

Application of Rice Pest Repellent Using ESP32 Microcontroller and Internet of Things Based Sound Wave

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ABSTRACT

This research aims to create an automatic pest-repellent system using the Internet of Things. This system uses a microcontroller model ESP32 Devkit and PIR sensor to detect the attack of rice field leafhopper pests. In addition, the application is also equipped with a buzzer and a servomotor that can repel leafhoppers. The circuit can be used to expel leafhoppers because it can emit ultrasonic waves in the range of 40 kHz. The resulting system is IoT-based, so it can be controlled via smartphone. The application can eradicate leafhoppers at a radius of 3 meters and can kill leafhoppers within 2 hours. However, if the distance is 6 meters, this tool can kill leafhoppers and locusts in a 4-hour time interval.

INTRODUCTION

Rice is the staple food for most Indonesians. In addition, many people are also farmers and rely on the economy from rice harvests. Agriculture itself is one of the main sectors in the global economy that has a strategic role in fulfilling the food needs of the world's population. One of the main challenges in agriculture is the control of pests and plant diseases that can result in large losses in agricultural production (Gao et al., 2021). Because until now pests are still an obstacle for farmers to get maximum results. Almost every season there is an explosion of pests in rice plants. Especially rat pests, rice stem borers, and brown planthoppers. Some other pests that have the potential to damage rice crops are white-backed leafhoppers, green leafhoppers, stoneflies, armyworms, leaf folders, and walang sangit. Therefore, this needs to be a serious concern for the continuity of rice production (Becker et al., 2015). So effective pest control is key in increasing agricultural productivity.

The development of technology and information is currently growing very fast. Even in recent years, the Internet of Things (IoT) has opened up new opportunities in the development of agricultural technology, including technology that can provide pest detection and eradication information quickly and precisely. Microcontrollers such as the ESP32, have become a very important component in building IoT-based applications. Because they are affordable and can be accessed remotely (Mendoza & Villaseñor, 2020). So this time IoT is a concept to utilize the internet to eradicate pests in rice fields. Because this system makes it easier for users to get information. Where the system used is directly connected to the IoT device. This automatically connected system will make it easier for rice farmers to operate the sound wave device remotely so that the sound wave device can work quickly and precisely to eradicate pests in rice fields. In addition, the use of sound waves as a pest-repellent method attracts attention due to its non-chemical approach, making it more environmentally friendly and sustainable.

The results of previous research in agriculture conducted by (Simbolon et al., 2019) recommended a decision support system to determine the best pesticide to get rid of pests. Although it was successfully carried out, to get rid of pests, it was not environmentally friendly because it still used pesticides, besides that it also still used mathematical calculations not using IoT-based devices.

While the results of research conducted by (Ratnawati et al., 2020) to eradicate rice pests in rice fields and proved successful by using IoT devices. However, it still has weaknesses because the tool cannot be duplicated so that it cannot be used in bulk (non-portable).

Meanwhile, according to (Hamdani, et al., 2020) this research has used ultrasonic sensors around 20 kHz with the target object being birds. The system is also equipped with ESP32 Devkit as a microcontroller, passive infrared sensor (PIR), ultrasonic sensor, light dependent resistance sensor (LDR), buzzer, servomotor, and connected to a smartphone. So that it can be used to automatically, repel birds in rice fields.

While what is different and additional from this researcher is that, we develop it into an application system for exterminating leafhoppers using an ultrasonic sensor at a frequency of 40 kHz and controlled via a smartphone. Because the previous system used ultrasonic sensors, around 20 kHz with the target object being birds. While the frequency that can disrupt the communication of leafhoppers, even able to cause passive motion reactions until the pests die is ≥ 40 kHz. This application is also designed to be portable so that it can be moved around in rice fields affected by leafhoppers so that it can be used thoroughly. The system is also equipped with the Blynk application as a remote hardware controller. In addition, it can also display and record data read on sensors, timers, and switch the application on and off. This makes it easier for farmers to eradicate leafhoppers more stably and safely.

This research aims to design an IoT-based rice pest repellent application using ESP32 microcontroller and sound waves as a solution that can help farmers in facing pest control challenges such as leafhopper disease. Appropriate technology for farmers through IoT-based techno-pest control to repel and kill leafhoppers. After completing the application design stage, product dissemination and training on the operation of the tool were carried out, and the test of the tool was carried out in the Pati Regency rice field area by researchers and rice farmers.

LITERATURE REVIEW

Pests have always been the most dangerous disease for rice fields. Since their inception, pests have always been the most dangerous disease for rice and a nightmare for farmers and rice producers. Usually during the rainy season in Indonesia, which is between March and April, the breeding population of pests in the form of small animals such as leafhoppers and locusts has increased significantly. Rice pests attack in the vegetative phase, by sucking the liquid of the rice stem so that it can transmit tungro and dwarf virus. The worst symptom is hopperburn, which will cause total crop failure.

Meanwhile, locust pests usually attack in the generative phase by sucking the liquid in the rice grains, which causes the rice grains to not be full. Figure 1 shows the cumulative area of attack of rice plant pest organisms in the Pati region of Central Java.

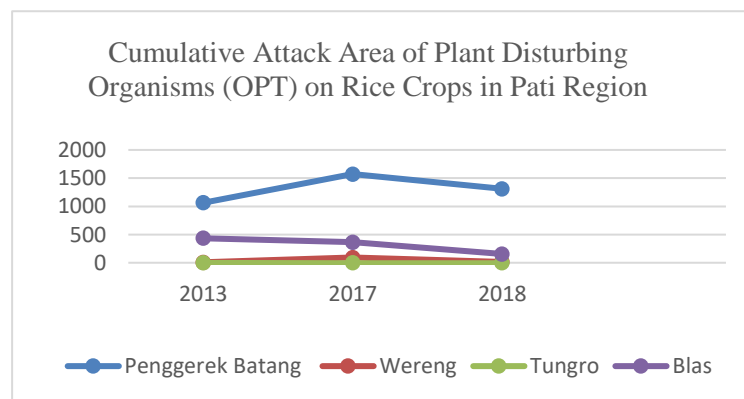


Figure 1. Plant Disruptive Organism Attacks (BPS 2013-2018)

Although strategies and efforts have been made, it turns out that the pest population can still grow rapidly. This is because the pests move from one field to another without being controlled. Even to combat these pests, farmers have to sacrifice large amounts of their farm capital. This includes the use of phytosanitary products which results in high product prices in the market. Even if such products are used excessively, it can have an impact on the environment as well as the risk of new diseases arising from the first disease. So it is also important to consider the impact of the disease on the crop before applying this kind of fungicide protection (Ratnawati et al., 2020).

So by considering some of the problems above, to meet food needs, various efforts and strategies are needed for decision making. So researchers are interested in developing a rice pest-repellent application using an ESP32 microcontroller and IoT-based sound waves. Because we can maximize the benefits of a real-time internet connection, so that it can be connected and integrated to various devices on an ongoing basis.

Internet of Things

The Internet of Things (IoT) is a concept of objects that have the ability to transfer data through without requiring human-to-human or human-to-computer interaction. According to McKinsey Global Institute analysis, IoT technology, machines, factories, sensors and batteries can be connected to collect data and manage system performance, so that they can work together and produce goals. Because IoT can make connections between machines. So that machines can interact and work independently based on data received and processed independently (Wahyudi and Wibowo, 2021).

The church way of IoT refers to three elements namely: IoT installed objects, internet connection and data cloud to store the database. That is, by utilising the program argumentation of each command to produce automatic interaction at any distance because the internet is the connection. Therefore, the researcher proposes an effective IoT system to help prevent the arrival of pests and eradicate them with a sound wave tool that can be controlled remotely consistently. In addition, it is also an effort to control pest populations because it can be done with ultrasonic sound waves > 20 kHz to disrupt pest communication, movement reaction patterns, disperse from their groups, and inhibit their reproduction. (Ratnawati et al., 2020) explained that the frequency that can disrupt the communication of leafhoppers is ≥ 40 kHz, because at that frequency it can cause passive motion reactions until the pests die.

Android

Android is a frequently used operating system for mobile phones that is based on Linux. Linux is an open-source operating system that is modifiable and can be developed. For this reason, developers can use Android as an open platform to design and develop their own applications. These applications may be further linked to varied facilities or devices that may be operated (Patel, 2019).

Seeing the development of smartphones that are already owned by farmers, it is relevant to be used as a supporting medium for leafhopper and

locust pest-repellent tools. This research aims to produce appropriate technology tools, namely IoT-based techno-pest control to repel and kill leafhoppers and locusts; and determine the impact of using techno-pest control tools in controlling leafhoppers and locusts on rice plants.

ESP32 Microcontroller

The ESP32 microcontroller is a hardware device developed by the Expressive Systems Company. It is one of the most popular microcontrollers used in various electronic and (IoT) applications. The ESP32 microcontroller has powerful features, including integrated Wi-Fi and Bluetooth capabilities, a high-speed processor, and low power consumption. ESP32 microcontrollers are used to control electronic devices and connect them to wireless networks, making them very suitable for IoT projects (Espressif Systems, 2019). In addition, this research also uses the Blynk application which functions as a hardware controller for long distances because it can display data read by sensors, can record data, display results visually, and many other sophisticated things (Kalbii et al., 2022).

Ultrasonic Sensor

Ultrasonic waves are longitudinal mechanical waves whose frequency is above 20 kHz. The characteristics of ultrasonic waves that propagate through the medium result in particle vibrations (Agusdian, et al., 2012). The way this sensor works is based on the principle of the reflection of a sound wave so that it can be used to interpret the existence (distance) of an object with a certain frequency. It is called an ultrasonic sensor because this sensor uses ultrasonic waves (ultrasonic sound). Ultrasonic waves are sound waves that have a very high frequency of 20,000 KHz. The ultrasonic sound cannot be heard by the human ear, but ultrasonic can be heard by dogs, cats, bats, dolphins, and insects that become pests. Ultrasonic sound can propagate through solids, liquids, and gases. So using ultrasonic frequencies at 15-30 KHz can repel insect pests of rice (Ratnawati et al., 2020).

METHODOLOGY

This planthopper exterminator application was tested in the rice fields of Dukuh Rendole, Muktiharjo Village, Margorejo Pati Subdistrict. This application is equipped with ESP32 Devkit as a microcontroller, passive infrared sensor (PIR), ultrasonic sensor, light-dependent resistance sensor (LDR), buzzer, and servo motor. All of these tools are integrated into a smartphone that has been installed with the Blynk application which allows it to be used to automatically repel rice pests. PIR sensor is used to detect leafhoppers that attack rice fields, a buzzer and servo motor are used to repel leafhoppers, and LDR is used to turn on the lights at night. The ESP32 system sends signals or pulses to the servo motor, buzzer, LED and notifies through the Blynk application.

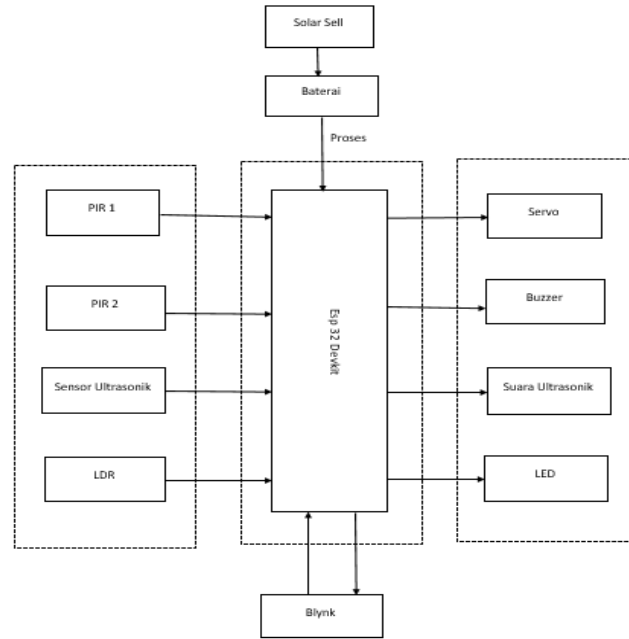


Figure 2. Block Diagram of Planthopper Pest Repellent Prototype (Hamdani, et al., 2020)

The terminal application part of the PIR sensor starts working to detect movement in the rice field area and the LDR sensor also works to detect the intensity of ambient light. If the PIR sensor detects the presence of pest movement in the rice field, then the PIR sensor takes input from the ESP32 then the bell and servo motor are active to repel the presence of rice field pests. After completion there will be a notification to the Blynk application. In addition, when the LDR sensor senses dark light intensity, the LDR sensor sends input to the ESP32 Devkit so that the LED lights up. ESP32 at the same time also sends a notification to the Blynk app when night has come. So through the Blynk app the app user or farmer can switch off the switch and switch on the PIR sensor when they want to check the paddy field area.

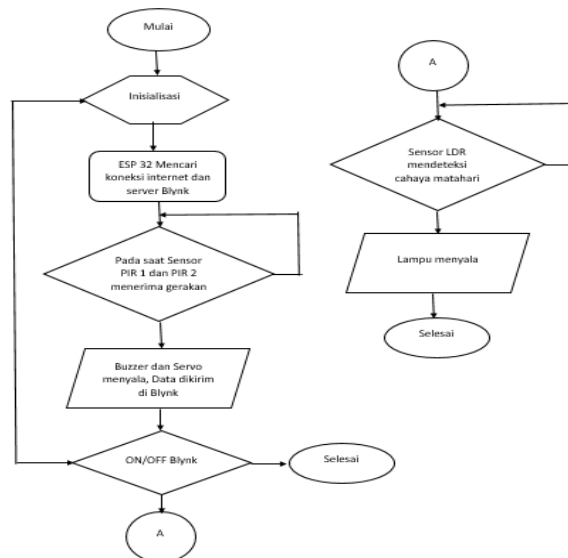


Figure 3. Application Workflow System

As for the pin component of the tool scheme, it can be seen in Table 1.

Table 1. Pin Component

Component Name	Pin	Description
Sensor PIR 1	Vcc	Connects to ESP32 pin
	Out	Connects to IO12 pin
	Gnd	Connects to Gnd ESP32 pin
Sensor PIR 2	Vcc	Connects to ESP32 pin
	Out	Connects to IO14 pin
	Gnd	Connects to Gnd ESP32 pin
Sensor LDR Module	Vcc	Connects to ESP32 pin
	Gnd	Connects to ESP32 pin
	A0	Connects to IO35 pin
Sensor Ultrasonik	Vcc	Connects to ESP32 pin
	Tring	Connects to IO21 pin
	Echo	Connects to IO19 pin
	Gnd	Connects to ESP32 pin
Resistor	Kaki 1	Connects to IO4 pin
	Kaki 2	Connects to Gnd Buzzer pin
Buzzer	+	Connects to ESP32 pin
	-	Connects to IO23 pin
LED	+	Connects to ESP32 pin
	-	Connects to 4 pin
Motor Servo	Vcc	Connects to ESP32 pin
	Gnd	Connects to Gnd ESP32 pin
	Pwm	Connects to IO17 pin

RESULTS AND DISCUSSIONS

The technology produced in this research is IoT-based which is set at a frequency of 40 kHz and controlled via a smartphone. The test results at a distance of 3m were able to kill leafhoppers within 6 hours. While at a distance of 6m, it can kill leafhoppers and locusts within 12 hours. In the initial stage, the pests showed a silent reaction because their metabolism was disturbed by the sound effects issued by the application until the pests died.

Light Dependent Resistor (LDR) Sensor Voltage Testing

Light Dependent Resistor (LDR), is a kind of resistance, its resistance value depends on the intensity of light received. The resistance of LDR decreases when the light is bright and its resistance value will be high when it is dark. In other words, the function of LDR (Light) can conduct electricity, receive constant light intensity (light condition) and suppress current flowing in darkness. The steps of testing the sensor are as follows:

1. Set the scale position of the multimeter selector to 20 V.
2. Connect the red probe of the multimeter to the VCC pin and the black probe of the multimeter to the GND pin.

3. Apply bright light to the LDR, and then read the voltage value on the multimeter display.
4. Close the sensor on the LDR, then read the voltage value on the multimeter display.

Table 2. LDR Sensor Voltage Testing

Condition	Out	Volt
When it's dark	Hight	4.27V
When it's bright	Low	4.14V

Based on table 2, it can be concluded that when the sensor detects the presence of light, the resistance of the LDR sensor will increase and cause the voltage, because when measured it becomes smaller than when there is no light.

Passive Infra-Red (PIR) Sensor Testing

The PIR sensor will detect objects that appear in the coverage area of the PIR sensor. In the test results, this time the researcher set the sensor sensitivity potential at maximum rotation and the time delay potential at maximum speed. After that, continued by testing the effectiveness of the capture and range of PIR sensors in the field in detecting the presence of living things.

Table 3. PIR Sensor Testing

Sensor	Distance (m)	Output	Display Blynk
Sensor PIR 1 and	3	On	Incoming Notifications
Sensor PIR 2	6	On	Incoming Notifications

Looking at the test results in table 3 above, it can be concluded that the effective distance of PIR sensor capture ranges from 3-6m. The sensor can also only detect the presence of objects if there is movement. Meanwhile, if this application is applied to real rice field conditions, the size of the rice field area used is 70m². Because based on the range of the PIR sensor 10m, the range of the PIR sensor to the side at a length of 3m to 6m.

Use of Ultrasonic Sensor

Testing ultrasonic sensors to detect the movement of pests is very effective in repelling leafhoppers. Leafhoppers and locusts belong to the same class of insects. Because insects generally use ultrasonic waves to communicate in the frequency range of 20 kHz to 60 kHz. So with techno pest control tools that can produce sound with a frequency of 40 kHz, the communication between insects will be disrupted. The step is to press the ultrasonic detector application on a smartphone to test the ultrasonic power generated by the ultrasonic sensor.

Table 4. Ultrasonic Sensor Testing

Distance (m)	Ultrasonic Sound (kHz)	Results
3	40 kHz	Distracted Pests
6	23.6 kHz	Distracted Pests
7	21.7 kHz	Distracted Pests

10	20.7 kHz	Hama Tidak Terganggu
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Based on Table 4 above, it can be concluded that leafhoppers are distracted when exposed to ultrasonic sound ≥ 21.7 kHz.

Application Display

1. Blynk Display Before Notification and When There's Movement

In Figure 4 is the initial display for users to start scanning pests on rice plants by pressing the LED and ULTRASONIC ON button. While in Figure 5 is the result of the process of scanning pests of rice plants if there is a movement of pests that are successfully captured and will come out in the form of images, pest names, pest types, weaknesses and pest attack times.

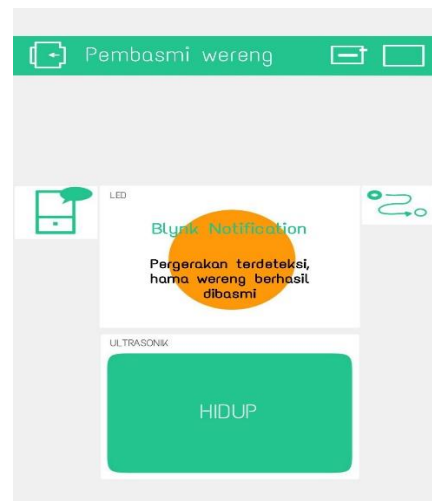
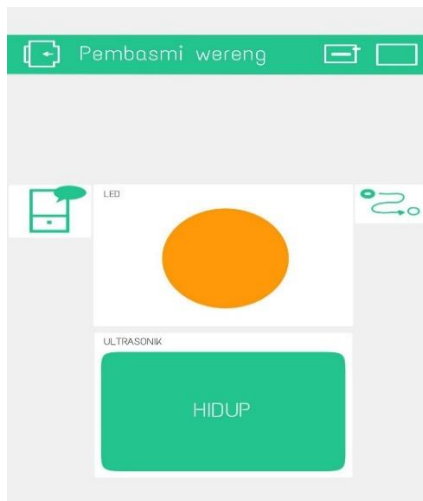


Figure 4. Blynk View before Notifications. Figure 5. Display When There is Movement

2. Blynk Nighttime and Morning View

Figure 6 shows a description of the use of the rice plant pest detection application at night. While in Figure 7 contains information and notifications for using the application in the morning.



Figure 6. Blynk Night time View.

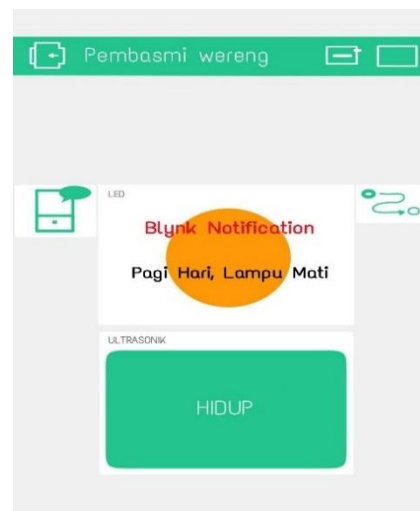


Figure 7. Blynk Morning View

This research can make a significant contribution to improving agricultural productivity, especially in rice cultivation. Because it can reduce losses due to pest attacks, so that farmers can produce more healthy and quality rice crops. In addition, it can also reduce the use of chemical pesticides because by using sound waves as a pest-repellent method. Therefore, this research can help reduce dependence on chemical pesticides that are harmful to the environment and human health. This is in line with the principle of sustainable agriculture, which is environmentally friendly.

IoT-based applications with ESP32 can enable more efficient monitoring and control of rice pests. It can reduce the time and effort required by farmers to deal with pest problems. IoT-based technology enables remote control, which is especially beneficial for farmers who may have to manage their farmland from a long distance. It can also help in emergencies, such as sudden pest attacks.

CONCLUSIONS AND RECOMMENDATIONS

Rice farmers can carry out Pest control technology using IoT because it is possible to replace pesticide substances to eradicate leafhoppers to be more effective and environmentally friendly. The technology produced in this research is based on IoT, which is set at a frequency of 40 kHz and controlled via a smartphone. The results of the application trial also show that at a distance of 3m, it can kill leafhoppers within 6 hours. While at a distance of 6m, it is able to kill leafhoppers and locusts within 12 hours. This application requires a stable internet connection so that the device can work and there is no delay when sending data from the ESP32 Devkit to the Blynk application on the Smartphone. So a power supply that has a stable power output is needed, so that the microcontroller does not lack power.

FURTHER STUDY

This research can serve as a basis for future research in the use of IoT technology and sound waves for agricultural pest control. This may trigger the development of more advanced and effective solutions in the future. Thus, this study has broad significance in the effort to increase agricultural productivity, reduce environmental impact, and utilize IoT technology for agricultural sustainability.

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