2]. In a series of elegant experiments with Ae. Aegypti using accurate signal generators and sound level meters for the first time, they showed that mature flying males were attracted by a point source of pure sine waves between 300 and 800 Hz at 23°C. With the most attractive frequency of about 440 Hz, approximately 80% of the flying mosquitoes in a cage of males were attracted within 5 seconds. This technique was totally objective and yielded reproducible results. They showed that a sine wave was as attractive as the harmonic-laden natural sound of a female that the sound pressure level of mature females at 1 cm was about 40 dB, and that males could hear this at a distance of about 25 cm [3]. This paper leverages these pieces of information to proceed on the research.

The previous studies had a problem regarding the loudness of a constant high level sound that repelled the mosquitoes which gave the researchers the idea of adding multiple speakers that are away from each other in order to help in increasing the coverage of sound while maintaining the loudness of not more than 100 dB that will not repel the mosquitoes. Accordingly, we developed a soundwave based devices in order to lure mosquitoes into a trap and eliminate them. Additionally, to augment the attraction of the mosquito towards the trap, a yeast generating CO_2 is added [10]. The device also automatically counts the number of eliminated mosquitoes.

The remainder of this paper is organized as follows. Section II introduce the scope and limitation of the study. The research methodology is dicussed in Section III followed by the presentation of our results in Section IV. Finally, Section V concludes this paper.

2 Scope and Limitation

The system is composed of both software and hardware. A PC-based JAVA graphical user interfaces was developed for the real-time visualization of the data gathered from the hardware components. The gathered data were limited to the eliminated mosquito count and the level of CO_2 generated by the yeast. Additionall, the gathering of the said data occurs every second.

Furthermore, the device has no way of distinguishing the species and gender of the mosquitoes. The specie and gender identification must be done manually by a biologist or mosquito-specialist.

3 Research Methods

Research Variables The variables use in the research are mosquitoes as shown in figure 1. There are one hundred fifty mosquitoes contained inside the plastic cups which are both captured and donated by the Department of Biology, University of San Carlos. A net covers each cup with cotton balls on top. which were soaked with water-diluted honey to serve as the mosquitoes' food.

Research Instruments The prototype's body shown in Figure 2 is made up of a 5-inch Polyvinyl chloride (PVC) cylinder and composed of the following components as presented in figure 3:

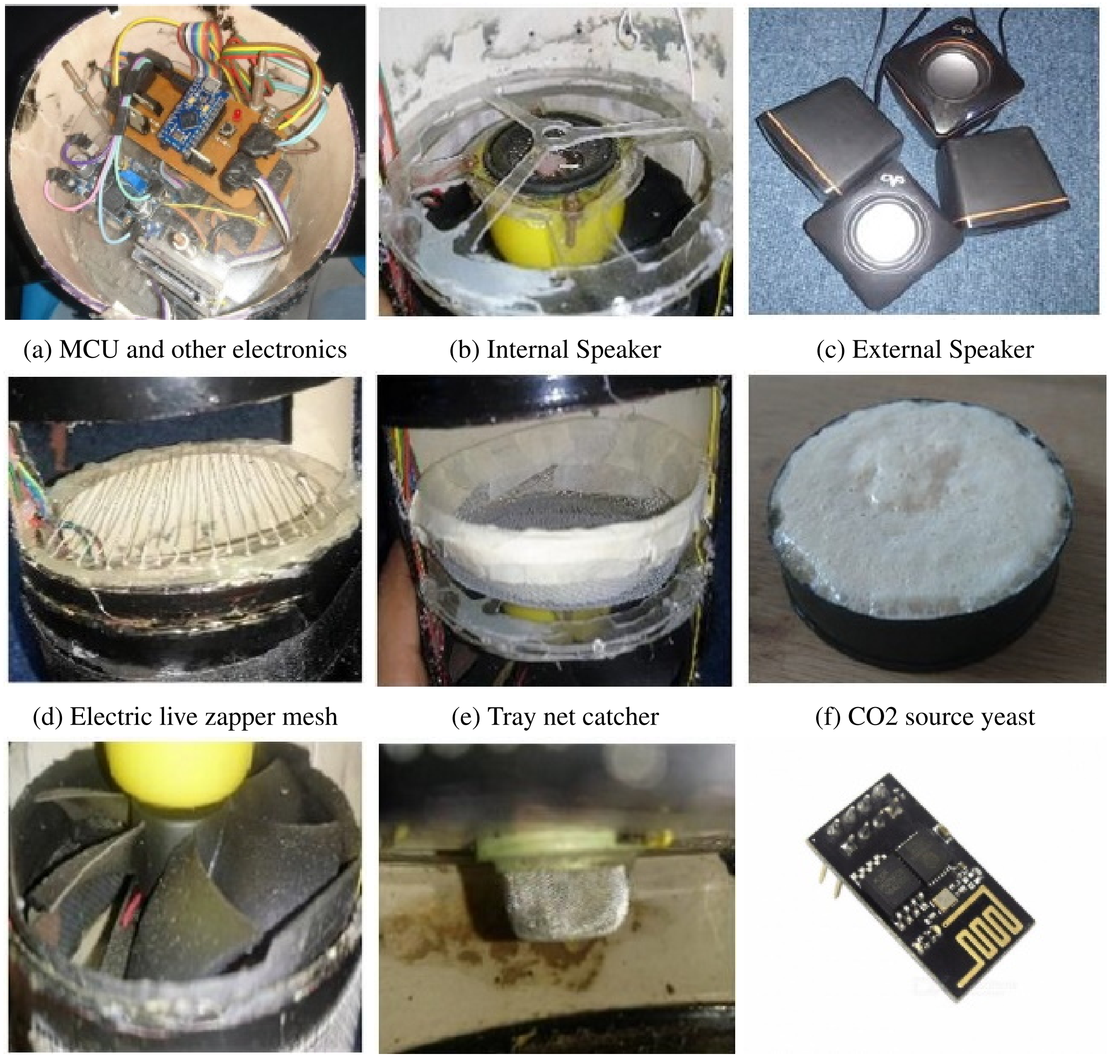
- A Sparkfun Pro-micro microcontroller unit (MCU) that controls all other components.
- A Low-powered Mp3 player with SD card that carries the harmonic audio file.
- A USB powered internal and external speakers, and amplifiers that plays out the harmonic sound.
- A Intersil X9C104 digital potentiometer that allows MCU to control the volume level.

Figure 1: Cultured Aedes Aegypti Mosquitoes

Figure 2: Actual Device Prototype

- An Electric live zapper mesh that electrocute the mosquito causing its death. It was designed using two lines of uninsulated wires weaved alternately to a circular hollowed-center fiberglass. Each lines has a separation of 4.5 mm, which is average length of a mosquito. Under this is a tray net that catches all electrocuted mosquito.
- A small fan strategically positioned for two reasons. First, it was used to induce a light vacuum effect to pull mosquito towards the electric zapper when it is near the device. At the same time, it is also helps to blowout the CO2 plume from the yeast that is positioned at the bottom of the device.
- A MQ135 gas sensor that measures the CO2 level from the yeast. This value is used as indicator if the yeast needs to be replaced to produced a stronger scent.
- An opto-isolator that captures voltage fluctuations caused by the short-circuit of the two lines in the electric zapper mesh.
- a wifi module (ESP8266) used to wirelessly transmit data to a local visualizer.

- 5V voltage regulator for power supply.



(a) MCU and other electronics (b) Internal Speaker (c) External Speaker

(d) Electric live zapper mesh (e) Tray net catcher (f) CO2 source yeast

(g) Fan (h) CO2 gas sensor (i) Wifi-module ESP8266

Figure 3: Different components of the device

Conceptual Operation Flow Figure 4 illustrates an overview on the how the system works. The micro-controller (MCU) of the device reads two input sensors at uniform interval but with different periodicity. The gas sensor is used to estimate the concentration level of CO2. Since CO2 sampling for monitoring is not critical in this case, the data acquisition occurs at a longer interval, thus we set the sampling time every 1 minute. On the other hand, the light sensor module is used to detect presence of mosquito that is in contact with the zapper. Each time a mosquito gets in contact with the zapper mesh, the voltage across a capacitor fluctuates down. To protect the MCU from getting damaged due to sudden electric current surges caused by this fluctuation, an opto-isolator that is connected with a light emitting diode (LED) is utilized. Accordingly, as voltage fluctuation occurs, light intensity produced by the LED changes, hence,

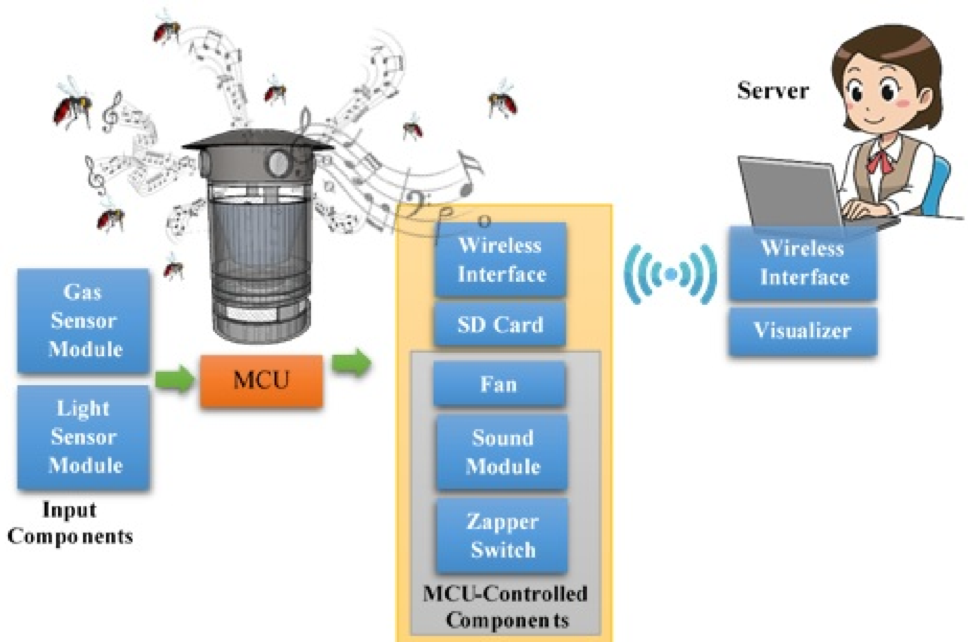


Figure 4: Conceptual operation flow of the system

causing the light sensor reading to change as well. This change is associated to a mosquito having contact with the zapper, and consequently, increments the mosquito counter. In such case, capturing the sudden change of light intensity is vital, thus, data acquisition from light sensor module is done continuously in order not to miss the counting of eliminated mosquito. Finally these values, e.g. CO2 and count, are logged to the SD card along with the log time. At the same time, it is also wirelessly transmitted to a server, which is connected through a Wi-Fi local area network, for data visualization. This allows users, that are connected to the LAN, to check the CO2 level whether it needs replacement as well as obtain the population of eliminated mosquito. Data logging and reporting were set at every 1 second interval.

Aside from collecting information, the MCU also controls the functions of the fan, sound, and zapper module. The fan is deactivated only when it is time to sample CO2 level from the gas sensor. Furthermore, the speakers, which output the sine wave tone played from the mp3 player, are controlled to produce an inward-like audio effect, i.e., the harmonic sound travels inward within the trap on the perspective of the listener. This is done by adjusting the volume of the outer and inner speakers. The outer speaker start with full volume while the inner one is set to half. Subsequently, the MCU gradually adjusts the volume of the outer speakers to zero and then the inner speaker afterwards. This process in repeated during the operation. Consequently, the mosquito will hypothetically follow this sound until at the opening portion of the trap, then eventually be sucked in towards the electric zapper due to the vacuum fan. Lastly, the MCU also controls activation of the electric zapper through a digital switch. When a mosquito is in contact with the zapper, it continuously stick on the mesh unless no electric current passes through the wires. During this situation, the zapper is deactivated in order for the mosquito to freely fall unto the tray net. In our investigation, an average of 0.7 seconds deactivation period is required to avoid multiple count with the same mosquito.

4 Experimentation and Results

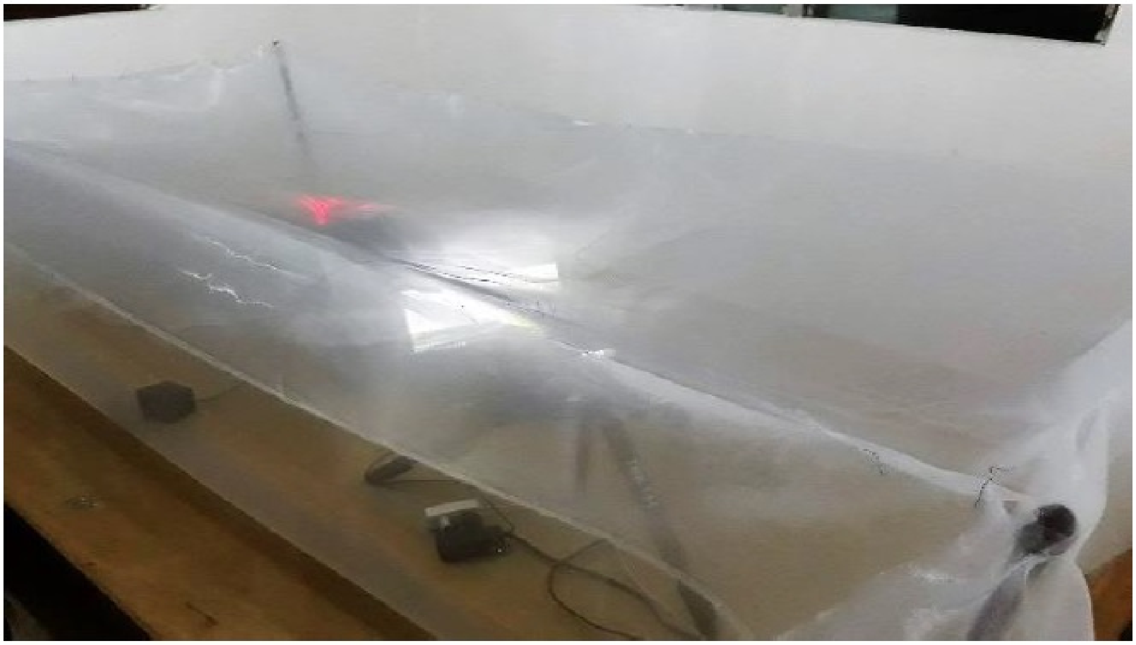


Figure 5: The Controlled Environment Setup

4.1 Experimentation

Experimentation Environment In our initial experiment, we test the developed prototype in a controlled environment to evaluate its effectiveness. The controlled environment setup is a 3x5x5 ft box made out of transparent materials on all sides and covered with mosquito net at the top, as shown in figure 5. The device was placed inside and a number of mosquitoes regardless of gender were released, allowing them to freely fly within it. Series of tests was conducted to investigate important parameters such as the effective sine wave frequency as well as the voltage fluctuation threshold.

Finding optimal sine wave frequency Setting the right sine wave frequency for the sound was hypothesized to be an essential parameter to effectively lure the mosquito towards the trap. To find this value, a series of frequency testing was performed. The lowest and highest frequencies played are based on the wing beat frequency range of mosquito that ranges from 100 to 1000 Hz[8]. In turn, we select the frequency from 300 to 700 Hz and divided the range into 8 groups as listed in Table 1. The device plays a sound with different frequencies within each group. We left the device playing a specific frequency range for at least 30 minutes without anyone in the room to eliminate human influence since mosquitoes are attracted to human body heat, perspiration, and human odor [6, 9]. Subsequently, we manually count the number of mosquitoes collected in the tray net. We can see in the table that mosquitoes are most attracted to sine wave frequencies ranging at approximately 400 Hz - 600 Hz.

Finding voltage fluctuation threshold Setting the optimal threshold voltage, which is used to compare the output voltage across the LDR sensor during electronic surge, is also important for the accuracy of the automated mosquito counting. Using the collected mosquitoes during the frequency testing, we subjectively selected 4 mosquitoes of 2 different sizes, e.g., approximately 6 mm and 3 mm, for our investigation. One after the other, we used a plastic tweezer to hold the mosquito and drop it into the zapper mesh. Simultaneously, we continuously sample the output voltage across the LDR through an analog-to-digital converter device and store results to an SD card. As shown in figure 6, the maximum voltage measured across the LDR sensor during normal state is approximately 3.5 volts. Moreover, we can observe that the voltage fluctuation level has a relationship with the size of the mosquito. Subjectively, the large-sized mosquitoes fluctuates voltage down to approximately 2.5 volts while the small-sized ones reached around 2.85 volts only. Theoretically, the reason for this is that the capacitor connected to the light source LED, dissipates its stored power at a relatively longer time when a large-size mosquito is electrocuted compared to the smaller ones. Consequently, we adopted a threshold of 2.9 volts as basis for counting, i.e., the voltage fluctuating lower than the set threshold is associated to mosquito in contact with the zapper.

4.2 Result Discussion and Analysis

Finally, after obtaining these parameters, we again conducted another test to evaluate the efficacy of the trap. The trap setup generated a sine wave sound with frequencies between 400 Hz - 600 Hz. A fermented yeast as source for CO2 was also added to the setup to augment the luring purpose of the trap.

Accordingly, the final testing was conducted from 5:55 AM to 6:55 AM and a total of 70 mosquitoes were released inside the testing environment. During testing, presence of human body was likewise removed from the testing room. Just few minutes after the release of all the mosquitoes, the device starts counting. Figure 7 depicts the real-time graph count from the java-based visualizer module. When a mosquito is electrocuted by the zapper, the system automatically increment the counter. The CO2 level is also shown at the bottom of the graph.

After the testing period, we checked the setup and manually count eliminated mosquitoes shown in figure 8. Out of 70 mosquitoes released in the setup, the actual eliminated mosquitoes has reached 39, however, the device only counted 23. There was an error of about 41%. Based on our observation, one reason for this is that there were mosquitoes smaller than 3 mm that may have caused a voltage fluctuation and yet still above the threshold value. We are also looking at the possibility that some mosquitoes may have been in contact with the zapper mesh at the same time resulting for a single count. This issues will be further investigated in the future works.

5 Conclusion

This paper presents the development of a system that lures mosquitoes to a trapper using artificial wing-beat sound. The device is attractive to the mosquitoes when the harmonic sound is played between 400 Hz to 600 Hz frequency. A CO2 generating fermenting yeast was also added to augment mosquito attraction to the device. Moreover, the system also automatically counts the number of eliminated mosquitoes that

Table 1: Frequency Investigation Result

Frequency (Hz)	No. of Mosquitoes
300 - 350	3
350 - 400	5
400 - 450	20
450 - 500	25
500 - 550	30
550 - 600	20
600 - 650	15
650 - 700	2

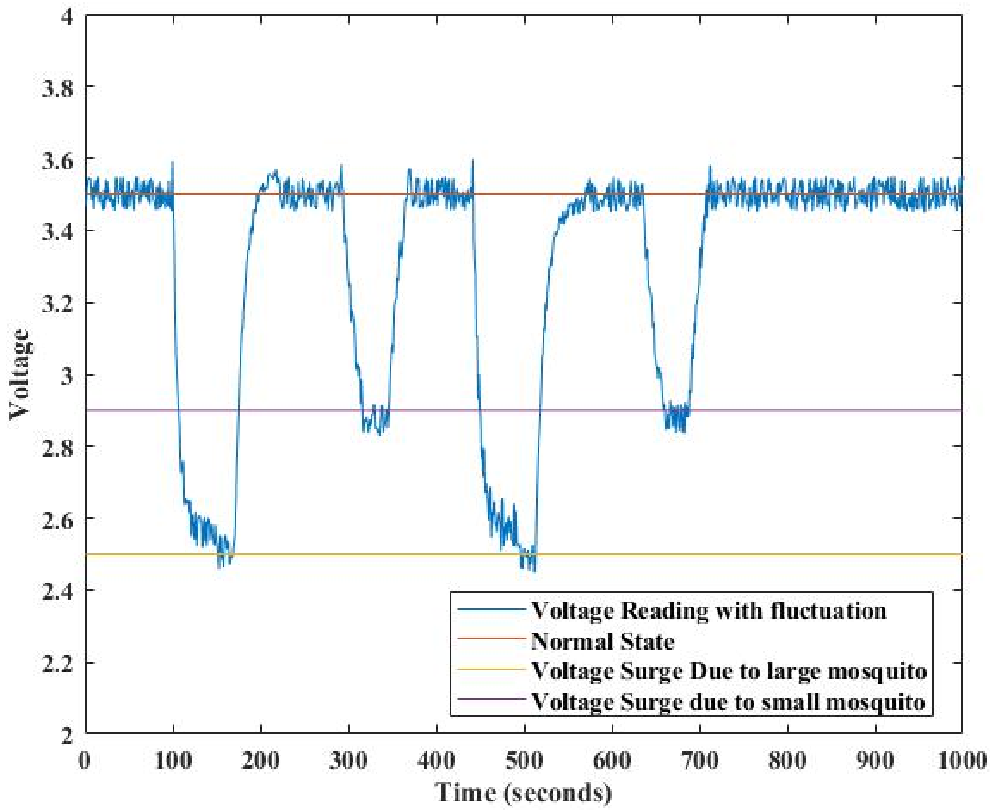


Figure 6: Voltage fluctuations due to zapping

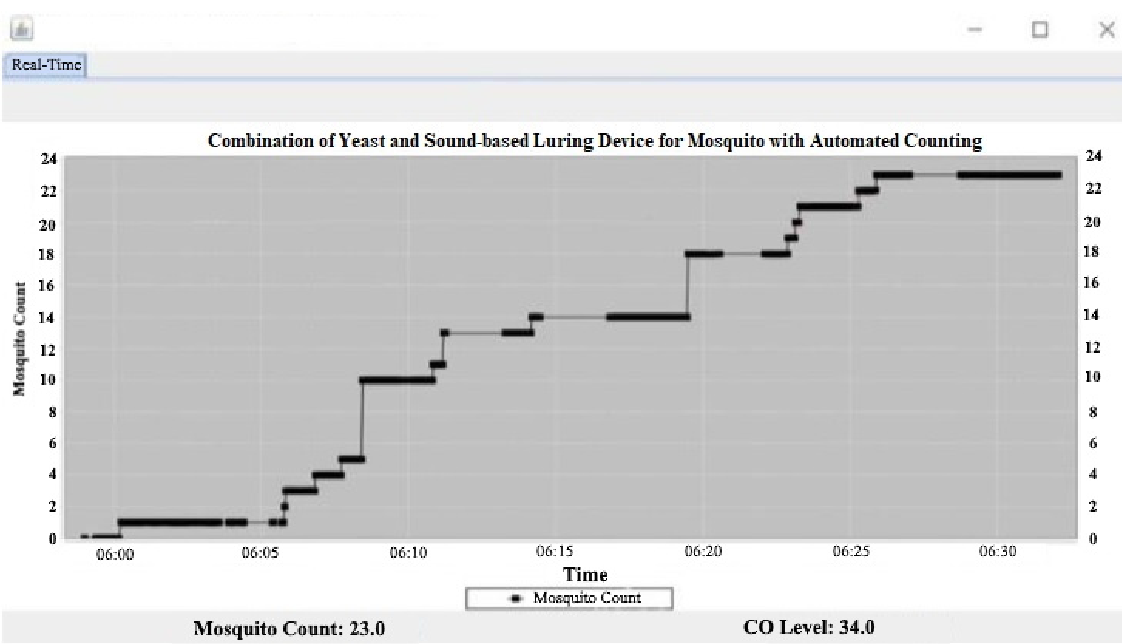


Figure 7: Real-Time Data Visualization of Mosquito count

Figure 8: A number of eliminated mosquito

made in contact with a zapper mesh. It also reports this information, e.g. CO2 level and mosquito count, through Wi-Fi to a local station allowing users to view data on the developed java-based visualizer. However, this paper still have many challenges, which we target for the future work. Accordingly, we recommend for a more extensive tests especially in searching for the optimal voltage fluctuation threshold. Additionally, a more stable mesh with more precise separation is desirable. Furthermore, the deployment of the system to the natural environment is also the ultimate goal. In that case, an improvement on the area of data communication with wider coverage is necessary. Thus, the researchers plan to leverage the current 4G mobile network infrastructure or explore the emerging fifth generation (5G) cellular network technology when the infrastructure starts to roll out in the country.

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