International Journal of
Microelectronics and Digital Integrated Circuits

ISSN: 2456-3986
Volume 10, Issue 1, 2024
January–June
DOI (Journal): 10.37628/IJMDIC

http://ecc.journalspub.info/index.php?journal=JMDIC&page=index

Research IJMDIC

Predictive Modeling of Dengue Mosquito Populations Using Artificial Neural Networks for Effective Zapping Solutions

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Abstract

The World Mosquito Programme highlights the significant global threat posed by dengue fever, estimating that over half of the world's population is at risk, with approximately 390 million cases reported annually. In 2023, India witnessed a substantial increase in dengue cases, recording over 270,000 cases compared to 74,000 in 2017. Dengue Virus (DENV) transmission occurs through Aedes Aegypti Mosquito bites, and with no specific treatment or vaccine available, effective management and prevention are crucial for public health. To address this, an engineering solution is proposed to eliminate Aedes Aegypti Mosquitoes, primarily found in areas such as harbours and stagnant waters. The solution involves an electric fence equipped with UV LED technology to attract mosquitoes, with captured images analysed using Artificial Neural Network (ANN) techniques. The suggested approach seeks to transform conventional mosquito control techniques by utilizing AI and image processing technologies. By training the network with images of Aedes Aegypti and similar species, mosquitoes are accurately identified and subjected to electrification upon detection, facilitated by a Raspberry Pi supporting the ANN technology. This innovative approach aims to mitigate the risk of dengue transmission in high-risk areas such as hospitals, residential buildings, and communal spaces.

Keywords: Dengue fever, Aedes Aegypti Mosquito, Image processing, ANN technology, Raspberry Pi

INTRODUCTION

The paper introduces a novel approach to tackling the persistent threat of dengue fever transmission by leveraging artificial intelligence (AI) and image processing [5, 6] techniques. Dengue fever, a mosquito-borne viral illness primarily transmitted by the Aedes aegypti mosquito species, continues to pose a significant global health challenge, particularly in tropical and subtropical regions. Traditional methods of mosquito control, such as insecticides and larvicides, have encountered limitations such as resistance development and environmental concerns. Consequently, there is an urgent need for innovative strategies to enhance mosquito control efforts and mitigate the spread of dengue fever.

In response to these challenges, the paper proposes an integrated system that combines artificial neural networks (ANNs) with advanced image processing algorithms for real-time mosquito detection and elimination. The core objective of the research is to design and implement an ANN-based

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Received Date: May 28, 2024
Accepted Date: June 17, 2024
Published Date: June 25, 2024

Citation: Bassalel Biju, Amaldev H., Mohammed Rezin S., B. Sivaganga, Abdhulla Navas, Thasreef H.R. Predictive Modeling of Dengue Mosquito Populations Using Artificial Neural Networks for Effective Zapping Solutions. International Journal of Microelectronics and Digital Integrated Circuits. 2024; 10(1): 27–36p.

system capable of accurately identifying dengue mosquitoes from captured images. The methodology involves data collection using specialized cameras equipped with high-resolution sensors, followed by preprocessing techniques [3] to enhance mosquito visibility. The trained neural network model then analyzes incoming images to identify potential mosquito vectors, enabling the activation of targeted zapping mechanisms for effective mosquito control [2].

By harnessing the power of AI and image processing technology, the proposed system aims to revolutionize traditional mosquito control methods. The integration of ANN-based mosquito detection with real-time image processing offers a proactive and sustainable approach to mosquito control [1], minimizing the risk of disease transmission and improving public health outcomes. Through collaborative research efforts and the deployment of innovative solutions, the paper envisions a future where advanced technologies play a vital role in mitigating the burden of mosquito-borne diseases, ultimately enhancing the well-being of communities worldwide.

LITERATURE REVIEW

Previous research efforts have explored various methods for mosquito control, including chemical insecticides, biological control measures, and physical traps. While these methods have been effective to some extent, they often come with drawbacks such as environmental concerns and limited effectiveness. Recent advancements in technology, particularly in the fields of machine learning and image processing, have opened new possibilities for mosquito control. Several studies have investigated the use of machine learning algorithms for mosquito detection and classification based on visual features. However, few studies have explored the integration of artificial neural networks with image processing techniques for real-time mosquito control [4], [6].

PROPOSED METHODOLOGY

Conventional methods of dengue mosquito killing, such as insecticide spraying and larval source reduction, have shown limited effectiveness in controlling mosquito populations and curbing disease transmission. The dynamic nature of mosquito ecology, coupled with factors like urbanization, climate change, and insecticide resistance, underscores the need for innovative and adaptive approaches to mosquito control.

Artificial Neural Networks (ANNs), a subset of artificial intelligence, offer a promising avenue for addressing the complex challenges associated with dengue mosquito killing. ANNs possess the ability to analyse large and diverse datasets, identify intricate patterns and relationships within data, and make predictions based on learned patterns.

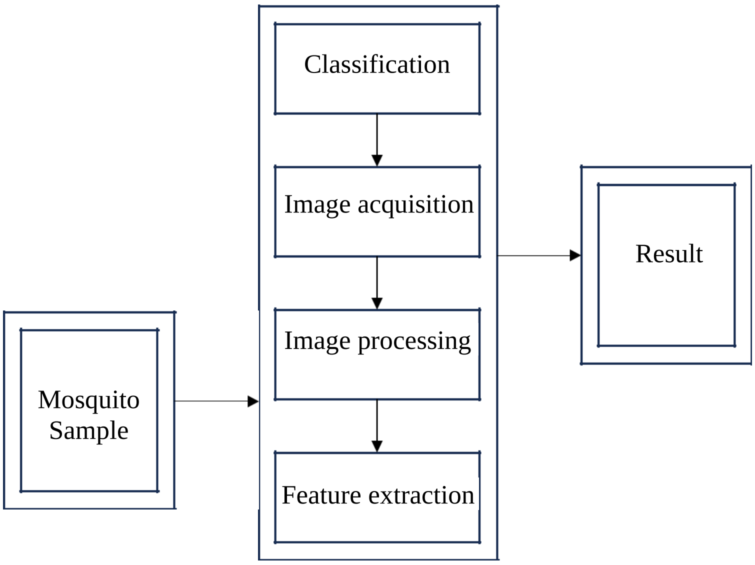

Figure 1. Block diagram of the proposed system.

By harnessing the power of ANNs, researchers and public health authorities can develop more targeted and effective strategies for mosquito control. ANN enable the integration of diverse data sources, including environmental variables, mosquito population dynamics, and disease incidence rates, to generate predictive models that guide mosquito control efforts in real time. Block diagram of the proposed system is shown in Figure 1.

Flowchart

Flow of information in the form of chart is shown in Figure 2.

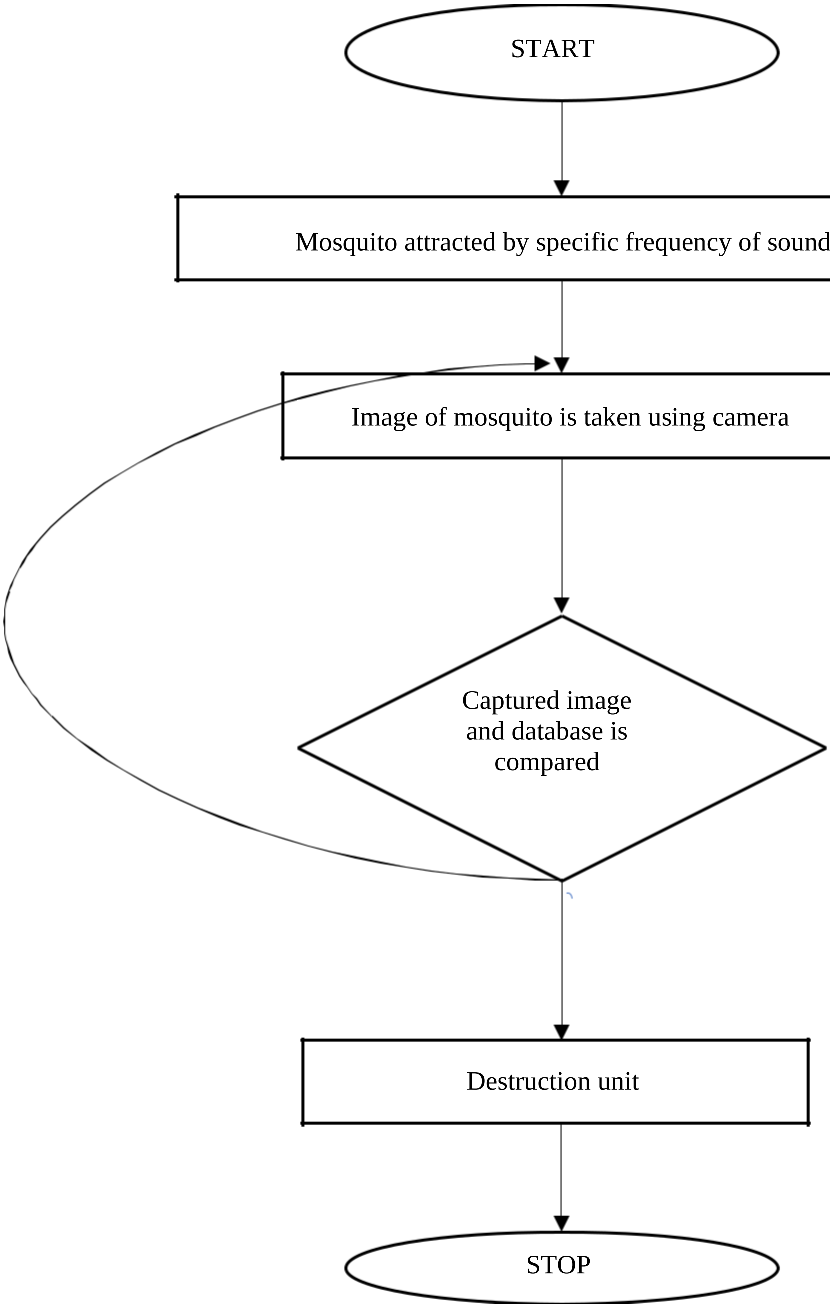

Figure 2. Flow of information in the form of chart.

RELEVANCE OF THE SYSTEM

The project is incredibly valuable for paramedics and emergency responders. Its portability allows them to provide advanced life support while closely monitoring vital signs, which is crucial in highstress and time-critical situations. In emergencies like natural disasters or pandemics, the compact ventilator's mobility and monitoring capabilities become even more crucial. It can be rapidly deployed in temporary medical facilities, like field hospitals, ensuring patients receive the respiratory support they need. In remote areas with limited healthcare access, the compact ventilator is a game- changer, bringing advanced medical care directly to those in need.

SUBSYSTEM IN THE PROPOSED SYSTEM

Artificial Neural Network (ANN) Subsystem

The ANN subsystem within the proposed system serves as the cornerstone for accurate dengue mosquito detection. Employing sophisticated neural network architectures, this subsystem leverages machine learning algorithms to train models capable of recognizing dengue mosquitoes based on their distinctive visual features. Through an iterative training process on annotated mosquito images, the ANN learns to discern relevant patterns, enabling it to classify new images with high accuracy. Once trained, the ANN is seamlessly integrated into the system's framework, ready to analyse incoming images in real-time and identify potential dengue mosquito threats swiftly and effectively.

Image Processing Subsystem

Operating in tandem with the ANN subsystem, the Image Processing subsystem acts as a critical precursor to mosquito detection. This subsystem is tasked with preprocessing captured images of mosquitoes to enhance their quality and extract relevant visual information. Leveraging a suite of image processing techniques such as contrast enhancement, noise reduction, and edge detection, the subsystem optimizes the input images, ensuring optimal conditions for subsequent analysis by the ANN. By effectively isolating mosquitoes from background noise and enhancing their visibility, the Image Processing subsystem plays a pivotal role in facilitating accurate mosquito detection, thereby fortifying the system's overall efficacy in combating the spread of dengue fever.

WORKING

The system begins by collecting comprehensive datasets related to dengue fever incidence, mosquito population dynamics, environmental factors (e.g., temperature, humidity, rainfall), land use patterns, and geographical information. These datasets serve as input for training the ANN model. The collected data undergoes preprocessing to clean, normalize, and transform it into a suitable format for input into the ANN model. This involves handling missing values, scaling numerical features, encoding categorical variables, and removing outliers to ensure data quality. Relevant features are selected and engineered to enhance the predictive power of the ANN model. Feature selection techniques help identify the most informative variables for predicting dengue transmission hotspots, while feature engineering may involve creating new features or transforming existing ones to improve model performance. Various ANN architectures, such as feedforward neural networks or convolutional neural networks, are explored and evaluated for their ability to predict dengue transmission hotspots. The ANN model is trained using historical data on dengue fever incidence and mosquito population dynamics, adjusting model parameters to minimize prediction errors. The trained ANN model is validated using separate datasets to assess its generalization performance and ensure accurate predictions of dengue transmission hotspots in unseen data. Cross-validation techniques may be employed to evaluate the reliability of the model. Once validated, the ANN model is deployed for real time monitoring of dengue transmission risk. Environmental data and mosquito surveillance data are continuously fed into the model to generate predictions of dengue transmission hotspots and high-risk areas. The predicted dengue transmission hotspots are integrated with a mosquito zap system equipped with targeted mosquito control mechanisms. Mosquito zappers are strategically deployed in high-risk areas identified by the ANN model to reduce mosquito populations and mitigate the risk of dengue transmission. The performance of the ANN-based dengue mosquito zap system is periodically evaluated to assess its effectiveness in reducing dengue transmission rates. The system may be fine-tuned and optimized based on feedback and new data to improve its predictive accuracy and efficiency.

COMPONENTS USED

Raspberry Pi

Raspberry Pi 4 Model B as shown in Figure 3. features a high-performance 64-bit quad-core processor, dual-display support at resolutions up to 4K via a pair of micro HDMI ports, hardware video decoder at up to 4Kp60, up to 8GB of RAM, dual-band 2.4/5.0 GHz wireless LAN, Bluetooth 5.0, Gigabit Ethernet, USB 3.0, and PoE capability (via a separate PoE HAT add-on). For the end user, Raspberry Pi 4 Model B provides desktop performance comparable to entry-level x86 PC systems. This product retains backwards compatibility with the prior-generation Raspberry Pi3 Model B+ and has similar power consumption, while offering substantial increases in processor speed, multimedia performance, memory, and connectivity. The dual-band wireless LAN and Bluetooth have modular compliance certification, allowing the board to be designed into end products with significantly reduced compliance testing [7].

Figure 3. Raspberry Pi.

Frequency Generator

A frequency generator using the IC 555 timer is a simple yet effective circuit for generating square wave signals at a desired frequency, making it a popular choice in hobbyist and educational electronics projects. An astable multivibrator using a 555 timer IC is a simple oscillator circuit that generates continuous pulses. The frequency of the circuit can be controlled by adjusting the values of resistors R1, R2, and capacitor C1. Here we are using resistors R1 with 1.5k, R2 with 1ohm, and capacitor C1 with 2 µf. By using the components with these values we can generate frequency with states between 420Hz – 600Hz.

Speakers

Speakers will produce the sound of frequency generated. The speaker has an impedance of 4 ohms, which is the total resistance to the flow of electrical current. This impedance affects the amount of electrical power the amplifier must supply to drive the speaker. The speaker can handle a maximum power of 3 watts. It’s essential to ensure that any signal fed into the speaker does not exceed this power rating to prevent distortion, overheating, or damage to the speaker. The frequency response of the speaker refers to the range of frequencies it can reproduce accurately. While the speaker may have a specified frequency range, typically, for basic frequency generation applications, the frequency response should cover the desired range of frequencies without significant distortion [8].

Power Adapter

A 12V - 3.0A power adapter is a device used to convert AC (alternating current) power from a wall outlet into DC (direct current) power at 12 volts with a maximum current output of 3.0 amps. The power adapter provides a constant voltage output of 12 volts. This voltage is suitable for powering a wide range of electronic devices that require 12V DC power. The maximum current output of the power adapter is 3.0 amps. This current rating indicates the maximum amount of electrical current that the adapter can supply to a connected device while maintaining a stable voltage output.: The power rating of the adapter can be calculated by multiplying the output voltage (12V) by the maximum output current (3.0A). In this case, the power rating would be 12V * 3.0A = 36 watts. This means the adapter can deliver a maximum of 36 watts of power to the connected device. The 12V - 3.0A power adapter is commonly used to power various electronic devices that require a 12V DC power source. It's often used in home and office settings to provide reliable power to devices such as routers, modems, networking equipment, LED lighting, CCTV cameras, and more [10].

Power Converter

A 12V to 5V 5A power converter, also known as a step-down voltage regulator, is a device used to convert a higher voltage (in this case, 12 volts) into a lower voltage (5 volts) while maintaining a high current output capability (5 amps). The power converter takes an input voltage of 12 volts and converts it to a lower output voltage of 5 volts. This type of conversion is common when you need to power devices that require a lower voltage than what is available from the power source. The power converter has a maximum current output capability of 5 amps. This means it can supply a continuous current of up to 5 amps to the connected load while maintaining the 5volt output voltage. The power rating of the converter can be calculated by multiplying the output voltage (5V) by the maximum output current (5A). In this case, the power rating would be 5V. This means the converter can deliver a maximum power of 25 watts to the connected load [9].

UV Light

UV light can attract mosquitoes because many species of mosquitoes are attracted to light in general. However, it's not specifically the UV component of the light that draws them in; rather, it is the visible light spectrum that they're most responsive to. Mosquitoes are known to be particularly attracted to certain wavelengths of light, including blue and violet, which are often present in UV light sources. Research suggests that mosquitoes are especially attracted to light in the 300 to 400 nanometre range, which includes UV light and adjacent visible blue light. This attraction to light is believed to be an evolutionary adaptation, as mosquitoes use light cues to navigate and find hosts for blood meals. While UV light itself might not be the primary attractant for mosquitoes, it can enhance the attractiveness of a trap or a light source that emits light in the wavelength mosquitoes are responsive to.

Stainless Steel Mosquito Mesh Net

Stainless steel is known for its durability and resistance to corrosion, making it an excellent material choice for mosquito mesh nets. These nets can withstand exposure to extreme outdoor elements without deteriorating, ensuring long-term effectiveness. Stainless steel mesh nets are often designed to be visually appealing and they provide a clean and modern look while effectively serving their functional purpose. All the mosquitoes are attracted towards the mesh by the UV light.

Digital Camera

Utilizing a digital camera (as shown in Figure 4). capable of recording at 60 frames per second (fps) offers precise and detailed footage for mosquito detection. This high frame rate enables smooth motion capture, aiding in the analysis of mosquito behaviour and movement patterns. The camera's high resolution capabilities facilitate accurate identification and classification of mosquito species, while integration with advanced algorithms enhances detection accuracy and efficiency. In summary, a 60fps digital camera serves as a powerful tool for real-time monitoring and analysis, contributing to effective mosquito control and disease prevention efforts.

SOFTWARE USED

MATLAB Software

MATLAB, a versatile high-level programming language and environment, stands as a pillar in the realm of numerical computing. Designed specifically for tasks like data analysis, simulation, and algorithm development, MATLAB offers a seamless interactive platform where users can execute commands, visualize data, and analyse results in real-time. Its robust capabilities encompass a wide array of domains, including image processing, signal processing, control systems, and more, supported by extensive built-in functions and toolboxes. With its user-friendly interface, powerful scripting capabilities, and cross-platform compatibility, MATLAB remains a go-to solution for professionals, researchers, and educators alike, enabling them to tackle complex computational challenges with ease and efficiency.

Figure 4. Digital camera.

EXPERIMENTAL EVALUATION

The proposed approach is evaluated through extensive experimental testing using real-world mosquito datasets. The performance of the ANN model is assessed in terms of detection accuracy, false positive rate, and computational efficiency. Additionally, the effectiveness of the zapping mechanism in eliminating dengue mosquitoes is evaluated under various environmental conditions. The experimental results demonstrate the effectiveness and efficiency of the proposed approach in accurately identifying and zapping dengue mosquitoes, with minimal false positives. Furthermore, the system's real-time operation and scalability make it suitable for deployment in urban environments prone to dengue fever outbreaks.

Attraction Unit

Utilizing UV light as an attractant in mosquito control presents a promising avenue for drawing mosquitoes into controlled environments. UV light capitalizes on mosquitoes' innate phototaxis, their tendency to be attracted to light sources. Circuit diagram and experimental set up of attraction model is shown in Figures 5 and 6 respectively. This method offers several advantages, including its environmentally friendly nature, low risk to non-target organisms, and affordability. By strategically deploying UV light sources in experimental setups, researchers can effectively lure mosquitoes for further investigation or targeted control measures. In essence, the incorporation of UV light as an attractant holds immense potential in advancing mosquito control strategies, paving the way for more efficient and sustainable approaches to mitigate the spread of mosquito-borne diseases.

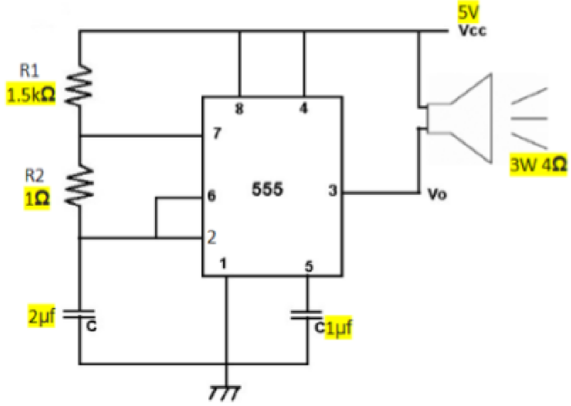

Figure 5. Circuit diagram of Attraction unit.

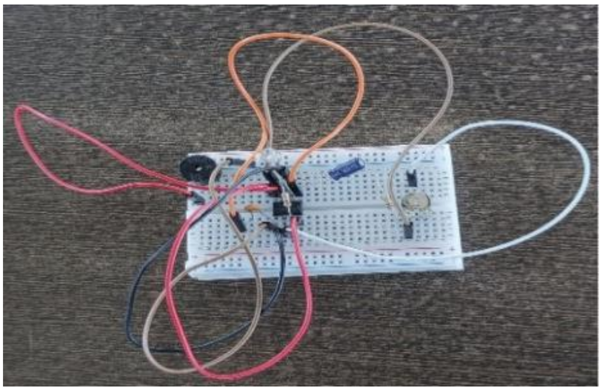

Figure 6. Experimental setup of attraction unit.

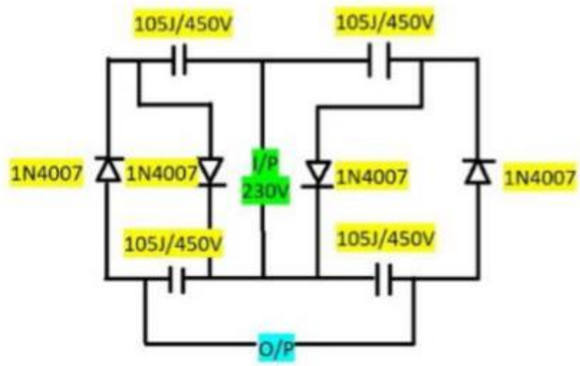

Figure 7. Circuit diagram of Distraction unit.

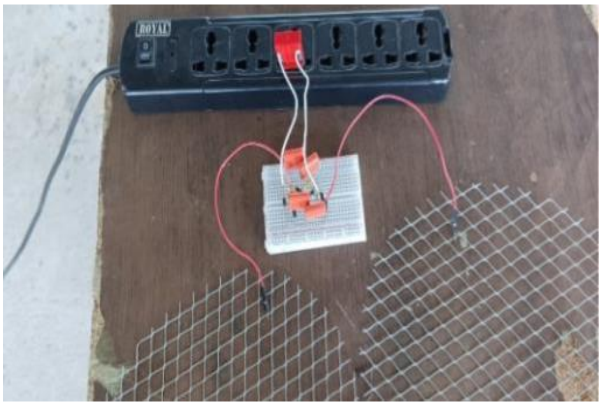

Figure 8. Experimental setup of distraction unit.

Distraction Unit

The distraction unit employing electricity in mosquito control serves as a key mechanism for diverting mosquitoes away from human populations. By utilizing innovative technologies such as electric grids or mosquito zappers, this unit effectively captures and eliminates mosquitoes upon contact. Electric grids emit low-voltage electrical currents that attract mosquitoes and swiftly eliminate them upon contact, providing a targeted and efficient approach to mosquito control. Circuit Diagram and Experimental set up is shown in Figures 7 and 8 respectively. This method offers advantages such as minimal environmental impact and rapid mosquito eradication. Through the strategic deployment of electric distraction units, researchers and public health officials can effectively manage mosquito populations and mitigate the spread of mosquito-borne diseases, contributing to improved public health outcomes.

CONCLUSIONS

The Aedes aegypti mosquito stands as a formidable vector for the transmission of dengue fever, a significant global health concern. Its ability to thrive in urban environments, breed in small, stagnant water sources, and feed readily on human hosts has contributed to the widespread dissemination of the dengue virus. The complex interaction between the mosquito vector, the dengue virus, and human populations underscores the necessity for comprehensive control and prevention strategies. This project aims for the eradication of dengue causing mosquitoes thereby not disturbing the population of other insect or mosquito species. It is a user friendly project and does not release the chemicals like other mosquito repellents. In this project, a UV light source is used to attract the mosquitoes. Apart from this a speaker is used which produces the frequency that attracts the mosquitoes. The image of the attracted mosquitoes are captured using a camera and mosquito classification is carried out by Artificial Neural Network through feature comparison. After image processing, the mosquito is identified as either Aedes Aegypti or not, and firing circuit is triggered. Thus the Aedes Aegypti mosquitoes are killed. Therefore we can strive towards reducing the burden of mosquito-borne diseases and protect the health and well being of populations worldwide

Acknowledgment

We hereby express our sincere gratitude to our guide Mr Thasreef H R, Assistant Professor, Electrical and Electronics Engineering Department, College of Engineering Perumon for his valuable guidance and suggestions. We also express our sincere thanks to Dr Mohanalin Raja Ratnam, HOD, Electrical and Electronics Engineering Dept. for his valuable assistance and necessary directions which aided us in the completion of this venture. We also express our sincere thanks to our principal Dr. Bindhu S J for her support and guidance.

Finally, we extend our gratitude to the entire faculty of the department and to all our friends for their help in carrying out this work successfully.

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