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Microcontroller-based prototype design for bird pest repellent technology in agriculture

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Abstract

Rice is a fundamental pillar in the diet of the Indonesian people. The New Order government's investment in the Green Revolution during the 1970s and 1980s reinforced the role of rice in culture and tradition. Dependence on local rice production is crucial for food security, but farmers face serious challenges related to bird pest attacks, particularly from the bondol bird, which can harm crop yields. Farmers have adopted various strategies, including scarecrows and chemicals, but their effectiveness tends to be limited. The focus of this study is to design bird pest detection technology by implementing a detection system in rice fields. As a solution, an automatic bird pest repellent is proposed using a PIR sensor, buzzer, and Esp8622 microcontroller. Although promising, challenges and effectiveness need to be evaluated through periodic data collection. The aim of this research is to identify potential technological solutions to mitigate bird attacks and improve crop yield resilience in Indonesia's agricultural sector.

Keywords: buzzer, esp8622, pest detection technology, pir sensor

1. Introduction

The Indonesian people have a close relationship with rice as a staple food. According to research conducted by Licorice: Southeast Asian Market Insights, 88.4% of respondents (Indonesians) prefer rice over other foods, while only 6.8% favor noodles and 4.8% prefer bread. Since ancient times, rice has been a fundamental part of the Indonesian diet. The abundance of rice in Indonesia cannot be separated from the role of the New Order government in driving the Green Revolution. In the 1970s and 1980s, the New Order government made large investments in agriculture. As a result, rice has not only served as a nutritional source but has also become a vital element in daily life, deeply rooted in the culture and traditions of the Indonesian people (Nugroho, 2018).

Dependence on local rice production is the cornerstone of achieving sustainable food security. With a growing population, accommodating rice agriculture is not merely about fulfilling daily food needs but also about creating national food independence. Thus, improving agriculture has become a necessity to meet food demands in Indonesia. However, farmers face serious challenges related to the number of bird pests in the fields, which can damage their crop yields. Birds, particularly the bondol species, pose a significant threat by consuming up to 10% of their body weight in seeds. The bondol peking bird can consume an average of 5 grams of rice per day. Their attacks target rice grains in the milky stage or rice planted for 70 days, resulting in a 30-50% decrease in rice production due to these bird attacks. These attacks often occur during overcast weather when birds flock together. As a result, rice plants may dry out, and rice grains may fail to develop, leading to reduced yields and financial losses for farmers (Ardjansyah et al., 2017).

Farmers have attempted various strategies to deter bird pests from damaging their crops. One common approach is to set up scarecrows or tie old cans along strings at certain intervals. The strings are shaken to create noise intended to scare off the birds. However, when this method proves ineffective, farmers often have to manually chase away the birds themselves, which is exhausting and inconvenient, especially in large fields. During the rice maturation stage, farmers must be more vigilant, particularly during the critical hours of 6–10 a.m. and 2–6 p.m., when birds tend to feed (Hardiansyah & Pertanian, 2020).

Some farmers even hire workers to guard their fields due to the large areas they must cover. However, this approach is not economically efficient, as it requires additional expenses to pay workers. Facing these challenges, some farmers turn to alternative methods by using chemicals to control pests. Although this method can be effective, excessive use of chemicals can harm the crops and may pose potential risks when the harvested rice is consumed. Therefore, it is crucial to find the right balance in pest control methods to maintain crop health and ensure safe consumption (Oleh, n.d.).

Advancing bird pest detection technology to address bird attacks on rice crops can be an effective step forward. Implementing detection systems in the fields could be key to optimizing rice growth and maturation without interference from bird pests. Some of the most common bird species found in the fields include Pipit, Peking, and Bondol (Pengusir et al., 2023). However, challenges and obstacles may arise during the implementation of this technology, including the effectiveness of the device and the need for periodic data collection to determine the most appropriate measures. By focusing on detection technology, this research aims to gain deeper insights into the potential technological solutions that can support crop yield resilience in the agricultural sector. One proposed solution is to develop an automatic bird pest repellent using a PIR sensor with motion output. This device utilizes the Esp8622 microcontroller to control the tool and also functions as a pest monitor. The PIR sensor is used to detect pest movement, while a buzzer is used to repel the pests. It is hoped that bird detection technology can contribute to the development of efficient and sustainable bird pest control methods in Indonesian agriculture. The following can be seen in Table 1.

Table 1. Main hardware components

No	Main Hardware Components	Specifications.	Number
1	Motion Sensor	PIR HCSR 501	1
2	Mikrokontroller	Arduino Uno	1

PIR (Passive Infrared Received) sensor, or passive infrared sensor The main function of the PIR sensor lies in its ability to detect temperature changes produced by moving objects in its surroundings. This sensor is commonly used in the design of PIR-based (Passive Infrared Received) motion detectors. Since all objects emit radiant energy, movement is detected when an infrared source with a certain temperature (e.g., a human) passes by another infrared source with a different temperature (e.g., a wall). The sensor compares the infrared emissions it receives over time, so when movement occurs, the sensor's reading changes (Toyib et al., 2019).

One common use of this sensor is in home and business security systems, where the PIR sensor acts as a sensitive eye to detect movement in its vicinity, triggering responses such as activating an alarm system or security cameras. Additionally, PIR sensors are used in automatic lighting systems to improve energy efficiency by adjusting lighting based on the presence of people inside or outside a room. The sensor works passively by converting the heat energy emitted by objects into electrical signals without emitting any signals of its own. Therefore, PIR sensors are considered efficient in identifying movement without affecting the surrounding environment. In this project, the PIR sensor detects temperature changes caused by moving objects, specifically birds (Aribowo et al., 2020).

Arduino Uno is supported by the ATmega328 microcontroller, which is reprogrammable, allowing users to develop various creative applications without significant limitations (Oleh, n.d.). The main advantage of Arduino Uno is its ability to provide an open-source development environment accessible to everyone. This fosters an active community that collectively shares projects, source code, and solutions through online forums and platforms. Arduino Uno also features a variety of input/output (I/O) options that support connections with various sensors, motors, and other devices, making it an ideal choice for experimentation and prototyping. The following can be seen in Table 2.

Table 2. Arduino uno specification

No	Parameter	Value
1	Microcontroller	ATmega328
2	Operating Voltage	5 Volts
3	Input Voltage	7-12 Volts
4	Digital I/O Pins	14
5	Analog Input Pins	6
6	DC Current per I/O Pin	50 mA
7	DC Current at 3.3V	50 mA
8	Flash Memory	32 KB
9	SRAM	2 KB
10	EEPROM	1 KB
11	Clock Speed	16 MHz

2. Methodology

This research adopts the Research and Development (R&D) method to develop technological solutions for detecting and repelling bird pests in Indonesian agriculture. By employing scientific principles and technology, the R&D approach enables this study not only to understand the challenges posed by bird attacks on farmers but also to create practical and effective solutions. Through a series of steps that include problem identification and prototype testing, this research aims to contribute to sustainable agriculture and food security in Indonesia (31_M1FBjEy, n.d.).

In this phase, an analysis of the problems was conducted, leading to the identification of several necessary components: (1) Input Section. This section requires an HC-SR501 ultrasonic module to detect birds approaching the rice field area; the data sent by the sensor will be processed within the ESP32. (2) Processing Section. In this section, the device needs components that can process the input data, which will then be sent to the output section. A microcontroller is required here as the main control component for data processing. The ESP32 was chosen due to the number of pins that meet the project's needs. The Arduino IDE is utilized as the programming editor to upload code to the Arduino chip. This application is preferred because it is open-source and commonly used by makers to develop programs for Arduino boards. For data processing and parameter settings, Visual Studio software will be used by the end-users. (3) Output Section. The primary component in the output section is the buzzer, which will be controlled by the Arduino. The buzzer is used to repel bird pests due to its loud sound, which effectively drives them away (Oleh, n.d.). The following can be seen in Figure 1.

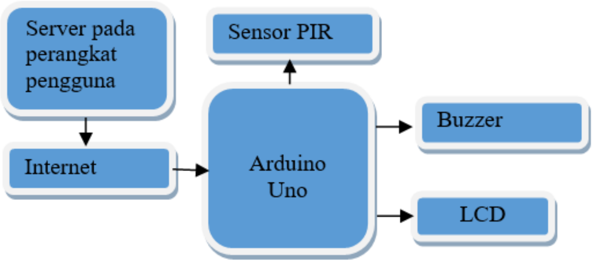

Figure 1. Microcontroller I/O system

Figure 1 shows the block diagram of the overall system circuit applied to the prototype of the rice paddy bird pest detection device using a PIR sensor. The workflow of the device is as follows: the device receives commands from the user through communication between the Arduino Uno and the web server, with processing occurring in the Arduino IDE and Visual Studio. When the device is active, the sensor detects the presence of a bird that triggers the PIR sensor, which then sends data to the server. The server processes this data in the database to identify whether the movement is from a bird, after which it activates the buzzer. The device will operate for a few seconds before stopping, and it will reactivate when the sensor detects further bird movement. The following can be seen in Figure 2.

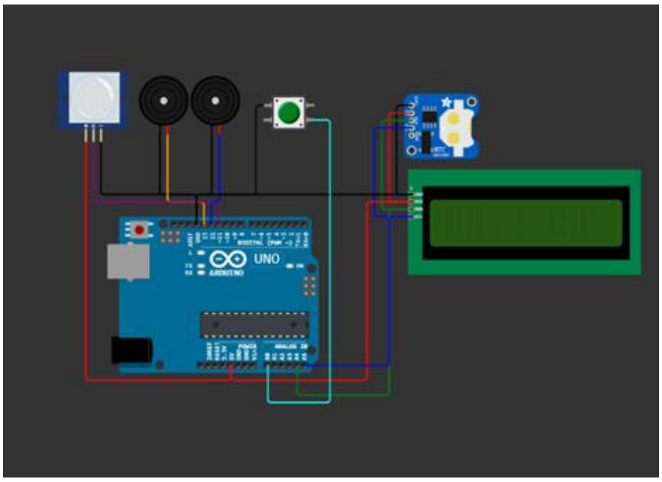

Figure 2. Microcontroller I/O Wiring

This research focuses on the development of a device to detect birds as a response to bird pests in the rice agricultural sector. The prototype is constructed using the following components: (a) a PIR sensor to detect the presence of birds; (b) an Arduino Uno as the microcontroller; (c) an LCD to display the time and date on the device; (d) a loudspeaker/buzzer as the sound output; and (e) a button to deactivate the buzzer.

The next step involves code development in the software, which includes writing, editing, and compiling code in C/C++ optimized for the Arduino microcontroller using the Arduino IDE. The Arduino IDE offers a simple and user-friendly interface, along with the capability to upload programs directly to the Arduino board. In contrast, Visual Studio, Microsoft's integrated development environment, can be configured for microcontroller development by adding specific extensions or plugins. Visual Studio provides advantages in terms of robust debugging support and integration of hardware and software. The choice between the two depends on the preferences and needs of the developer in the context of Arduino project development. The following can be seen in Figure 3.

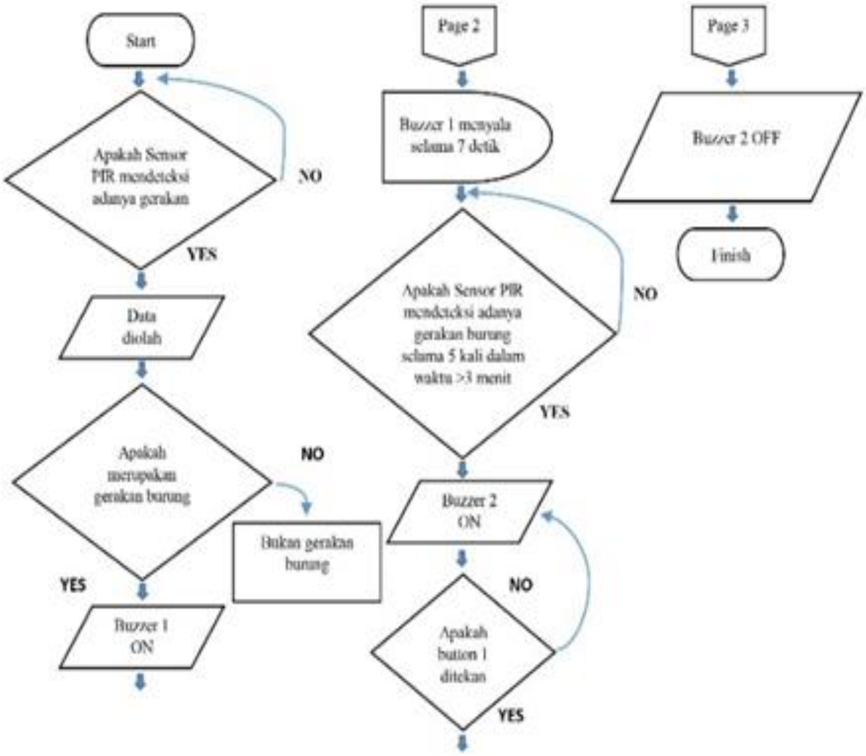

Figure 3. Programming flowchart

3. Result and Discussion

Generally, PIR sensors have an effective detection range of up to 5 meters; however, the detection range and angle can vary depending on the characteristics of the sensor. This testing was conducted to determine whether the sensor could operate effectively in detecting objects, allowing it to activate a motor to move a door. The testing involved measuring the voltage output from the sensor. Table 3 presents the results of the PIR sensor distance test with a human subject (Oleh, n.d.). The following can be seen in Table 3.

Table 3. Range test

No	Input Voltage PIR	Range of Sensor Object	Output Voltage PIR
1	5 Volt	0.5 meter	3.5 Volt
2	5 Volt	1.0 meter	3.5 Volt
3	5 Volt	1.5 meter	3.5 Volt
4	5 Volt	2.0 meter	3.5 Volt
5	5 Volt	2.5 meter	3.5 Volt
6	5 Volt	3.0 meter	3.5 Volt
7	5 Volt	3.5 meter	3.5 Volt
8	5 Volt	4.0 meter	3.5 Volt
9	5 Volt	5.0 meter	3.5 Volt
10	5.3 Volt	5.1 meter	0.0 Volt

The measurements from Table 3 above were taken using a Sanwa digital multimeter. Based on the results of these measurements, it can be concluded that the PIR sensor operates effectively and can detect movement at a distance of up to 5 meters from the sensor. The following can be seen in Table 4.

Table 4. Buzzer Test

Value	Experiment	Detect	No Detect	Buzzer NO 1	Buzzer NO 2
0	Ke-1	-	V	-	-
1	Ke-2	V	-	V	-
1	Ke-3	V	-	V	-
1	Ke-4	V	-	V	-
1	Ke-5	V	-	V	
1	Ke-6	V	-	V	V

In Visual Studio, the results of motion detection are processed, allowing the use of data to evaluate the effectiveness of the device. The information generated from the motion analysis provides a clear picture of the device's performance, facilitating monitoring and assessment of its effectiveness. The following can be seen in Figure 4.

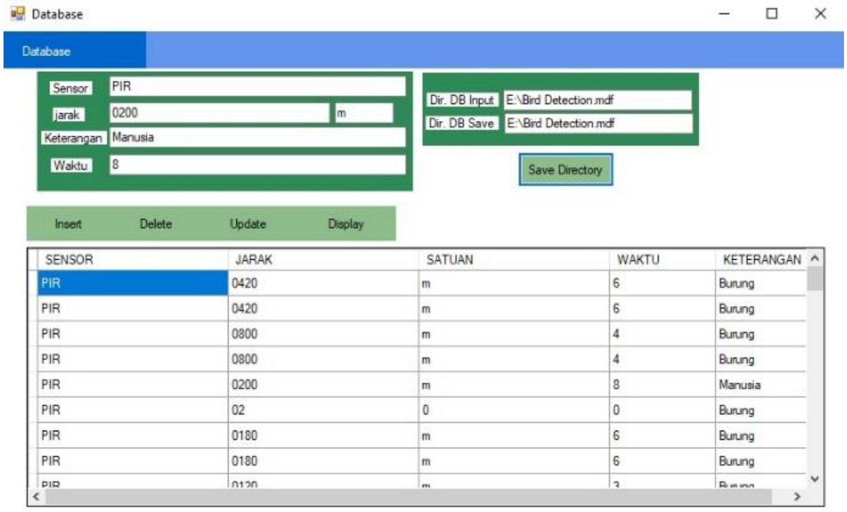

Figure 4. Database

The software testing in Visual Studio related to the database section demonstrates the software's ability to differentiate movements based on the detection time of the motion sensor. The data processing results in an output that identifies the movement as either Human or Bird. In the testing, if the movement lasts for 6 seconds or more, the software interprets it as human, while movements lasting 5 seconds or less are considered bird movements. Additionally, the database form presents information on the distance taken from the graph displayed in the form.

```
  textBox1.Text = jarak; //
  int jarakInt;
  if (int.TryParse(jarak, out jarakInt))
  {
    // Konversi berhasil, gunakan nilai jarakInt sesuai kebutuhan
    textBox1.Text = jarakInt.ToString();
  }
  textBox2.Text = "";
  if (chart1.Series.IndexOf("Bird Detector") == -1)
  {
    // Jika tidak, tambahkan seri 'Bird Detector' ke koleksi
    chart1.Series.Add("Bird Detector");
    chart1.Series["Bird Detector"].ChartType =
System.Windows.Forms.DataVisualization.Charting.SeriesChartType.Line;
  }
  // Tambahkan poin ke seri 'Bird Detector'
  chart1.Series["Bird Detector"].Points.AddY(Convert.ToInt16(jarakInt));
}
```

This program is a snippet of code written in C# that manages values and updates the user interface. First, the value of the distance variable is used to populate the text element in textBox1, allowing the user to see the distance value in the user interface.

Second, the program attempts to convert the distance value to an integer data type using int.TryParse(jarak, out jarakInt). The result of this conversion is stored in the jarakInt variable. Third, if the conversion is successful (the value in jarak can be changed to an integer), then this integer value is displayed again in the text element of textBox1 using textBox1.Text = jarakInt.ToString(). After that, the text in textBox2 is cleared with textBox2.Text = "".

The program then checks whether the chart (chart1) already contains a series named "Bird Detector" using chart1.Series.IndexOf("Bird Detector"). If not, a new series with that name is added to the chart's collection. The chart type for the "Bird Detector" series is set to a line chart using chart1.Series["Bird Detector"].ChartType = System.Windows.Forms.DataVisualization.Charting.SeriesChartType.Line. Finally, the generated integer value (jarakInt) is added as a new point to the "Bird Detector" series on the chart using chart1.Series["Bird Detector"].Points.AddY(Convert.ToInt16(jarakInt)). Thus, the data flow concerning the distance involves retrieving, converting, and processing values to be displayed in the user interface elements and used in a graphical representation on the "Bird Detector" chart.

Visual Studio displays the motion detection distance information in real-time, allowing farmers to easily monitor the device's performance. The effectiveness of the tool can be assessed by observing how far the bird movement is from the sensor after the buzzer sounds. This data is presented in meters and updated every second. The following can be seen in Figure 5.

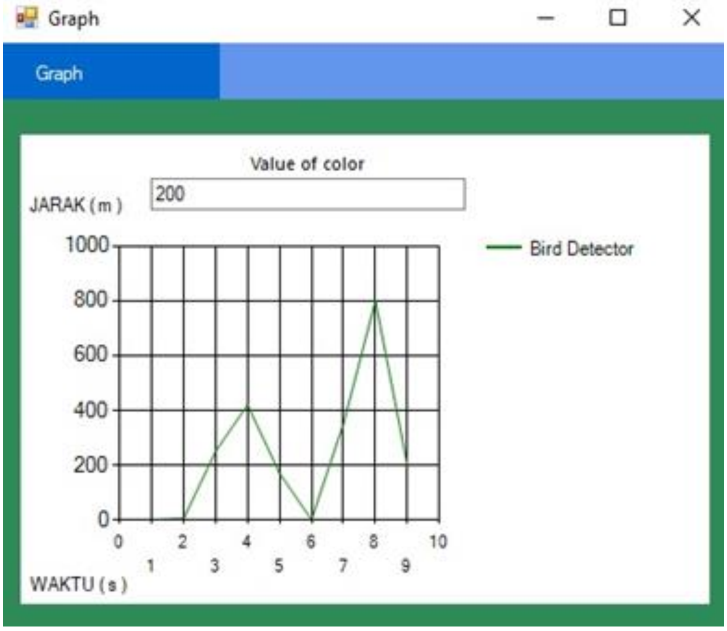

Figure 5. Distance vs time graph

4. Conclusion

In conclusion, this research highlights that the use of a bird pest detection tool integrated with a PIR sensor in the form of a prototype has produced satisfactory results. This tool can accurately identify the presence of birds and effectively activate a buzzer to deter them. Through data processing conducted by Visual Studio, farmers can easily schedule pest deterrence processes, allowing them to take preventive measures without the need for additional labor or chemicals. Thus, this solution is not only efficient in addressing bird pest issues but also provides an environmentally friendly and sustainable alternative for agricultural practices. The introduction of this technology is expected to enhance productivity and the well-being of farmers in managing their crops.

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