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Design of Pest Detection and Repellent Device Based on Arduino Uno using Pir (Passive Infrared Receiver) Sensor

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ABSTRACT

This research aims to design and develop a technology-based pest detection and repellent device using the Arduino Uno R3 microcontroller. This tool is designed to overcome the problem of the presence of insect pests and rats on the KWT Gemas Imlan agricultural land. The developed system integrates various sensors and modules to achieve optimal performance. The PIR sensor is used to detect the movement of pests around agricultural areas, while the LDR sensor functions to measure light intensity as one of the parameters of equipment operating conditions. As an expulsion measure, this device is equipped with an NE555 module which emits high frequency sound waves to repel or force pests to leave the agricultural area. Testing is carried out in stages, starting from individual testing of each sensor to testing the entire system. The research results show that this tool can operate automatically with a fast and accurate response, so it has the potential to be an effective solution for controlling pests on agricultural land.

Keywords: *Arduino Uno R3, Microcontroller, NE555 Module, Pest Detection Device, Pest Repellent Device, PIR Sensor*

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INTRODUCTION

The Agricultural productivity is often hampered by the persistent problem of pest infestations, which cause 30 percent losses in crop yields per year (Agarwal, 2024). One of the most challenging pests for farmers, particularly in Indonesia, are the brown planthopper (Nilaparvata lugens) and locusts. Brown planthoppers cause considerable damage to rice crops by sucking sap from plants, leading to what is known as "hopperburn," which can lead to total crop failure (Awal, 2024). Meanwhile, locusts are known for their ability to devastate large areas of crops by feeding on leaves and stems, causing extensive damage to agricultural land in a short period.

The agricultural community of KWT Gemas Implan, located in Jatiuwung, Tangerang, has faced ongoing challenges in managing pest outbreaks, particularly from these two pests. Covering 1,2 hectares, the farm produces various crops such as leafy greens, peppers, and corn, which are essential to the local food supply chain. Despite the importance of these crops, pest management has been a persistent issue, reducing both productivity and the quality of the yield. Conventional methods, such as manual scarecrow systems or pesticides, have been found inadequate or detrimental to long-term soil health and human safety (Inam, 2023). The use of chemical pesticides, though effective in the short term, poses environmental risks and threatens the health of farmers and consumers due to residue accumulation in crops and groundwater (Kumar, 2024).

Recent advances in technology have opened the door to new, automated solutions for pest control. Devices that employ microcontrollers and sensors can offer more precise and sustainable pest management. Such systems allow for real-time detection of pests and their removal from the area without causing harm to the crops or the ecosystem. In particular, the Arduino Uno R3 microcontroller, known for its flexibility and ease of integration with sensors, has emerged as an excellent platform for building pest detection and repellent systems (Yuliana, 2023).

This study proposes the design and development of an automated pest detection and repellent device that combines the Arduino Uno R3 with Passive Infrared (PIR) sensors, Light Dependent Resistors (LDRs), ultrasonic waves, and ultraviolet light. This device aims to detect pests' movement and repel them using ultrasonic frequencies while simultaneously attracting and trapping insects using UV light. By utilizing this technology, farmers can potentially reduce their reliance on chemical pesticides, decrease labor costs, and minimize environmental impacts, leading to sustainable pest management in agriculture.

Literature Review

Pest Control in Agriculture

Pest control is a critical component of sustainable agricultural practices. Traditional pest control methods, including manual intervention and chemical pesticides, have been widely used to mitigate the damage caused by pests. However, these methods often present limitations. According to (Ziani dkk., 2023) the reliance on chemical pesticides can lead to long-term negative impacts on both the environment and human health. Excessive pesticide use can result in chemical residues accumulating in soil and water sources, leading to contamination and potential health risks for consumers.

In response to these challenges, research has increasingly focused on developing environmentally friendly, automated pest control technologies (Pratama dkk., 2024). Developed a system based on PIR sensors and ultrasonic waves to repel rats from agricultural fields. Their study demonstrated that ultrasonic waves, which are inaudible to humans, can effectively deter pests by causing discomfort. Similar approaches have been employed by (Nurikhsani, 2022) who designed a pest repellent system using a NodeMCU microcontroller and ultrasonic waves to repel birds and other pests from farms.

Microcontroller-Based Pest Control Systems

Microcontrollers, such as the Arduino Uno R3, have become increasingly popular in modern agricultural applications due to their ability to integrate various sensors and modules to create automated systems. Arduino Uno, based on the ATmega328P chip, is a highly flexible platform that supports a wide range of sensors, making it ideal for detecting environmental changes and responding accordingly (Nnebedum, 2019). It has been used in several studies to control farm equipment, monitor environmental conditions, and manage automated systems like irrigation and pest control.

For instance (Pratama dkk., 2024) developed an automated pest control system using PIR sensors to detect movement and trigger ultrasonic sound to repel pests. This system was found to be highly effective in repelling pests from agricultural areas without human intervention. Similar research by (Rahayu, 2023) explored the use of ultrasonic pest repellers combined with PIR sensors, achieving positive results in protecting crops from insects and rodents.

PIR and LDR Sensors

PIR sensors are widely used for motion detection, particularly in security systems and automation projects. In agricultural applications, they can detect the movement of pests such as rats, birds, and larger insects. A study by (Roihan, 2020) demonstrated that PIR sensors could be effectively combined with ultrasonic modules to create a pest repellent system that activates automatically when pests are detected.

LDR sensors, on the other hand, are used to detect changes in light intensity, making them useful in controlling systems that need to respond to day-night cycles (Matta dkk., 2023) In agricultural pest control systems, LDRs can activate devices like UV lights at night to attract and trap pests. This is particularly effective for small flying insects that are drawn to light sources after dark.

These components, when integrated with a microcontroller, create an efficient, automated system capable of detecting pests and responding to their presence without requiring human oversight. By utilizing PIR and LDR sensors, along with ultrasonic and UV technologies, the system proposed in this study offers a sustainable and non-invasive alternative to traditional pest control methods.

RESEARCH METHODOLOGY

The methodology for this research was developed through the NIDA (Need, Idea, Decision, Action) framework, which provided a systematic approach to identifying the core needs, conceptualizing a solution, making informed design decisions, and implementing a prototype for testing (Yauri, 2023).

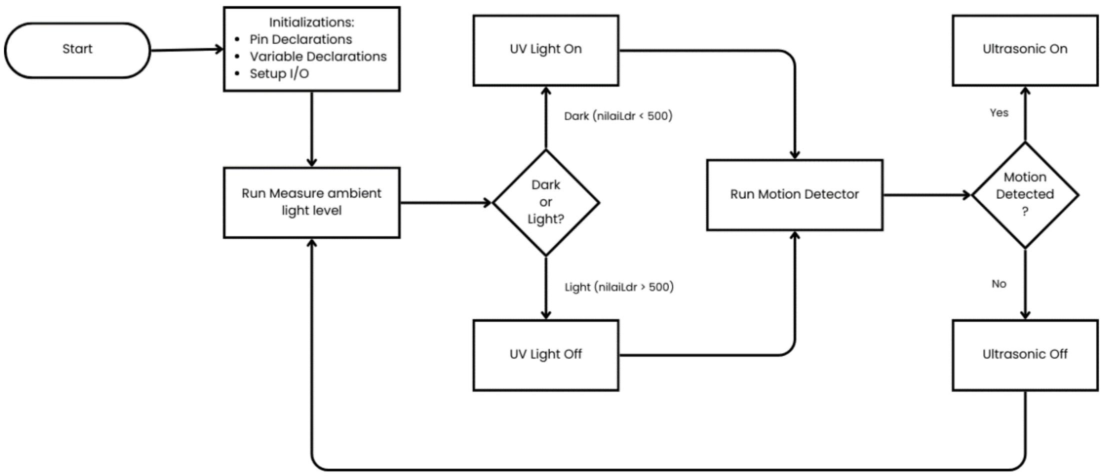
Need

KWT Gemas Implan faces significant crop losses due to pests, particularly brown planthoppers and locusts. Chemical pesticides, though commonly used, pose health risks to both the farmers and the consumers. Additionally, excessive pesticide use can lead to pest resistance over time, diminishing their effectiveness. Therefore, there is a strong need for an eco-friendly and cost-effective solution that can automate pest control without relying on harmful chemicals.

Idea

The primary idea was to develop a system that can detect pests' movement and activity through PIR sensors and environmental conditions through LDR sensors. Once detected, the system would use ultrasonic sound waves to repel pests like locusts, while UV light would attract and trap smaller pests such as brown planthoppers. The Arduino Uno R3 microcontroller was chosen for its ease of programming, availability, and compatibility with various sensors and modules. The goal was to create an affordable, scalable solution that could be implemented on different types of farms.

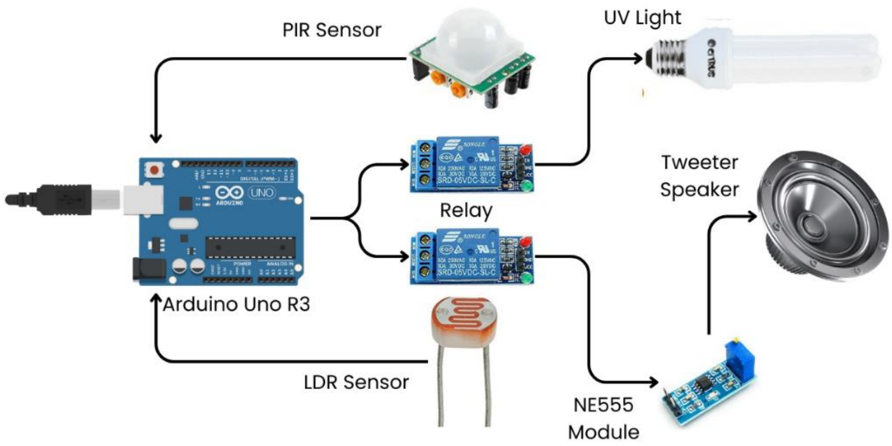
Figure 1. Flowchart Diagram



Decision

After brainstorming different technological possibilities, a detailed analysis of available components was conducted. The following components were selected:

Figure 2. Hardware Device Design



Arduino Uno R3: The core microcontroller to handle input and output signals from sensors and control actuators.
PIR Sensor: For detecting motion and the presence of pests within a 10-20 meter range. This sensor triggers the ultrasonic waves, which are used to repel pests.
LDR Sensor: Used to measure ambient light levels, enabling the system to determine whether it is day or night. This sensor controls the activation of the UV light during nighttime.
Ultrasonic Module (NE555): Capable of emitting ultrasonic waves at frequencies higher than 20 kHz, which humans cannot hear but can repel pests.
UV Light: Used to attract insects like brown planthoppers, which are naturally drawn to ultraviolet light, thereby luring them into traps.

Action

Once the design was finalized, the system was constructed and tested. The implementation process involved both hardware and software development; 1) Hardware Development: The physical setup of the components was built using a breadboard to ensure easy modification during the testing phase. The Arduino Uno was connected to the PIR sensor, LDR sensor, UV light, and NE555 ultrasonic module. Jumper wires were used to connect all components on the breadboard, and relays were integrated to control high-power devices like the UV light.

Figure 3. Design Results

2) Software Development: The software for the system was developed using the Arduino IDE (Integrated Development Environment). The code was written to read inputs from the PIR and LDR sensors and to activate the respective outputs (UV light or ultrasonic module) based on the sensor readings. The system was programmed to activate the UV light at night and to emit ultrasonic waves whenever pest movement was detected.

Figure 4. Code Declaring Pins and Initializing Variables

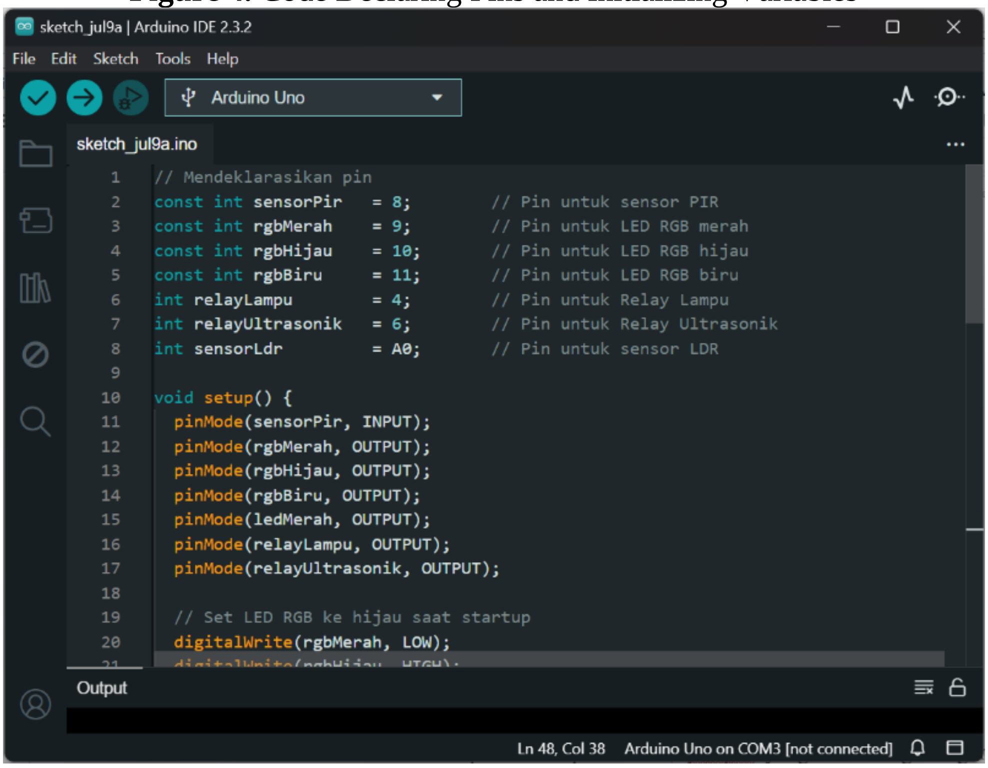


Figure 5. System Initialization Code

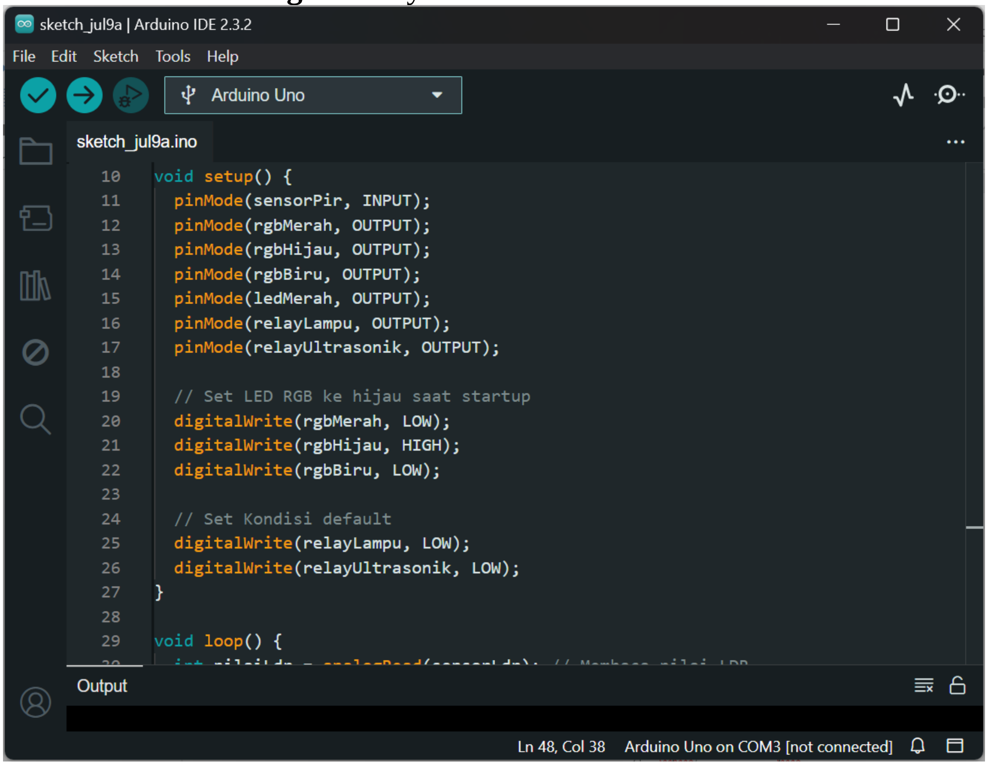


Figure 6. Light Intensity Detection Code for LDR

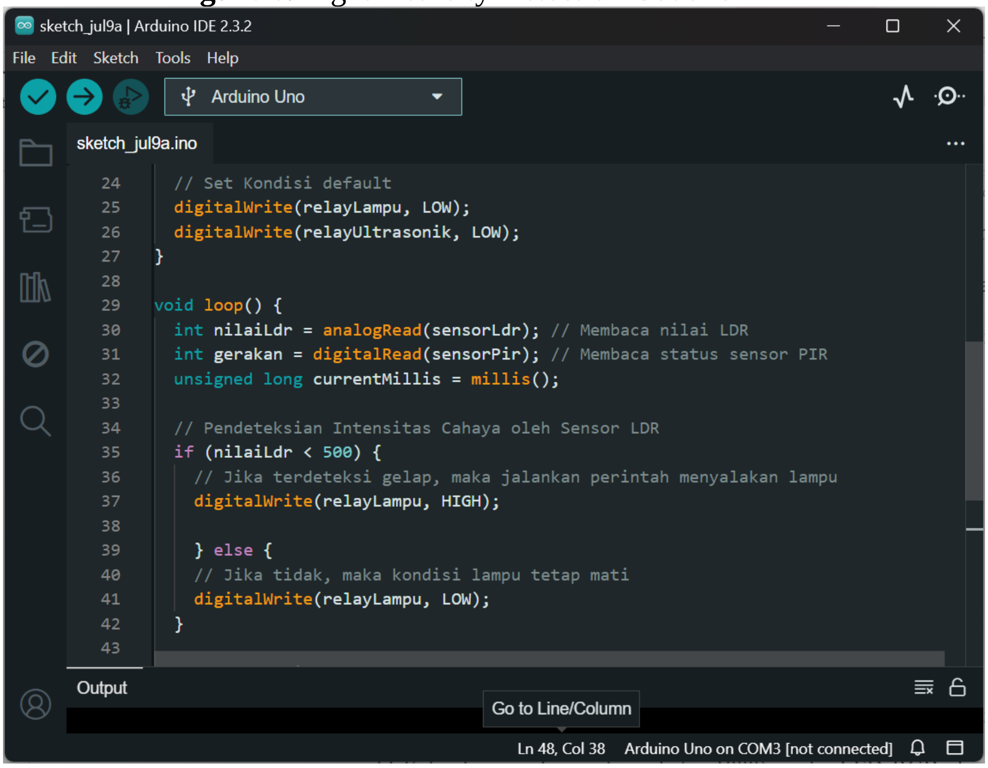
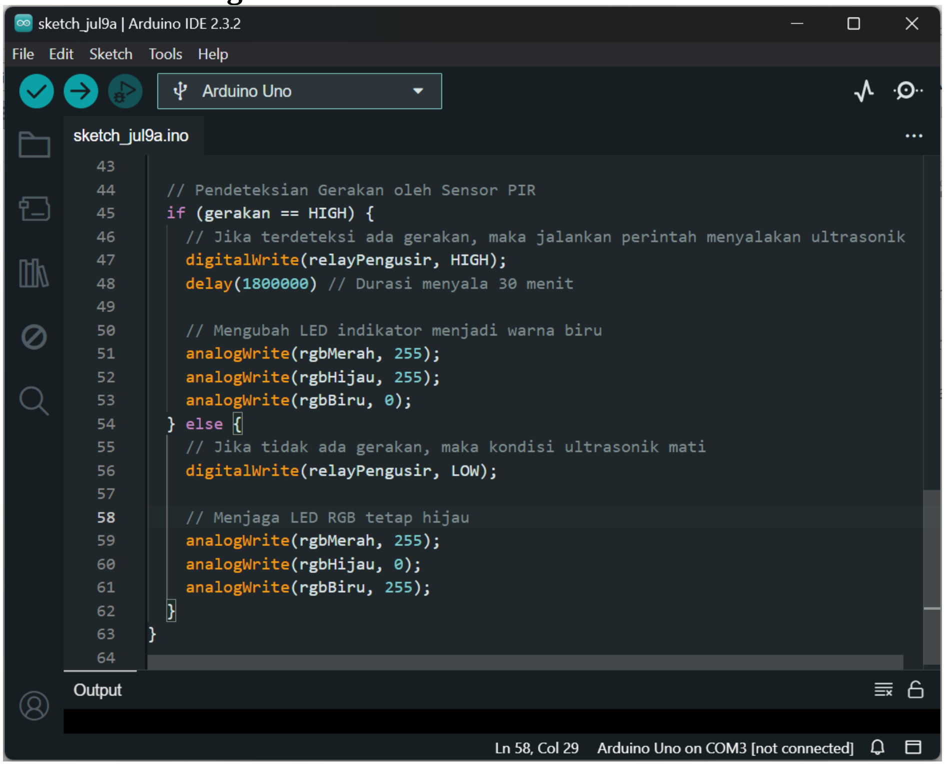


Figure 7. Motion Detection Codes for PIR



The system was deployed at KWT Gemas Implan for a one-day field test. During this time, various environmental factors were observed, and data were collected on the system's performance.

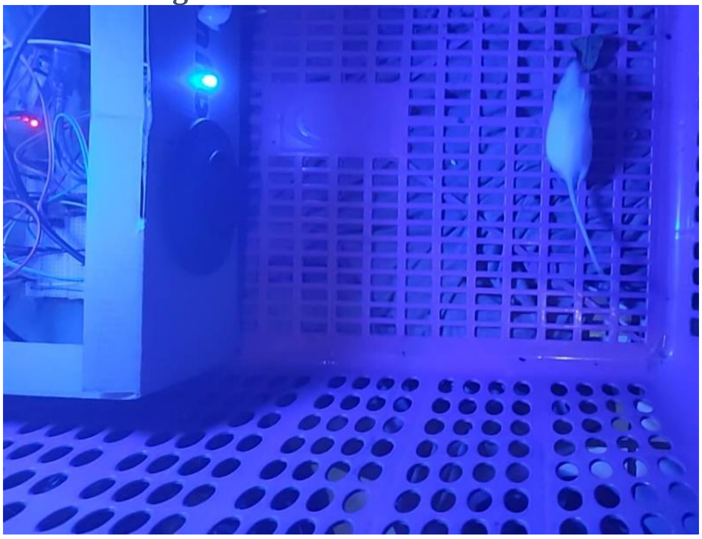
RESULT AND DISCUSSION

The results from the field testing were highly promising, demonstrating the effectiveness of the automated pest detection and repellent system. The system was able to detect pests, repel them using ultrasonic waves, and trap insects using UV light, all without human intervention.

PIR Sensor Performance

The PIR sensor successfully detected movement within a 10–20 meter radius. Once motion was detected, the system automatically triggered the NE555 ultrasonic module to emit high-frequency sound waves. These waves, with frequencies ranging between 20-60 kHz, proved to be effective in repelling larger pests such as locusts. Locusts, being highly sensitive to these frequencies, moved away from the source of the sound. The ultrasonic waves also prevented pests from lingering in the area, which was observed through decreased pest activity within the vicinity of the system.

Figure 8. PIR Sensor Test



LDR Sensor and UV Light

The LDR sensor effectively distinguished between day and night conditions by measuring the intensity of ambient light (Nanda dkk., 2020). Once the system detected low light levels (indicating nightfall), it automatically activated the UV light. The UV light attracted small insects, especially brown planthoppers, which are drawn to ultraviolet light (Jabbar dkk., 2019). These insects were subsequently trapped in water-filled containers placed near the UV light source. Over the course of the test, a significant number of insects were collected in the traps, highlighting the effectiveness of the UV component in pest management.

Figure 9. LDR Sensor and UV Light Test

Energy Efficiency

Since the system was designed to operate only when pests were detected or during nighttime, it exhibited low energy consumption. This energy-efficient design makes it feasible for long-term use in agricultural fields, particularly in areas with limited access to electricity. Further optimizations, such as using solar panels, could make the system even more sustainable.

Field Test Observations

During the one-day test, the system demonstrated the ability to reduce pest activity in the target area. The UV light trap successfully captured a variety of small flying pests, while the ultrasonic waves kept larger pests, like locusts, away from the crops. The automated nature of the system relieved farmers from the need for constant monitoring and manual pest control, thereby reducing labor costs and improving farm efficiency.

Figure 10. Test Observations Results

Challenges and Improvements

Some challenges were encountered during testing. For example, the PIR sensor occasionally detected false positives due to movement caused by wind or other environmental factors. Additionally, while the ultrasonic waves were effective in repelling pests, their effectiveness was limited to a certain range, meaning that multiple devices may be necessary for larger fields. Further improvements in the system could involve refining the sensor calibration and extending the range of the ultrasonic module.

CONCLUSION

Based on the results of the research that has been carried out, it can be concluded as follows; 1) The research successfully designed and developed an automated pest detection and repellent device using the Arduino Uno R3 microcontroller, incorporating PIR (Passive Infrared Receiver) and LDR (Light Dependent Resistor) sensors, 2) The system effectively detects pests using PIR sensors and repels them through ultrasonic sound waves, while the LDR sensor manages the activation of UV light to trap insects during nighttime, 3) Field testing at KWT Gemas Implan showed the system's potential in reducing pest activity without using harmful chemicals, offering an eco-friendly alternative to conventional pest control methods, 4) The device's ability to function autonomously with minimal human intervention reduces labor costs and enhances agricultural productivity, making it a practical and sustainable solution for farmers.

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