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IMPLEMENTATION OF AN AUTOMATED MOSQUITO NET AND REPELLENT SYSTEM FOR MALARIA PREVENTION IN RESIDENTIAL SETTING: A CASE STUDY OF CYABINGO SECTOR, GAKENKE DISTRICT.

A dissertation submitted in partial fulfillment of the requirements for the award of a Bachelor's Degree of Science with Honors in Computer Science, Option of Industrial Information Technology.

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DECLARATION OF ORIGINALITY

I do hereby declare that the work presented in this dissertation is my own contribution to the best of my knowledge. The same work has never been submitted to any other University or Institution. I, therefore declare that this work is my own for the partial fulfilment of the award of a Bachelor's degree with honors in Computer Science, option of Industrial Information Technology at INES-Ruhengeri.

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APPROVAL

This is to certify that this dissertation work entitled "Implementation of an Automated Mosquito Net and Repellent System for Malaria Prevention in Residential settings" is an original study conducted by MANIRAKIZA Gedeon under my supervision and guidance.

Supervisor's name: NIYOMUGABA Alexandre

Supervisor's signature: ....

Submission date: ....

DEDICATIONS

To my:

Parents

Family

Friends

ACKNOWLEDGEMENTS

This project has completed with the help of many people, including my family, friends, classmates, and lecturers. Without their support and encouragement, this work would not have been possible. I thank the Almighty God for giving me life, health, and strength from primary school up to this level of education. I also express my deep thanks to the Government of Rwanda, the Ministry of Education, and INES-Ruhengeri for their support in providing quality education and helping students become independent. My special thanks go to my supervisor, Mr. NIYOMUGABA Alexandre, for his support, guidance, and patience during this research work. Lastly, I sincerely appreciate my dear parents, brothers, sisters, and friends for their love, sacrifices, and encouragement, especially during difficult times.

ABSTRACT

The implementation of this Automated Mosquito Net and Repellent System for Preventing Malaria in Residential Areas, prioritizing the Cyabingo Sector, Gakenke District, employs IoT technology to provide an effective, cost-effective solution for malaria risk reduction. The smart system provides automated control of the manner in which a mosquito net oscillates and a repellent triggers, based on climatic factors and human activity. The system uses an ESP8266 microcontroller, an ultrasonic sensor to detect the presence of a human, a DHT11 sensor to detect temperature and humidity, a servomotor to raise or lower the mosquito net, and a relay module to control the repellent device. A push button also made available for user control so that users can turn the net and repellent ON or OFF regardless of the sensor input. The working rationale is simple and efficient, whenever a human detected or the temperature exceeds 30°C, the mosquito net turns HIGH and the repellent switched ON using the relay. When the button activated, the system reverses the current state. Its simplicity, affordability, and modularity establish it as an ideal tool for home-based malaria prevention in the developing world. First priority. By automatically managing mosquito netting and releasing repellent, this system offers a low-cost, noninvasive malaria preventive measure that supports community health resilience and local healthcare efforts. A cheap, simple technology enables effective disease control and quality-of-life enhancement in malarial region.

Keywords: IoT, ESP8266, Ultrasonic Sensor, DHT11, Servomotor, Relay Module.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

ADC:	Analog to Digital Converter
API:	Application Programming Interface
BME280:	Bosch Environmental Sensor 280
DAC:	Digital to Analog Converter
DHT11:	Digital Humidity and Temperature Sensor (version 11)
EMR:	Electromechanical Relays
ESP32:	Espressif Systems Protocol 32
ESP8266:	Espressif Systems Protocol 8266
GPIO:	General Purpose Input/output
GUI:	Graphical User Interface
I2C:	Inter-Integrated Circuit
IDE:	Integrated Development Environment
INES:	Institut d'Enseignement Supérieur de Ruhengeri.
IoT:	Internet of Things
IRS:	Indoor Residual Spraying
ITNs:	insecticide-treated mosquito nets
LED:	Light Emitting Diode
LoRa:	Long Range Radio
PWM:	Pulse Width Modulation
SDG:	Sustainable Development Goal
SSR:	Solid State Relays
UART:	Universal Asynchronous Receiver/Transmitter
WHO:	World Health Organization
Wi-Fi:	Wireless Fidelity

LIST OF APPENDICES

CHAPTER I: GENERAL INTRODUCTION

1.1 Background of the study

In this fourth industrial revolution, Malaria is one of the biggest public health threats in sub-Saharan Africa and Rwanda, especially in CYABINGO Sector. The disease, caused by Plasmodium parasites transmitted through bites of infected female Anopheles mosquitoes, has led to significant morbidity and mortality worldwide. According to WHO, in 2019, there were 229 million cases and 409,000 deaths globally (Monroe et al., 2022), with Africa bearing the highest burden.

In Rwanda, despite malaria control programs such as the distribution of insecticide-treated mosquito nets (ITNs) and indoor residual spraying (IRS), malaria remains a major challenge, particularly in rural areas like CYABINGO Sector in Gakenke District. Many households are not consistently protected due to the misuse of mosquito nets highlighting the need for innovative malaria prevention solutions(Tyagi et al., 2024). Integrating modern automation, embedded and IoT technologies into public defense can maximize total security by using smart sensors to monitor environmental factors and initiating mechanized systems based on real-time input. With such cutting-edge technologies (Salam & Farooq, 2020).

With these technologies, an automatic mosquito net can programmed to deploy only when needed, minimizing exposure and ensuring full coverage while sleeping. The integration of these smart technologies will make malaria control (Birkett et al., 2013) in homes. This system developed based on the limitations faced in the current malaria prevention processes in the CYABINGO Sector. Furthermore, the increasing resistance of mosquitoes to insecticides has made traditional control measures less effective, calling for an alternative approach(Oxborough, 2016). By employing an automated mosquito net and repellent system, we can facilitate these challenges.

1.2 Problem Statement

Despite national efforts to combat malaria in Rwanda, rural communities like CYABINGO Sector in Gakenke District continue to experience high rates of infection due to the limitations of traditional prevention methods. These include improper or inconsistent use of mosquito nets; discomfort caused by heat and poor airflow under the nets, low durability of insecticide-treated nets, and reduced effectiveness of indoor residual spraying due to insecticide resistance. As a result, existing manual interventions fail to provide reliable and user-friendly protection. There is a need for an automated solution that enhances usability, ensures consistent protection, and reduces dependence on human intervention.

1.3 Objectives

1.3.1 General objective

The main objective of this study is to Implementation of an Automated Mosquito Net and Repellent System for Malaria Prevention in Residential Settings.

1.3.2 Specific objectives

To achieve the main goal of developing an Automated Mosquito Net and Repellent System for Malaria Prevention in Residential Areas, the following specific objectives were set to guide the design, implementation, and evaluation of the system:

i. To collect data gathering that offers true and comparative data on the occurrence of malaria, level of mosquito activity,

ii. To analyze data received to make realistic conclusions and ascertain operational and technical requirements required in an attempt to create an automated mosquito net

iii. To develop, design and deploy an automated mosquito net through the application of sensors

iv. To test if the system works by verifying that it is performing as per prescribed requirements at home.

v. To conduct tests on the energy efficiency of the system for optimal power utilization and sustainability for household use over a long time.

vi. To evaluate long-term reliability and endurance of the system under different conditions of the environment to determine its performance in the field.

1.4 Research Questions

To introduce the research questions focusing on malaria incidence rates, mosquito behavior, and weaknesses of conventional protective measures, along with data-driven observations for deriving functional and technical requirements for an automatic mosquito net and repellent device:

i. What are the dominant malaria incidence rates, mosquito behavior and weaknesses of conventional malaria protective mechanisms?

ii. What are some of the facts observed in the data gathered which can utilized in the derivation of the functional and technical requirements of an automatic mosquito net and repellent device?

iii. How can the automated mosquito net designed to function smoothly while ensuring user convenience and durability?

iv. To what extent does the applied system satisfy functional requirements, and to what extent does it eradicate mosquito-borne disease within indoor environments?

v. In what ways and to what extent is the presented system economically feasible, and how can the latter be sustained on a long-term scale within local communities?

vi. For how many years can the system survive under changing environmental conditions, and how cost-effective is it in the long term?

1.5 Choice of study

This work motivated by the depth of the case study method in order to provide a holistic study of issues, challenges, and environmental aspects that affect or will affect, in particular, the sector of CYABINGO in the Gakenke District. It has qualitative and quantitative data accumulated that analyzed to bring out meaningful conclusions about the efficacy of current malaria prevention measures. Allow capturing the exact experience of the people in the selected area regarding the use of ITNs/IRS. The case study method involves direct interaction with the community through observations, interviews, and surveys to ensure better perception of local views and practices on malaria prevention. It gives the researcher room for detail without the dilution that might occur in larger, multi-site studies. Such an insight from a localized study may then be adapted and scaled up for similar rural areas facing comparable challenges.

1.6 Significance of study

1.6.1 Personal Interest

The current research interest to individuals it promotes innovative health solutions by using automation to improve malaria prevention. To researchers and scientists, as well as medical practitioners, this research is of significant information on intelligent health solutions and positioning them in disease control. The research also offers a platform for career development in professional fields of embedded systems, automation. By implementing an effective preventive mechanism, the research gives better protection for vulnerable groups such as children and the elderly with minimal reliance on manmade intervention.

1.6.2 Community Interest

Malaria remains a public health problem, and the system is a continuous and automatic protection system independent of human action. The project does not undermine national and global policy towards malaria control and assists Rwanda in the elimination of malaria incidence, and to the United Nations Sustainable Development Goal (SDG 3: Good Health and Well-being). This system solves one of the largest health issues in malaria-endemic rural communities due to inadequate mosquito protection behavior. Through providing automated protection, it covers everyone, even forgetful or defaulting ones, against mosquitoes,

1.7 Hypotheses

To guide the development and evaluation of the proposed automated mosquito net and repellent system, several hypotheses formulated. These hypotheses are based on the assumption that integrating Internet of Things (IoT) technologies with automated malaria prevention mechanisms can improve both functionality and user experience.

Hypothesis 1: It hypothesized to utilize an ESP8266 microcontroller board, an automatic mosquito net drive, and multi-color LED indicators for system status.

Hypothesis 2: It hypothesized to enable remote monitoring and control of the system, thereby reducing the need for manual interventions.

Hypothesis 3: It hypothesized to enhance the effectiveness and efficiency of malaria prevention efforts through the integration of automated technology

1.8 Delimitations of the study

The developed system designed to automate mosquito defense by deploying human detecting motion. Ultrasonic sensors detect human presence, triggering the automatic operation of the mosquito net and repellent dispenser. The system engineered for continuous operation with reliable power sources, including battery backup for use in unstable power conditions. It designed withstand various weather conditions, but may face with challenges due to architectural variations in buildings and climatic differences, affecting its reliability for permanent installation. The effectiveness of the technology relies on technical expertise during implementation and training for optimal operation and maintenance. While the system supplements existing malaria prevention methods such as medical treatment and public education, it should not be solely relied upon standalone solution. Its integration into a comprehensive malaria prevention framework enhances its overall effectiveness.

1.9 Research Methodology

Various methods applied to gain a comprehensive understanding of the challenges and potential solutions for malaria prevention in the CYABINGO Sector. The data collection process involved field surveys, structured interviews, and observational studies to capture both quantitative and qualitative data on current malaria control practices and community behaviors. These tools administered to a representative sample of households to assess malaria prevalence and evaluate the effectiveness of existing preventive measures. In-depth interviews with local health officials and community leaders provided valuable insights and expert opinions on the limitations of current interventions. Observational studies conducted to identify practical challenges associated with the use and maintenance of insecticide-treated nets and indoor residual spraying. To streamline data collection, Google Forms utilized for structured community responses. The collected data analyzed using thematic analysis and statistical techniques to identify key factors that be addressed through technological innovation. These findings guided the design and development of the automatic mosquito net and repellent system. The system, which incorporates an ESP8266 microcontroller, an automated mosquito net drive, multi-color LED indicators, and a battery-powered setup, tested under controlled conditions to assess its performance. IoT connectivity integrated to enable remote monitoring and reduce manual intervention. Validation procedures implemented to ensure the system met functional requirements and effectively contributed to malaria prevention.

1.10 Study organization

This study organized under five general chapters. Chapter one introduces the project by giving the study background, problem statement, objectives and research questions, hypothesis, scope, delimitations, and significance of the proposed system. Chapter Two provides an extensive literature review of the existing measures to prevent mosquitoes, which definition of key terms used and related works of other researchers. Chapter Three explains system design and analysis, hardware and software requirements, system design, component specifications, database design, and development methodology used. Chapter Four result abstained after discussing explains implementation and system testing and, , Finally, Chapter Five concludes the research by highlighting key findings, its contribution to the system, as well as its recommendations for its future technology improvement and mass application.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter presents an overview of a critical review of major technologies, subcomponents, and research studies on the design of an Automatic Mosquito Net and Repellent System. Literature review helps to understand the feasibility, technicalities, and justification for the approach adopted for solving the problem of preventing malaria. It has Section different, such as key term definition that is concerned with core technologies and components adopted in the system their categories and functionality with alternative comparisons.

2.2 Definition of key terms

2.2.1The Internet of Things (IoT)

The Internet of Things (IoT) enables smart devices like sensors and microcontrollers to communicate and automate tasks over a network. In this project, IoT allows remote monitoring and automatic control of the mosquito net and repellent system(Kevin Asthon, 2010). Automation refers to the system operating without human intervention, triggered by sensor inputs such as human presence. The ESP8266 microcontroller processes sensor data and controls outputs like the motor and repellent. Ultrasonic sensors detect humans by measuring distance, enabling the system to raise or lower the mosquito net. The repellent system disperses insecticide when the net is raised, enhancing malaria prevention. This solution uses home and programmable automation, improving efficiency and health outcomes in residential settings.

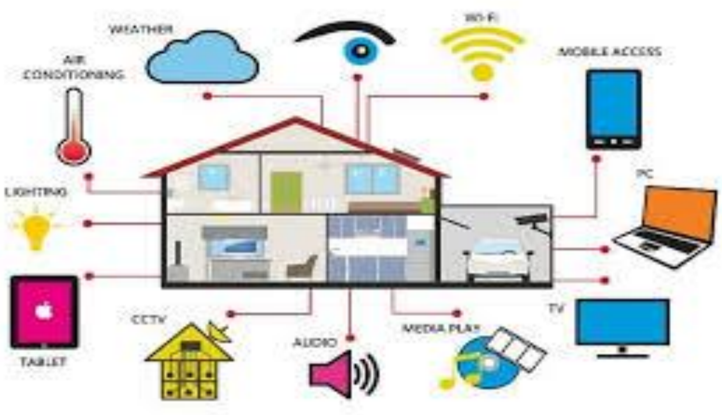

Figure 1: Internet of Things (Hickman & Akdere, 2018)

2.2.2 Automation

Automation is the use of technology to perform tasks with minimal or no human intervention, improving efficiency, accuracy, and reliability (Groover, 2015). In the context of this project, automation enables the mosquito net to respond intelligently to sensor inputs like human presence. There are three main types of automation**:** Fixed automation, which performs pre-defined tasks, Programmable automation, which allows the system behavior to modify through software; and Flexible automation, which adapts to changing conditions and user inputs (Lee et al., 2015).

Figure 2*:* Home automation (Selver et al., 2011)

2.2.3 Espressif Systems Wi-Fi Modulet

Espressif Systems recognized as a pioneer in wireless communication and IoT solutions, renowned for its cost-effective yet high-performance Wi-Fi and Bluetooth modules. The company's product line includes popular devices such as the ESP8266 and ESP32 series, widely adopted in diverse IoT and automation applications (Delvaux et al., 2024). Espressif's products known for their integratability, power efficiency and making them suitable for deployment across smart home appliances.

The ESP32, an advancement over the ESP8266, not only supports Wi-Fi but also Bluetooth, enhancing its versatility across a broad spectrum of applications. Featuring 34 GPIO pins, the ESP32 supports digital I/O operations, PWM for motor and LED control, and 18 analog input pins for sensor integration, all operating at 3.3V logic levels. Certain GPIO pins facilitate communication via standard protocols like I2C, SPI, and UART, facilitating seamless interfacing with peripherals. Notably, ESP32 GPIO pins are tolerant of 3.3V logic but susceptible to damage above 3.6V (Espinosa-Gavira et al., 2024).

The ESP32 here as it can offer both Wi-Fi and Bluetooth connectivity, which is advanced communication capability for the mosquito repellent system. Its increased processing capability and more available GPIO pins offer more flexibility in interfacing with other devices and thus best suited to offer the system's advanced IoT capability and enable mobile app control in a seamless manner.

Figure 3:ESP32 vs ESP8266 Modules (Conference, n.d.)

2.2.4 Servo Motor

A servo motor is a precision-controlled actuator that adjusts its position based on an input signal.it is categorize into actuators used in robotics, automation and IoT application, there are other different motors like DC Motor, Stepper motor and are different according to the Precision control type.

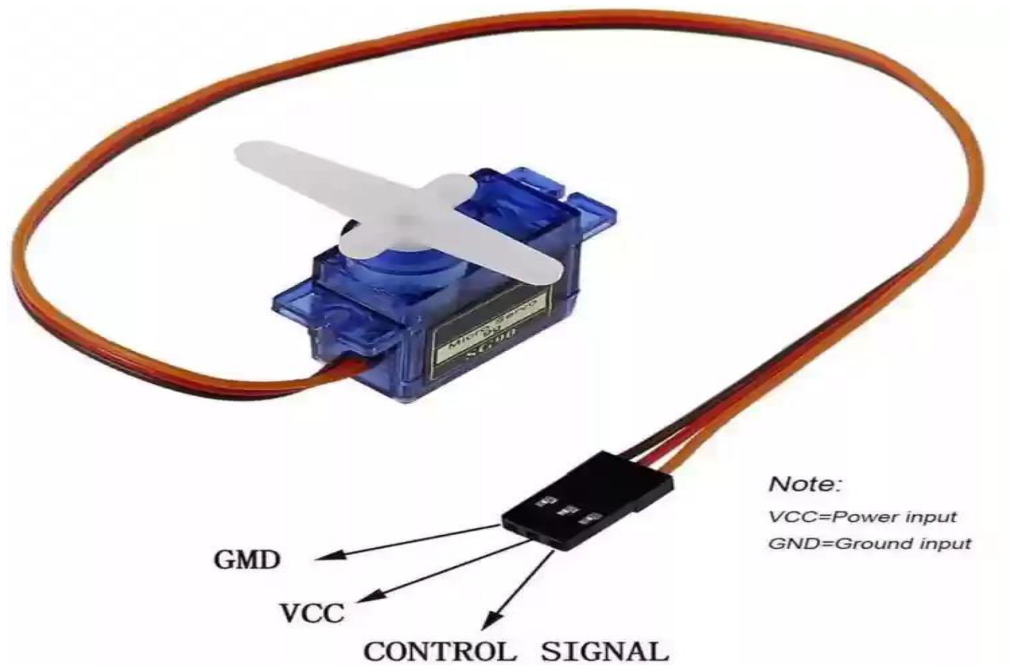

Figure 4: Servomotor (Abdul Ali et al., 2020)

where servo motor has high precision and use PWM as control type while DC motor have low precision and use Voltage -based as control type then stepper motor use low precision and step-based as control type

Within this project, I used servomotor selected because it allows precise control over the mosquito net's movement as servo motor application in home Automation said

2.2.5 DHT11 Sensor: Temperature and Humidity Monitoring

The DHT11 sensor is a digital temperature and humidity sensor commonly used in environmental monitoring systems. It contains a thermistor for measuring temperature and a capacitive humidity sensor for detecting moisture levels in the air. The DHT11 operates using a single-wire communication protocol, making it easy to interface with microcontrollers like Arduino and ESP8266 (Bulu, 2011). it is categorized as environmental sensor

While DHT22 provides higher accuracy and a wider temperature range, which is -40^{0}c to 80^{0}c, DHT11 is cheaper, energy-efficient, and reliable for general indoor applications and temperature range 0^{0}c to50^{0}c. The BME280, another alternative, also measures barometric pressure, making it suitable for weather stations temperature range -40^{0}c to85^{0}c. Temperature and humidity application is to influence mosquito breeding patterns (Fried, 2024). By monitoring climate conditions, the system can determine the

Optimal time to activate the mosquito repellent. Within this project, DHT11 used because it is cost-effective, power-efficient, and provides sufficient accuracy for monitoring indoor condition mosquito repellent system.

Figure 5: DHT11 and DHT22 Sensors (Fried, 2024)

2.2.6 Ultrasonic Sensor

The Ultrasonic Sensor is an ultrasonic distance sensor used to detect objects by measuring the time it takes for sound waves to bounce back after hitting an obstacle (Zhmud et al., 2018). It contain four different pins VCC pin, Echo pin, Trig pin and GND and it is categorized distance and proximity sensor and used in security, robotics and Automation.

Figure 6: Ultrasonic Sensor (Johnson et al., 2025)

The HC-SR04 ultrasonic sensor is a widely used model for distance measurement in embedded systems. It works by emitting 40 kHz sound waves and measuring the time it takes for the echo to return. This time is used to calculate the distance to an object using the formula: Distance = (Time × 0.0343) / 2. The sensor has a range of 2 cm to 400 cm with ±3 mm accuracy. It uses two pins: Trig to send the signal and Echo to receive it. In smart systems like an automatic mosquito net, it detects human presence to trigger automatic responses.

The Ultrasonic sensor use Ultrasonic waves as working principle with +/- 0.3cm Accuracy with low power consumption while IR us infrared based as working principle with moderate as accuracy and low power consumption and LIDAR us Laser-based as working principle with high accuracy and high power consumption. Within this project, I used the Ultrasonic sensor because is not affected by lighting conditions, which is Unlike to IR sensors. However, LIDAR sensors provide higher accuracy but are expensive, it is affordable, accurate, and reliable for detecting movement near the mosquito net, and it used to detect human presence, triggering the mosquito net's deployment when someone is near.

2.2.7 Relay

A relay is an electromechanical switch to power high-power loads from a low-power signal. It is an electromagnet, contacts, and a spring. The electromagnet pulls the contacts when energized and closes the circuit; the spring pushes the contacts when power cut, and the circuit opened and broken. Mechanical relays deliver high current (10–15 Amps), electrical isolation, reliability, and simplicity of use, and hence are optimally used in control and automation (Srivastava et al., 2018). A typical relay has five pins: coil pins, common (COM) pin, normally open (NO) pin, and normally closed (NC) pin, which have an impact on circuit wiring. Mechanical relays are cheaper and better suited for high-power applications than reed relays and solid-state relays (SSRs). A mechanical relay utilized in the project because it is cheap, efficient, and able to handle high-power devices like the mosquito repellent dispenser and net motor without exposing the microcontroller to electrical spikes.

Figure 7: Relay (high tech ltd)

Relays are switches used to control high-power devices using low-power signals. Common types include **Electromechanical Relays (EMR)**, which use moving parts, and **Solid State Relays (SSR)**, which use semiconductors for faster, silent switching. **SPST**, **SPDT**, and **DPDT** refer to the number of poles and throws for switching circuits. Some relays like **Time Delay** and **Latching Relays** offer specific control features. **AC and DC relays** designed based on the type of current they handle. The choice of relay depends on application needs such as speed, load, voltage, and isolation.

2.2.8 Mosquito Net Material

The material of a mosquito net is critical in its operation when it comes to providing protection from mosquitoes, especially in malaria-prone areas. Mosquito nets are typically made of polyester, cotton, or nylon material and are typically insecticide-treated to enhance their effectiveness. Mosquito netting materials also offer a number of essential aspects: durability, as polyester and nylon nets will withstand wear and tear, being able to last for the long term; insecticide treatment, which offers double protection by eliminating or repelling mosquitoes; and breathability, which offers airflow and keeps the area under the net pleasant. In comparison to other materials, cotton nets are less efficient and less durable but more ventilated, while nylon nets are tear-resistant but potentially less ventilated than cotton (Cucinotta & Vanelli, 2020). In this project, I have used a nylon mosquito net since it is lightweight, long lasting, and treated with insecticides easily, providing long-term protection against mosquitoes.

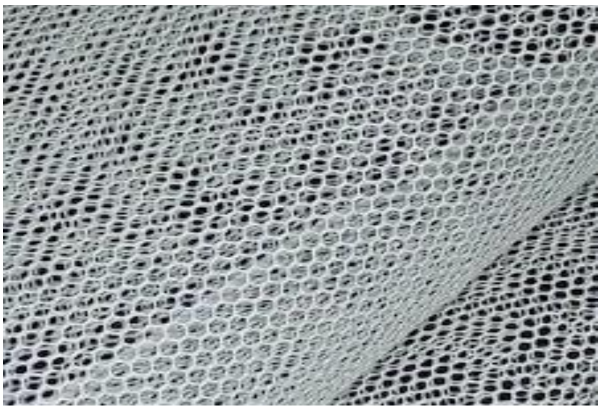

Figure 8: Mosquito net

2.3 Related works

This part reviews existing solutions related to mosquito control and highlights their limitations and potential improvements, forming the basis for our proposed automatic mosquito net and repellent system. Malaria remains a significant public health challenge, particularly in sub-Saharan Africa. Various technological advancements explored to mitigate the spread of malaria, including mosquito repellent systems, automated mosquito nets, and smart home integration for disease prevention.

2.3.1 Smart Mosquito Nets

Automated mosquito nets designed to deploy or retract based on environmental conditions or human presence.(Kim & Lee, 2020)developed a motion-sensing mosquito net that automatically lowers when a person enters a sleeping area. Their system relied on Passive Infrared (PIR) sensors, which detect body heat and motion. However, the system faced challenges in differentiating between human and non-human movements while they are inside, leading to inefficiencies in automation. Our approach differs by utilizing a manual button to control the mosquito net's movement. This method ensures that the net deployed only when needed, preventing false activations and enhancing user control (Darbari et al., 2025).

2.3.2 IoT Based Approaches for Smart Health Solutions

IoT technology had utilized in malaria prevention and control. Studies such as (Muhammad Waqas Shah & Pasha, 2017) highlight the effectiveness of IoT in monitoring mosquito activity and controlling repellents remotely via mobile applications. However, these solutions depend on internet connectivity, which is often unreliable in rural communities like Cyabingo Sector. By integrating a standalone control mechanism with minimal IoT dependency, our design addresses network reliability concerns, ensuring that the system remains functional even in areas with poor internet coverage (Khan et al., 2012).

2.3.3 Ultrasonic Based Mosquito nets

Proposed an ultrasonic sensor-based mosquito net system, where ultrasonic waves detect human presence. This system aimed to lower the mosquito net automatically based on the detection of human body movement and distance. The system was integrated ultrasonic sensors to detect human presence and activate the net accordingly and they use Ultrasonic sensors and motors technologies, the system was able detecting human movement and deploying the net based on this input effectively but it was unable to differentiate between human movement and other objects in the environment, such as pets. This increased false activations and wasted energy(Johnson et al., 2021). Unlike these systems, which rely on sensors like ultrasonic waves, our approach employs a manual button for user input and integrates an ultrasonic sensor for more accurate human presence detection. The manual button allows for more control that is reliable and ensuring the mosquito net only activates when the user chooses. The ultrasonic sensor detects human presence with greater precision, activating the net for a specific period.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter in this final project is concerned with the organizational structure and historic of the case study of the researcher choice then after provides the real practices or constructions that the researcher had to deal with for enhancement. The same the researcher explicitly and intensity state the problem basing on the data that researcher has collected. Researcher has to present each and everything in his research project in technical and practical way. Briefly, this chapter focused on finding solution to the problems stated in my research project.

3.2 Case Study

The CYABINGO Sector selected as the case study area due to its high malaria prevalence and limited access to mosquito prevention tools. It represents a typical rural setting in Rwanda with poor housing conditions that contribute to malaria transmission. The study targeted selected households to collect data on current prevention practices, mosquito presence, and community awareness. These insights guided the system design to meet actual user needs. The system uses sensors (ultrasonic, temperature/humidity, manual button), actuators (servomotor), and ESP32 microcontroller. Other components include LED indicators, battery power supply, and a protective housing frame with a mosquito net.

Figure 9: Case study Cyabingo Health Center

3.3 Data collection Techniques

3.3.1 Quantitative techniques

Both quantitative and qualitative techniques employed to collect data relevant to malaria prevention in CYABINGO Sector. Quantitative data gathered through household surveys and structured interviews focusing on the prevalence of malaria, current prevention practices, and mosquito exposure. Qualitative data was obtained through field observations, documentation reviews, and semi-structured interviews with community health workers, local leaders, and affected residents.

i. Sampling Techniques

A purposive sampling method used to select participants with firsthand experience of malaria exposure and prevention challenges. This included households that frequently use mosquito nets, community members aware of local health interventions, and health officials familiar with the limitations of current manual mosquito control measures. This approach ensured relevant and focused data for the development of the automated system.

ii. Sample size

The sample size was determined using Allain Bouchard's probabilistic method (Proceedings & Stage, 2003), with the

$$Equation: nc = \frac{n}{1+\frac{n}{N}} \quad Equation\ [1]$$

Where n is the estimated sample size, N is the total population, and n_c is the corrected sample. The target population in CYABINGO Sector estimated at 1,400 households. Using a preliminary sample size of 302 (based on a 95% confidence level and 5% margin of error), the corrected sample size calculated as:

$n_c = (302 \times 1400) / (302 + 1400) = 422800 / 1702 \approx 248$

Therefore, 248 households surveyed in this study.

3.3.2 Qualitative techniques

Interviews employed as a preliminary method of obtaining qualitative information regarding the utilization of the automated mosquito net and repellent system. Interviews conducted among the residents of the Cyabingo Sector, local health workers, and local program coordinators. Pre-tested structured interviews conducted using a set of questions in advance regarding available malaria prevention measures, problems associated with traditional mosquito nets, and their idea regarding the use of technology to prevent diseases. The objective was to gain first-hand experience and expertise that would drive the design and usability of an automated system based on detection of human presence using sensors and actuators such as the ultrasonic sensor, servo motor, and relay.

i. Focus Groups

Group focus meetings held to obtain feedback in groups and opinions regarding existing mosquito prevention technology and feasibility of the proposed automated system. Some community members, local health officials, and engineers familiar with IoT technologies attended the meetings. The deliberations introduced the deficiencies of manual mosquito nets, how environmental factors affect them, and whether the use of an automatic system consisting of ESP8266, ultrasonic sensors, DHT11 sensors, servomotors, and relays was feasible. The team also explored possibility of push button as the manual override control and how system improve malaria protection in inhabitable areas. The objective was to identify user requirements, acceptability, and expectations to assist in ensuring that the solution has the ability to fit actual applications within the Cyabingo Sector.

ii. Observation

Observation carried out in a subset of the 248 selected households to understand real-world challenges in using traditional mosquito nets. Researchers noted issues such as improper installation, infrequent usage, and discomfort caused by heat and poor airflow, and maintenance difficulties. These observations helped reveal practical limitations in existing malaria prevention practices and informed the design features of the automated system.

iii. Questionnaires

Questionnaires distributed to all 248 households involved in the study. The questionnaires gathered quantitative data on the frequency of mosquito bites, malaria infection history, usage and condition of mosquito nets, and perceptions of automated solutions. The structured format ensured consistent data collection and enabled efficient comparison across households.

iv. Interview

Semi-structured interviews conducted with a sample of community leaders, local health workers, and heads of selected households within the 248 respondent group. These interviews provided qualitative insights into current malaria prevention programs, the challenges faced by residents, and the community's openness to adopting automated systems. This feedback was essential for tailoring the system to meet local needs.

v. Data Analysis

Data collected from the 248 respondents analyzed using both statistical and thematic methods. Statistical analysis involved calculating frequencies, percentages, and correlations related to mosquito net use and malaria incidence. Thematic analysis applied to qualitative responses from interviews and observations, identifying key patterns in user behavior, system expectations, and environmental challenges. The analysis results directly influenced the system's technical specifications and user centered design.

3.4 System development methodology approach

System development methodology refers to the framework that is used to structure, plan, and control the process of developing an information system. A wide variety of such frameworks has evolved over the years, each with its own recognized strengths and weaknesses. One system development methodology is not necessarily suitable for use by all projects. Each of the available methodologies is best suited to specific kinds of projects, based on various technical, organizational, project and team considerations(Wan & Wang, 2010).

3.4.1 Agile model XP

Agile is a wide umbrella of software development beliefs. It is a conceptual framework for software engineering that begins with a starting planning phase and follows the road toward the deployment phase with iterative and incremental interactions throughout the life-cycle of the project. The initial goal for the agile methods is to reduce the overhead in the software development process with the ability to adopt the changes without risking the process or without excessive rework (Erickson et al., 2005).

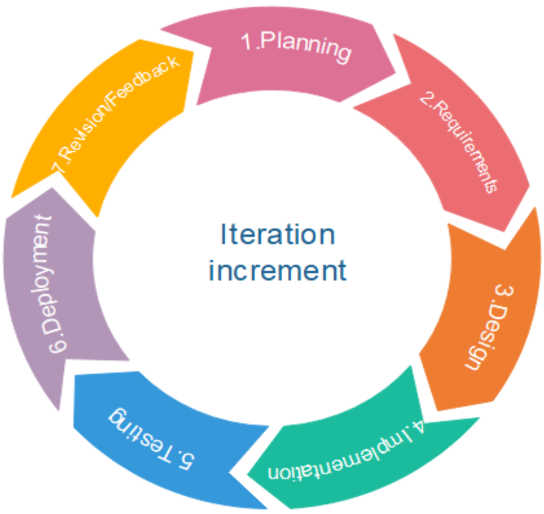

Figure 9: Agile model

3.4.2 Phase of Agile model XP

The Extreme Programming (XP) model is a type of agile software development methodology that emphasizes customer satisfaction, flexibility, and rapid delivery of high-quality software. It encourages frequent releases in short development cycles, which improves productivity and introduces checkpoints where new customer requirements adopted. The XP model consists of several well-defined phases that help teams build reliable systems efficiently while embracing changing needs and continuous feedback. The key phases of the XP model outlined below:

I. **Planning**: We defined the system's goal to automate mosquito net and repellent control for malaria prevention. Stakeholders identified, core features like human detection, climate sensing, motor control, and web display outlined. A sprint roadmap created.

II. **Requirements Gathering**: We gathered functional requirements such as automatic net and repellent activation, temperature and humidity sensing, and real-time GUI. Non-functional needs included low cost, low power use, and ease of operation. These guided hardware and software decisions.

III. **Design**: Hardware design included ESP32 pin mapping for sensors and actuators. Software design covered the GUI layout, database schema for storing sensor data, and HTTP communication between ESP32 and the server.

IV. **Implementation**: Development done in sprints. Sprint 1 focused on ESP32 programming and sensor integration. Sprint 2 handled GUI integration. Each sprint delivered a testable and functional module.

V. **Testing**: sensor tested accuracy, servo and relay response, data transfer, and GUI performance. Unit and integration testing done after each sprint to ensure reliability and detect bugs early.

VI. **Deployment**: Each sprint is output deployed in a simulated home environment. ESP32 and GUI were set up locally. Incremental deployment allowed real-time testing and fast feedback integration.

VII. **Revision & Feedback** User feedback led to adjustments in sensor sensitivity, GUI layout, and system timing. Improvements added in mini sprints without interrupting the system. The process ensured continuous user-focused enhancement

3.5 System Requirements

3.5.1 Functional Requirements

The functional requirements define the essential operations that the system must perform. They focus on how the system responds to inputs and carries out tasks such as sensing, controlling, and displaying information. This section outlines both the data handling and core automation functions. It ensures the system behaves as intended to achieve malaria prevention goals.

I. The system should use an ultrasonic sensor to detect the presence of a person inside the room or under the net.
II. When human presence detected, the system should automatically activate the servomotor to raise the mosquito net
III. A relay module control the operation of an electronic mosquito repellent or fluid dispenser.
IV. The system should automatically switch ON the repellent when the mosquito net raised and switch it OFF when the net lowered.
V. A push button integrated into the system to allow users to manually raise or lower the mosquito net and toggle the repellent ON or OFF. This is useful when someone wants to exit or enter the net without waiting for the automatic sensor response, ensuring flexibility in real-life usage.
VI. It energy-efficient and suitable for continuous 24/7 operation in rural residential environments with limited technical infrastructure.

3.5.2 Nonfunctional requirements

This describe how the system should perform rather than what it does. They ensure the system is reliable, user-friendly, maintainable, and efficient in real-world conditions. These requirements address performance, usability, and long-term operation. They are critical for ensuring the system's sustainability and effectiveness in rural environments.

I. **Reliability**: The system should function reliably around the clock (24/7) with minimal errors or breakdowns, even in harsh environmental conditions. Components should be durable in rural conditions.
II. **Usability**: The system should be easy to understand and operate by local residents and health workers, using clear labels, simple interfaces, and minimal technical knowledge.
III. **Maintainability**: It should be easy to update firmware, calibrate sensors, and replace hardware components like the servo motor, relay, or DHT11 sensor.
IV. **Performance**: The system should respond quickly (within seconds) to sensor inputs and user actions, with minimal delay in execution and display. The system must be highly responsive with sensor inputs and user actions processed in near real-time or real-time, ideally within 1–2 seconds.

3.6 Hardware requirements

3.6.1 Node MCU

The ESP32, like its predecessor the ESP8266, represents a significant advancement in making IoT development more accessible. Developed by Espressif Systems, the ESP32 is a powerful System-on-a-Chip (SoC) that includes dual-core processors, extensive memory, built-in Wi-Fi and Bluetooth capabilities, and a rich set of peripherals. These peripherals include General Purpose Input/Output (GPIO) pins, Analog-to-Digital Converter (ADC), Digital-to-Analog Converter (DAC), and various communication protocols such as Serial Peripheral Interface (SPI), Inter-Integrated Circuit (I2C), and Universal Asynchronous Receiver-Transmitter (UART). These protocols enable efficient data exchange between the ESP32 and external devices like sensors, displays, and other microcontrollers, making the board highly suitable for diverse IoT and embedded applications.

However, what about development boards? The ESP32 ecosystem has flourished with numerous development board options that mirror the Arduino philosophy of accessibility. Popular boards like the ESP32-DevKitC, ESP32-WROOM, NodeMCU-32S, and TTGO boards provide the ESP32 chip on ready-to-use PCBs with USB connectors, voltage regulators, pin headers, and built-in programming circuits.

Similar to Arduino's approach, these ESP32 development boards can utilize different types of processing cores (typically the dual-core Xtensa LX6 processors), varying amounts of flash memory and RAM, and different sets of built-in peripherals. The flexibility of ESP32 reference designs means significant variations across different manufacturers and board types. Some boards include additional features like LED displays, Long Range (LoRa) is a low power, long-distance wireless communication technology used in IoT applications to connect devices over wide areas connectivity.

Unlike many Arduino boards that lack built-in wireless capabilities, ESP32 boards inherently include both Wi-Fi and Bluetooth, making them exceptionally well suited for IoT projects. The ESP32 also offers significantly more processing power, memory, and peripheral options compared to traditional Arduino boards, while maintaining compatibility with the Arduino IDE and programming environment through the ESP32 Arduino Core.

This combination of powerful hardware, wireless connectivity, and familiar programming environment has made ESP32 development boards extremely popular for IoT projects, robotics, and embedded applications where both processing power and connectivity are essential as depicted on figure 3.

3.6.2 DHT11

The DHT sensor used to measure temperature and humidity in the room. These environmental factors greatly affect mosquito activity; for instance, mosquitoes are more active in warm and humid conditions. The sensor sends its readings to the ESP32. The DHT22 is preferred over DHT11 due to its higher accuracy and wider range. Including this sensor adds a smart environmental monitoring capability to the system, making it proactive rather than just reactive as depicted on figure 4.

3.6.3 Manual Push Button

The push button is an important safety and usability feature placed inside the mosquito net. It gives the user control manually lower the net if they want to exit the bed or if automatic operation fails. When the button is pressed, it sends a digital input signal to the ESP32, which then activates the motor to bring the net down. This ensures that the system is not only automatic but also user-friendly and reliable in different situations.
Application: Provides manual control of the net for the user.
How it works in the project: If the user wants to exit the net or override automation, pressing the button signals the ESP32 to lower the net immediately.

Figure 10: Manual Push Button (Tan et al., 2023)

3.6.4 Servo motor

The servomotor is a key part of the mechanical movement of the mosquito net in the automated system. When the ultrasonic sensor or when a push button pushed manually detects human presence, the ESP8266 microcontroller sends a control signal to the servomotor to lower or raise the mosquito net by rotating its shaft to a specific angle.

Servomotors are ideal for applications requiring controlled angular displacement and, as such, are perfectly suited to dropping or lifting light nets smoothly and efficiently. Stepper motors follow their path in steps while servo motors use PWM signal for precise position control so that they can move to exact angles such as 0°, 90°, or 180°. The selection of the servo motor must take into account the torque to drive the mosquito net, weight of the net, and total angular displacement needed to open or close the net entirely. A pulley utilized in an effort to reduce the load on the motor and ensure smooth motion. Standard servo motors like the SG90 or MG995 are suitable for these applications due to their compact nature and responsiveness. The servo motor is a critical component in automating the system by offering quick and consistent movement via sensor inputs or override where needed, particularly at night when effective mosquito protection is most essential. This feature offers energy-efficient, repeatable, and low-maintenance operation without requiring any external position feedback systems as depicted on figure 5.

3.6.5 Ultrasonic Sensor

The ultrasonic sensor used for non-contact human presence detection in the bed area. It works by emitting ultrasonic waves and measuring the time it takes for the echo to return after bouncing off an object (in this case, a human body). The ESP32 processes this data to determine if a person is present. If a person is detected within a specific range (e.g., 50–100 cm), the sensor triggers the system to raise the mosquito net and start the insecticide dispensing. This automation eliminates the need for users manually adjust the net, making it more user-friendly and especially beneficial for children or elderly individuals. The sensor plays a critical role in ensuring the system responds intelligently to actual human presence rather than working on a timer or random schedule.

Application: Human detection to automate mosquito net and repellent activation.

How it works in the project: It sends real-time distance readings to the ESP32. When human presence detected, it triggers the system to raise the net and start repellent spraying as depicted on figure 7.

3.7 Software requirements

3.7.1 Arduino IDE

The brain of the system, the ESP32 microcontroller, programmed using the Arduino Integrated Development Environment (IDE). The IDE allows programmers to directly write, compile, and upload embedded C/C++ code onto the ESP32. Control logic i.e., sensor reads, motor and relay enables, and data sends to the cloud or local database are programmed through the IDE.

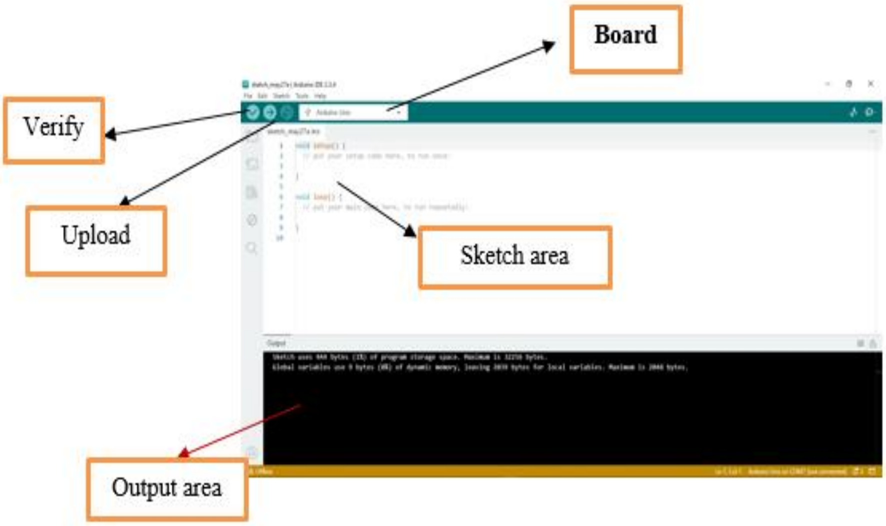

Figure 11: Arduino IDE Software

3.7.2 Discussion

I. Board: This dropdown is vital to hardware compatibility and allows developers to select their specific Arduino board (Uno, Nano, ESP32, etc.). The correct board selection affects the compilation settings, pin assignments, and memory usage. The wrong board selection can lead to upload failure or code that does not execute properly on the target hardware.

II. Verify: The checkmark button compiles the sketch without loading it onto the board. It is a basic debugging mechanism that checks for syntax, absent libraries, and code organization. Problems discovered early in development through the checkmark process, and time saved by finding issues before attempting hardware uploads.

III. Upload: The arrow button transfers the compiled code from the computer to the connected Arduino board. It is a compile, link, and flashing of firmware into microcontroller memory. It depends on proper board selection, proper port setting, and stable USB connection between computer and Arduino.

IV. Sketch area: The main white code area where programmers write Arduino code in C/C++ syntax. The editor includes at least syntax highlighting, auto-indent, and bracket matching.

V. Output zone: Compilation feedback, error messages, memory reports, and upload progress displayed in the black terminal zone. This feedback zone is crucial for debugging since it provides detailed error messages that warn developers of coding errors and how to debug them. It also provides success messages for uploads and technical information about compilation.

CHAPTER 4: DESIGN AND IMPLEMENTATION

4.1 Introduction

This chapter outlines the design process and implementation stages of the proposed IoT-based mosquito net and repellent system. It includes hardware and software design, logical architecture, system prototypes, user interfaces, and a discussion of the test results. Each component described with diagrams and justifications, providing a clear understanding of the system's functionality.

4.2 The output result from data analysis

Based on the data gathered, the response of the people towards the Automated Mosquito Net and Repellent System for Cyabingo Sector, Gakenke District, is highly receptive and adoptive. 56.3% of the respondents were highly positive and expressed keen interest and willingness to pay for the system, indicating high demand for automated equipment of malaria control. 37.5% conditionally favored them, which expressed interest but stated that adoption would be contingent upon matters such as affordability, i.e., cost-controlling measures such as subsidies could raise the level of acceptance. 6.2%, on the other hand, declared unsupportive and likely quoted low perceived need, lack of familiarity with IoT technologies, or economic limitation. These findings would reflect the system's viability within malaria-endemic populations and a call for low-cost delivery systems and educational programs to enable better penetration and impact throughout the population.

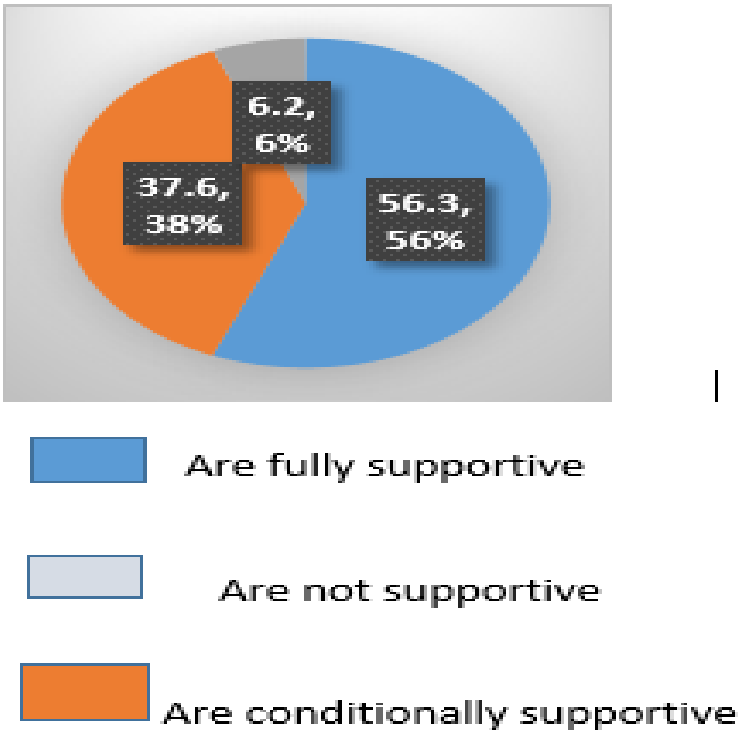

Figure 12: Output Results

4.3 System design

System design is the process of defining the architecture, components, interfaces, and data for a system to satisfy specified requirements. It involves a detailed and methodical approach to creating systems that meet both functional and non-functional requirements, ensuring that the system is scalable, reliable, maintainable, and performant.

4.3.1 Flowchart

A flowchart is simply a graphical representation of steps. It shows steps in sequential order and widely used in presenting the flow of algorithms, workflow or processes. Typically, a flowchart shows the steps as boxes of various kinds, and their order by connecting them with arrows. A flowchart used to define a process or project to implement.

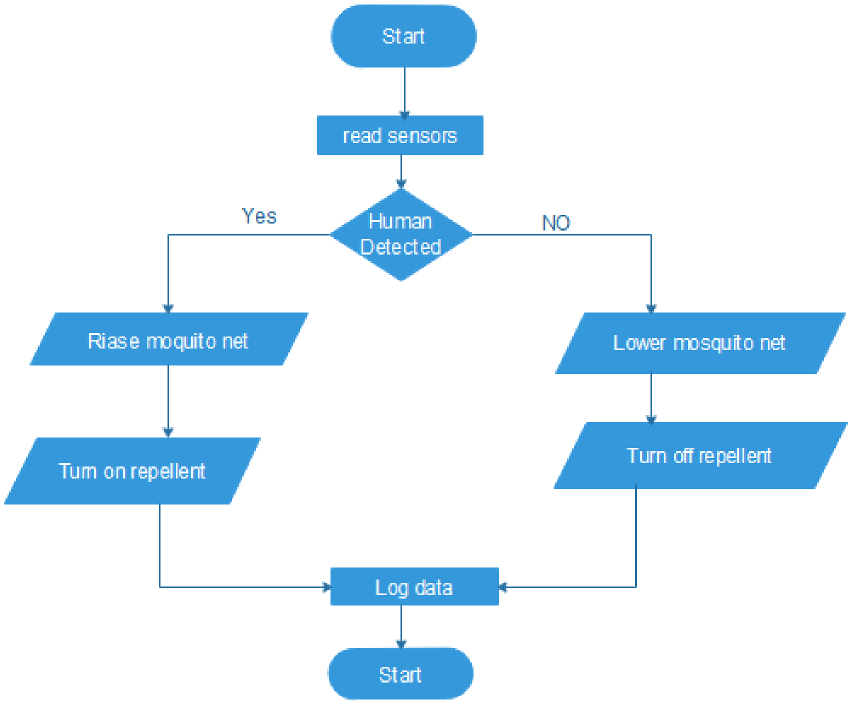

Figure 13: Flowchart

4.3.2 Use case diagram

A use case diagram can summarize the details of your system's users (also known as actors) and their interactions with the system. To build one, you will use a set of specialized symbols and connectors. An effective use case diagram can help your team discuss and represent. It represents all the scenarios that can happen between the user and the system.

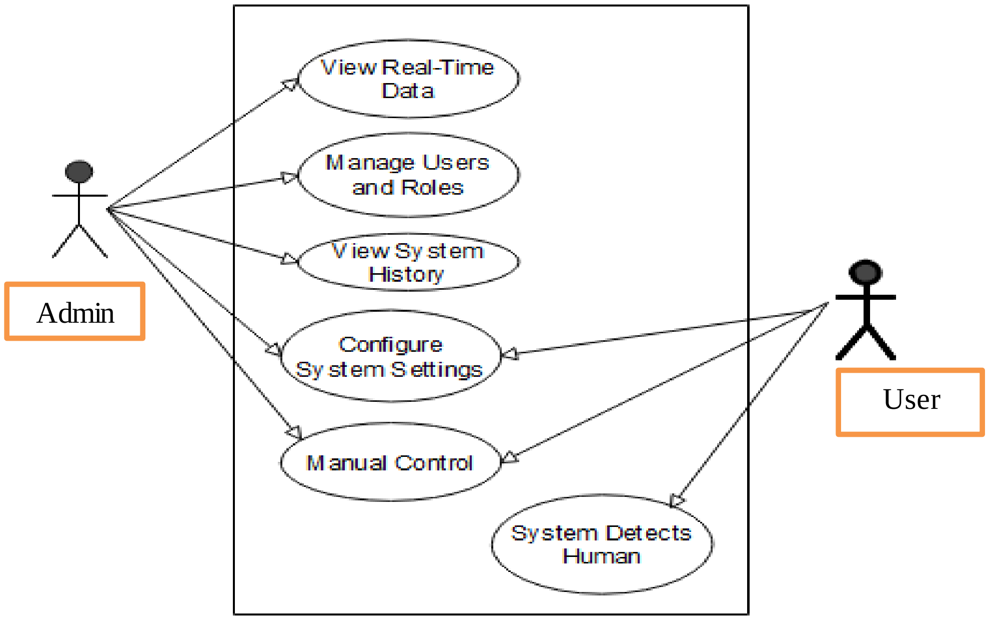

Figure 14: Use case Diagram

4.3.3 Sequence diagram

Designates the sequence of messages exchanged between various components or objects in a system to accomplish a specific process or function. It illustrates how the processes interact with one another and in what order, paying attention to time-dependent system behavior. The diagram read from top to bottom, vertical lines (lifelines) represent the objects or interactants, and horizontal arrows represent messages or signals passed between them. Sequence diagrams are widely used in software engineering to specify dynamic system behavior so that developers can comprehend, analyze, and document system behavior, especially in real-time and event-driven systems.

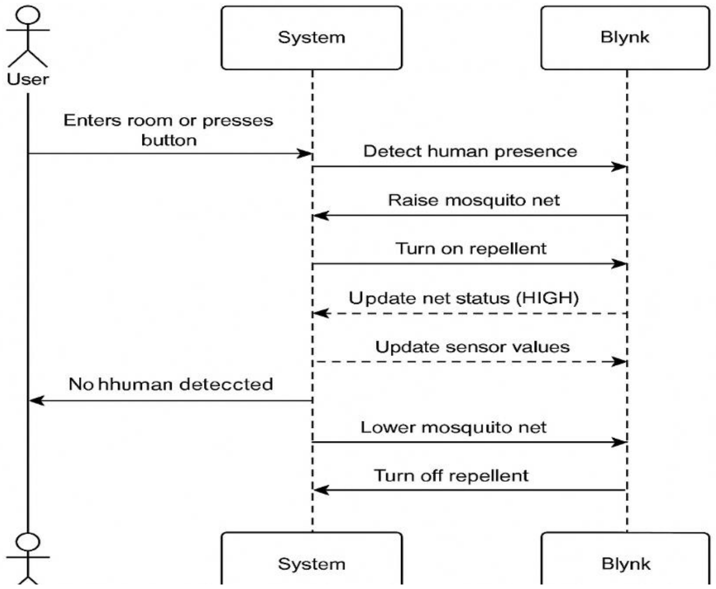

Figure 15: Sequence diagram

4.3.4 Physical architecture

Hardware setup of the Smart Mosquito Net and Repellent System based on the ESP32 microcontroller as the control device. It contains several key components integrated within itself that cooperate with each other to provide automated mosquito repellence. The ESP32 receives input from sensors and gives control signals to output devices. It uses an ultrasonic sensor to scan for distance to check if there are any human beings nearby and a DHT11 sensor to measure the surrounding environment temperature and humidity. Based on these inputs, a motor, relay system lowers, or raises the mosquito net accordingly. When the net raised and human presence detected, the repellent pump automatically sprays insecticide. The system powered by a stable power source, typically through USB or rechargeable battery. All the hardware modules interfaced with the ESP32 through its GPIO pins for hiccup-free real-time operation. The modularity allows for efficient operation and effortless modification or scaling of the system

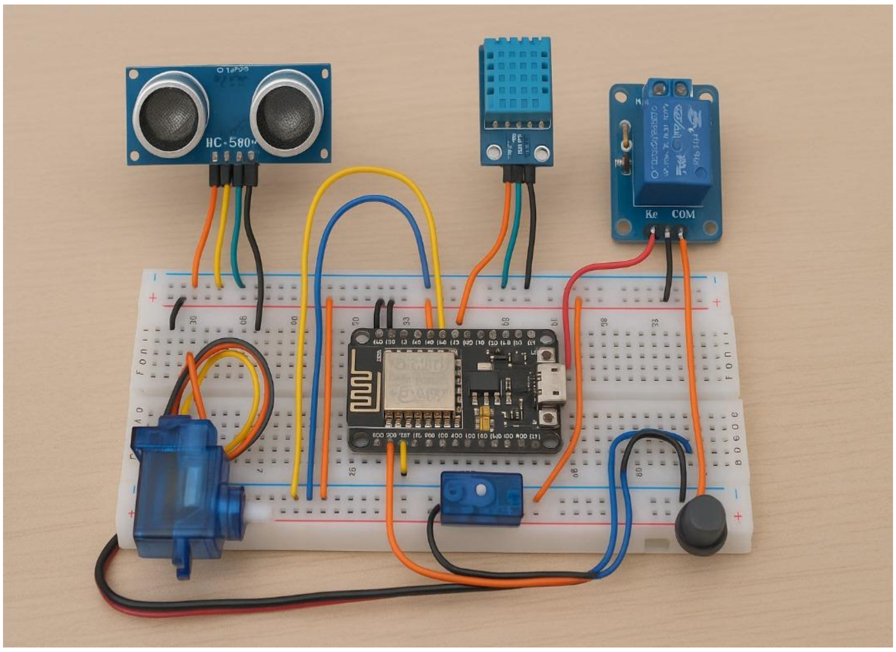

Figure 22: Physical architecture

4.4 System development

System development is the process of creating and maintaining computer systems, including both hardware and software. It involves defining, designing, testing, and implementing a new system or modifying an existing one. This process often follows a structured approach called the System Development Life Cycle (SDLC), which includes phases like planning, analysis, design, development, testing, implementation, and maintenance.

4.4.1 User graphical interface

The user's graphical user interface in this project obtained by employing the Blynk IoT smartphone application, whereby users and administrators control the Automated Mosquito Net and Repellent System remotely from a smartphone through central management. Unlike the traditional desktop application or online dashboard, Blynk presents a touch interface that is mobile-oriented and allows real-time monitoring of temperature, humidity, and human presence data and manipulation of the mosquito net and repellent system through virtual widgets such as buttons, switches, and displays allocated to specific virtual pins.

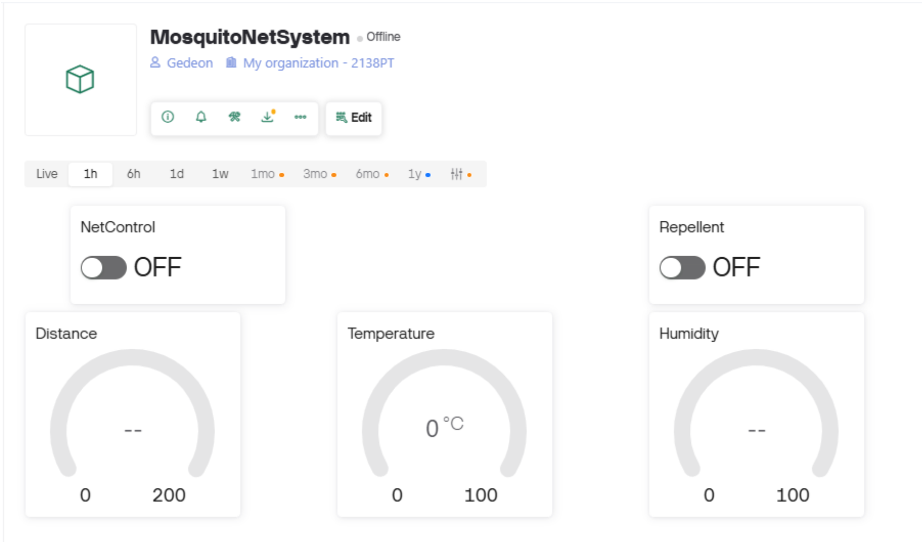

Figure 24: User graphical interface

4.4.2 Discussion

The graphical user interface shown in the image represents the Blynk IoT dashboard for the Mosquito Net System. It designed to provide users with a simple, mobile-friendly interface for monitoring and controlling the system remotely. The interface includes toggle switches for Net Control and Repellent, both currently in the OFF state, along with gauge displays for Distance, Temperature, and Humidity. While the design is clean and user-oriented, the system appears to be offline, with temperature fixed at 0°C and missing values for distance and humidity, indicating a lack of real-time data transmission. This highlights the need for stable connectivity and proper sensor integration to ensure accurate monitoring and control. Overall, the interface offers a solid foundation for interactive control, but enhancing its reliability and responsiveness is essential for practical deployment.

4.5 Result discussion

4.5.1 Physical connections

The physical connections in the Automated Mosquito Net and Repellent System involve the hardware components that enable sensing, control, and actuation. These include connections between different components that consist project. Proper connection and circuit stability are crucial to ensure accurate data transmission and reliable operation of the system.

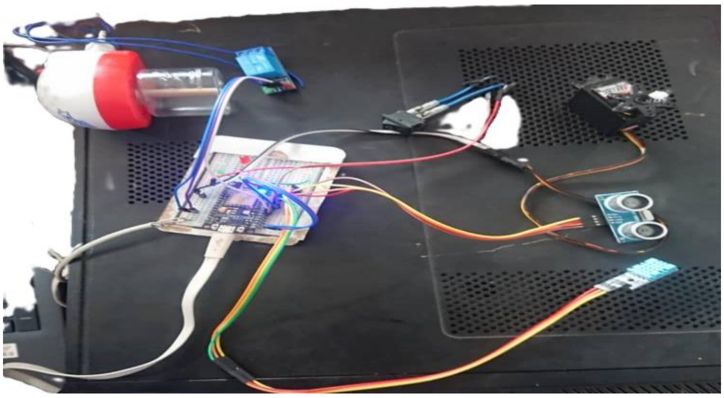

Figure 16: Physical connections

4.5.2 Discussion

The image shows the physical wiring of the Automated Mosquito Net and Repellent System prototype. At the center is the ESP32 microcontroller, which controls and communicates with all connected components. An ultrasonic sensor used to detect human presence by measuring distance. A DHT sensor is included to measure temperature and humidity levels in the environment. A servo motor connected to raise or lower the mosquito net, while a relay controls the repellent sprayer. All components powered and interconnected through jumper wires and breadboard, forming a compact and functional IoT-based setup.

4.5.3 Results

IoT-based Automated Mosquito Net and Repellent System is designed around an ESP8266 microcontroller with an ultrasonic sensor, DHT11 (temperature and humidity), servo motor, repellent control relay, and a push button for manual input. The system interfaced to the Blynk IoT platform, which is the GUI for real-time monitoring and control via a smartphone. Primary outcomes include automatic net deployment when human presence detected (as indicated by the ultrasonic distance reading) and automatic repellence. Administrators and users may also manually operate the net and repellent through Blynk switches, observe real-time sensor readings (temperature, humidity, distance), and receive real-time status updates through an intuitive mobile dashboard.

4.5.4 System Results

Overall, the system enhances home malaria prevention through automatic mosquito net and repellent management based on environmental and presence conditions. Real-time distance, temperature, and humidity displayed using interactive gauges and toggle buttons indicate and set the net and repellent status (ON/OFF). This reduces manual intervention, provides added user convenience, and facilitates 24/7 monitoring. Remote operation and graphical interface in Blynk ensure fast decision-making and maximum control, rendering the system easy to use and effective in urban and rural locations.

4.6 System Functionality and User Interface

The system combines sensors and control logic to automate mosquito net and repellent activation. It responds to human presence or manual input. The user interface allows easy monitoring and control through clear navigation. Key pages include status, control, and history. This setup ensures both automation and user interaction.

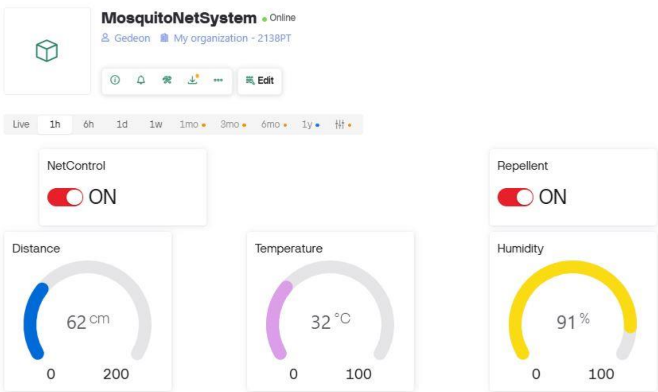

Figure 17: Output Results

The system effectively automates mosquito net control and repellent spraying based on sensor inputs. The Blynk interface offers real-time remote monitoring and control via smartphones, making it user-friendly. However, connectivity issues and sensor data delays noticed during testing, affecting dashboard accuracy. Improving network stability and adding error handling will enhance performance. Expanding the interface with notifications could also improve user trust and system responsiveness.

4.6.1 Hardware Integration and System Reliability

The ESP32-based hardware successfully coordinated sensors, motor, and relay for automated operation. The modular setup eased testing and future upgrades. However, wiring complexity and unstable power supply caused occasional data interruptions and motor issues.

4.6.2 System Impact, Usability, and Scalability

The community showed strong interest in adopting the system for malaria prevention, reflecting its practical value. Cost remains a concern, suggesting subsidies or affordable production methods needed. Automated operation reduces manual effort and enhances protection in rural areas. Future scalability could include solar power for off-grid use and multi-user controls for community monitoring. The system's IoT design supports integration with wider health and environmental networks

4.7 Discussion of results

The Automatic Mosquito Net and Repellent System, after testing and implementation, exhibited promising features such as automation, manual override, and effective mosquito control. The system uses an ESP32 microcontroller integrated with an ultrasonic sensor for detecting human presence and a relay-driven motor mechanism to actuate the mosquito net. The net consistently responded to human presence within the intended range, demonstrating both the sensitivity and accuracy of the ultrasonic sensor. Real-time sensor data especially temperature and humidity captured by the DHT11 sensor remained stable throughout,

In comparison to earlier PIR-based systems(Park et al., 2020), this project addressed core automation limitations by incorporating a manual override button to prevent false activation, particularly when a user is motionless under the net. Moreover, the automatic activation of the mosquito repellent when the net raised enhanced efficiency and reduced user involvement. While minor issues like occasional false ultrasonic readings and slight delays in the graphical interface refresh observed, they did not hinder the overall system functionality. These findings validate the system's reliability and show that an IoT-based hybrid model with partial offline capabilities can effectively support public health solutions, even in remote areas such as the Cyabingo Sector.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

An automated mosquito net and repellent system based on IoT is a smart, affordable, and user-friendly malaria prevention system for houses, particularly for rural communities such as Cyabingo Sector, Gakenke District. The system utilizes the ESP8266 microcontroller and an ultrasonic sensor to scan for human presence, a DHT11 sensor for temperature and humidity reading, a servo motor for lowering or lifting the mosquito net, an on/off relay switch for the repellent, and a push button for override. System integration with the Blynk IoT platform provides real-time remote monitoring and control of the repellent and net system via a smartphone app. Upon a person entering the room, the net automatically raises itself (HIGH) and the repellent activated; upon an empty room, the net automatically lowers (LOW) and the repellent deactivates. There is also switching through push button or Blynk app. Auto mode prevents excessive hand use, provides timely switching on of repellent, and provides maximum mosquito protection during risk hours. It is power-saving, human-friendly and scalable, and aligns with the overall vision of home automation and digital health intervention for populations at risk of malaria.

5.2 Recommendations

The project effectively developed an IoT-based mosquito control system capable of responding to environmental conditions and human activity. It designed for domestic application by homeowners requiring automatic and remote preventive measures against mosquitoes in urban and rural homes.

5.2.1 Recommendations to Researchers

Future development would need to be along the lines of incorporating system intelligence through machine learning to anticipate the danger of malaria dependent on ecological parameters (temperature, dampness, etc.) and conduct patterns of the user. Other sensors as CO_2 sensors or light sensors can utilized to introduce more precision in human presence identification. Researchers can also consider offline data logging combined with GSM/LoRa capability for facilitating off-internet locations, and pilot the system in various environments for testing and scalability. To improve reliability, future designs should use PCBs for secure connections and regulated power sources. Using sensors that are more accurate will also boost system responsiveness in different environments.

5.2.2 Recommendations to Users

It should check for cleanliness and accurate sensor alignment for precise distance and environment measurements. The users have to use the push button and mobile app correctly, and system checks have be conducted at regular intervals to confirm net movement and repellent function. Constant checking of the Blynk dashboard is also advisable by encouraging users informed about the room status and the system status at night or during malaria time.

5.2.3 Recommendations to Cyabingo Sector

The community and local authorities in Cyabingo Sector are encouraged to adopt this Automated Mosquito Net and Repellent System as part of their malaria prevention strategies. Implementing this system can provide consistent and automated protection against mosquitoes, reducing the incidence of malaria. Community training on its use and maintenance will ensure sustainability and ownership. Furthermore, integrating this technology with existing health programs can enhance overall effectiveness. Support through subsidies or local funding will improve affordability and encourage wider adoption within the sector.

5.3 Study Limitation

As great as the automatic mosquito net and repellent device is, it has its faults also. One although the design intended to utilize an automatic release of a repellent system, this part did not work as intended with technical integration issues and left out of the final device. Two, the system requires a continuous power source and internet connection to operate via the Blynk platform, which may be unreliable in rural settings. Three, dust, weather, or improper installation may interfere with the performance of the sensors and result in false detection. Fourth, the project done in a small home apartment setting and may need to accommodate different room sizes or rooms. Lastly, when the system is being with sensor data, secure data management and privacy must remembered if done by using cloud infrastructure. Frequent usage and acceptability demand that these matters are resolved.

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APPENDICES

Appendix A: Arduino code for ESP8266

```
#define BLYNK_TEMPLATE_ID "TMPL2xUG2fMwI"
#define BLYNK_TEMPLATE_NAME "MosquitoNetSystem"
#define BLYNK_AUTH_TOKEN "BKcg_rHLkEPxvZ5AYf-J8bY5iaT_Qeu0"
char auth[] = BLYNK_AUTH_TOKEN;
char ssid[] = "Becareful";
char pass[] = "55555551";
#include <Servo.h>
#include <DHT.h>
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
#define TRIG_PIN D1
#define ECHO_PIN D2
#define DHT_PIN D3
#define DHT_TYPE DHT11
#define SERVO_PIN D4
#define RELAY_PIN D5
#define BUTTON_PIN D6
DHT dht(DHT_PIN, DHT_TYPE);
Servo netServo;
bool netIsHigh = false;
bool lastButtonState = HIGH;
unsigned long lastDebounceTime = 0;
const unsigned long debounceDelay = 200;
Void setup () {
  Serial.begin (115200);
  Serial.println ("System Initializing...");
  Blynk.begin (auth, ssid, pass);
  PinMode (TRIG_PIN, OUTPUT);
```

```
  PinMode (ECHO_PIN, INPUT);
  PinMode (RELAY_PIN, OUTPUT);
  PinMode (BUTTON_PIN, INPUT_PULLUP);
  dht.begin ();
  netServo.attach (SERVO_PIN);
  LowerNet (); // Set initial state
  DigitalWrite (RELAY_PIN, LOW);98
  Serial.println ("System Ready.");
}
Void loop () {
  Blynk.run ();
  Float temp = dht.readTemperature ();
  Float hum = dht.readHumidity ();
  Long distance = measureDistance ();
  Bool buttonState = digitalRead (BUTTON_PIN);
  Serial.print ("Temperature: ");
  Serial.print (temperature);
  Serial.print (" °C | Humidity: ");
  Serial.print (hum);
  Serial.print (" % | Distance: ");
  Serial.print (distance);
  Serial.println (" cm");
   Blynk.virtualWrite (V2, temp);
  Blynk.virtualWrite (V3, hum);
  Blynk.virtualWrite (V4, distance);
  If (temp > 30.0) {
    Serial.println ("Temp > 30°C → Raising Net & Turning ON Repellent");
    RaiseNet ();
    DigitalWrite (RELAY_PIN, HIGH);
    Blynk.virtualWrite (V0, 1); // Sync net switch
```

```
    Blynk.virtualWrite (V1, 1); // Sync repellent
    Delay (3000);
    Return;
  }
  If (distance > 0 && distance < 10) {
    Serial.println ("Human Detected → Raising Net & Turning ON Repellent");
    RaiseNet ();
    DigitalWrite (RELAY_PIN, HIGH);
    Blynk.virtualWrite (V0, 1);
    Blynk.virtualWrite (V1, 1);
  }
  If (buttonState == LOW && lastButtonState == HIGH && (millis () - lastDebounceTime) > debounceDelay) {
    Serial.println ("Button Pressed → Toggling Net & Relay");
    ToggleNet ();
    LastDebounceTime = millis ();
  }
  LastButtonState = buttonState;
  Delay (2000); // Delay for stability
}
BLYNK_WRITE (V0) {
  Int Val = param.asInt ();
  If (Val == 1) {
    RaiseNet ();
    DigitalWrite (RELAY_PIN, HIGH);
    Blynk.virtualWrite (V1, 1);
  } else {
    LowerNet ();
    DigitalWrite (RELAY_PIN, LOW);
    Blynk.virtualWrite (V1, 0);
```

```
  }
}
  Int Val = param.asInt ();
  DigitalWrite (RELAY_PIN, Val);
  Serial.println (Val? "Repellent ON”: "Repellent OFF");
}
Long measureDistance () {
  DigitalWrite (TRIG_PIN, LOW); delayMicroseconds (2);
  DigitalWrite (TRIG_PIN, HIGH); delayMicroseconds (10);
  DigitalWrite (TRIG_PIN, LOW);
  Long duration = pulseIn (ECHO_PIN, HIGH, 30000);
  If (duration == 0) return one;
  return duration * 0.034 / 2;
}
Void raiseNet () {
  netServo.write (0);
  NetIsHigh = true;
  Serial.println ("Mosquito Net: HIGH (Raised)");
  Blynk.virtualWrite (V0, 1); // Sync to app
}
Void lowerNet () {
  netServo.write (90);
  NetIsHigh = false;
  Serial.println ("Mosquito Net: LOW (Lowered)");
  Blynk.virtualWrite (V0, 0);
}

Void toggleNet () {
  If (netIsHigh) {
    LowerNet ();
```

```
    DigitalWrite (RELAY_PIN, LOW);
    Blynk.virtualWrite (V1, 0);
    Serial.println ("Repellent: OFF");
  } else {
    RaiseNet ();
    DigitalWrite (RELAY_PIN, HIGH);
    Blynk.virtualWrite (V1, 1);
    Serial.println ("Repellent: ON");
  }
}
```

Appendix B: Questionnaire

Section 1 of 3

Section 1: Introduction

This questionnaire is part of a research study aimed at improving malaria prevention using smart technology. Your responses are confidential and will only be used for academic purposes. Thank you for your participation.

After section 1 Continue to next section

1.What is your age? *

- ◯ Under 18
- ◯ 18–25
- ◯ 26–35
- ◯ 36–45
- ◯ Above 45

2. What is your gender? *

- ◯ Male
- ◯ Female
- ◯ Prefer not to say

3. What is your occupation? *

- ◯ Student
- ◯ Farmer
- ◯ Teacher
- ◯ Health Worker

4. Do you live in a malaria-prone area? *

- ◯ Yes
- ◯ No

5. Have you or any member of your household suffered from malaria in the past year? *

- ◯ Yes
- ◯ No
- ◯ Maybe

6. What methods do you currently use to prevent mosquito bites? *

- ☐ Mosquito net
- ☐ Insecticide sprays
- ☐ Repellents
- ☐ Coils
- ☐ none
- ☐ Other...

7. How often do you sleep under a mosquito net? *

- ◯ Every night
- ◯ Sometimes
- ◯ Rarely
- ◯ Never

Section 3: Technical Questions

Description (optional)

8. Are you familiar with automated or IoT-based home systems (e.g., smart lights, sensors)? *

- ◯ Yes
- ◯ No

9. Would you be interested in using a system that automatically deploys a mosquito net and sprays repellent when it detects human presence? *

- ◯ Yes
- ◯ No
- ◯ Maybe

10. What features would you expect in such a system? *

- ☐ Remote control via phone
- ☐ Solar/battery backup
- ☐ Temperature and humidity sensors
- ☐ Automatic mosquito net movement

11. Do you think an automated mosquito protection system could improve malaria prevention? *

	1	2	3	4	5
Strongly disagree = 1 Disagree = 2 Neutral = 3 Agree = 4 Strongly agree = 5	○	○	○	○	○

12. Would you be willing to pay for such a system if it were available in your community? *

- ○ Yes
- ○ No
- ○ Depends on the price