

“GrainBot: An Android Controlled Rice Grain Collector Robot”.

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Abstract - Rice serves as a dietary staple for more than three billion individuals worldwide, yet notable postharvest losses persist despite improvements in production methods. Although traditional sun drying is economical and environmentally sustainable, it demands considerable labor, poses health hazards to farmers, and leads to inconsistent drying, which affects grain quality. To tackle these issues, this research introduced "GrainBot: An Android Controlled Rice Grain Collector Robot." This robot, which operates on two wheels, employs a suction mechanism to gather sun-dried rice and can be controlled wirelessly through a specially designed Android app. The evaluation of the system's functionality, usability, efficiency, compatibility, maintainability, reliability, and portability was conducted following ISO 25010 standards by farmers, agricultural experts, and IT professionals. The assessment resulted in an "excellent" grand mean score of 4.61, reflecting high levels of user satisfaction and the system's effectiveness in automating and streamlining the rice grain collection process. The proposed system presents a promising technological approach to reducing manual labor, alleviating health risks for farmers, and enhancing the efficiency of postharvest rice handling.

Keywords: Rice Grain Collector Robot, Android Controlled, Sun Drying, Postharvest Handling, Automation, Mobile Application, Suction Mechanism, ISO 25010, Wireless Control

I. INTRODUCTION

Background of the Study

Over three billion people around the world rely on rice as their basic diet. Despite significant advancements in improved breeds and production techniques, postharvest handling losses are still significant. Sun drying is a traditional technique that involves spreading the grains out in the sun to lower the moisture content of paddy. The pace at which water evaporates from grains is accelerated by the heating of the grains and the surrounding air caused by solar radiation. Due to its affordability as compared to mechanical drying, it is the most often used drying technique in Asia. Because it uses the sun as a heat source and doesn't emit CO₂, it is inexpensive and environmentally benign (Lenard De Leon, 2019).

Despite being accustomed to laboring in their farms under the intense sun, Filipino farmers are susceptible to heat stroke, according to Manny Galvez (2020), SCIENCE CITY OF MUÑOZ, Nueva Ecija, Philippines. Head of the University of the Philippines-Manila's institutional bio-safety and bio-security committee and an expert in infectious disease and internal medicine, Raul Destura, cautioned farmers about the dangers of heat stroke, also referred to as sunstroke, and advised them to take the appropriate safety measures. Destura,

who spoke on the health dangers associated with rice farming at the Philippine Rice Research Institute, instructed farmers on how to recognise the symptoms of heat stroke because, even in rural health units, the disease is frequently overlooked or misdiagnosed.

According to the statement of Mr. Nindro Paul Pountero, one of the laguerta farmer, is that when sun-drying the rice or any grains, they encounter challenges like too much heat, time consumption, and difficulties in manually putting rice on a sun-dried mat. (Sun drying of rice grains is very common, particularly in small and medium-sized batches of drying mat. Uneven grain spreading and overheating on the drying mat can cause the grains to become tough, and will lost its nutrients.) As a result, some grains may remain damp or under-dried while others become early dry, leading to uneven grain spreading of grains, inadequate exposure to sunlight, and varying weather conditions. As a result, some grains may remain damp or under-dried while others become overly dry, leading to uneven quality and potential spoilage. Achieving uniform drying is crucial to ensuring the longevity and market value of the rice crop.

However, sun-drying has a limited capacity and is typically labor-intensive. This method's temperature management is extremely challenging, and the grains are prone to cracking from overheating, which results in poor milling quality. Farmers may also be at danger for heat stroke, dehydration, skin cancer, back pain, strains, and sprains as a result of the sun-drying process. Gummert, M. (2010)

Based on the problem statement , we came up an solution this is to build a two wheeled robot for the movement, have a suction this vacuum that can collect the grains at sun-drying mat, have battery at the back of the robot that source of the electricity, switch for the on/off buttons, and the mobile application for the wireless connectivity of the robot, have a container at the back for packing process if its full. The suction of the robot has its limitation this is only for small grains like; rice grains, corns, beans and any small grains. This robot will lessen the labor of farmers this could be very useful for them.

Conceptual Framework

The Input-Process-Output (IPO) is a widely used approach in system analysis and software engineering for describing the structure of an information processing program or another process (Busbee & Braunschweig, 2019).

The system initiates with the Input stage as shown in figure 1, in which a Bluetooth module provides a wireless connection for the mobile application to connect to the Hardware, a Mobile application controller that allows user to control the movement of the Robot.

Fig. 1 shows the conceptual framework of the Grainbot: Smartphone Controlled Rice Grain Collector Robot.

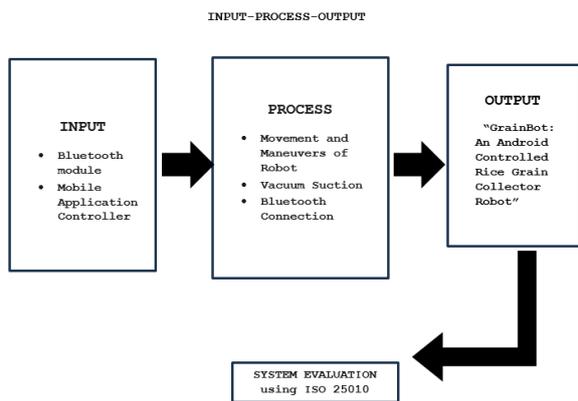


Fig. 1

In the Process, a smartphone sends wireless control commands to Hardware via Bluetooth Module using an Arduino Uno, that controls the robot movement and function of collecting rice grains.

The Output is the GrainBot: An Android Controlled Rice Grain Collector Robot.

In System Evaluation, the researchers use the ISO 25010 in terms of functionality, performance, compatibility, usability, reliability, maintainability, and portability.

II. METHODOLOGY

In this chapter, the methods used in developing the GrainBot: An Android Controlled Rice Grain Collector Robot are presented to generate usability and efficiency of the system. It consists of (1) Project Description, which describes the system, its function and how it works; (2) Requirements Analysis, which contains different diagrams of the system; (3) Design Specification, which contains the user interface of the system; (4) Testing and Operation, which states the method used and (5) Project Evaluation, which is based in ISO 25010.

Project Description

The goal of this project is to create a two-wheel drive robot that can be operated by an Android Application to gather sun-dried rice grains. The robot has a vacuum system that allows it to suction sun-dried rice grains. Using a Bluetooth module and an Android application, the user may control the robot's movements and vacuum switch from a distance. The system is a time-saving and human labor-efficient agricultural technology breakthrough.

Development Process

In developing the system, the researchers used the prototyping based model. According to Nurcahya, D., Nurfauziah, H. and Dwiatmodjo, H. (2022) the prototyping model, it is more suitable to be used in a system or software that is created based on certain requests and needs (even situations or conditions) or that are customized. Meeting activities are routine activities that are often held, especially in a school agency, the existence of the meeting serves to find a solution to a problem that is expected to reach a consensus, solution and determine a decision.

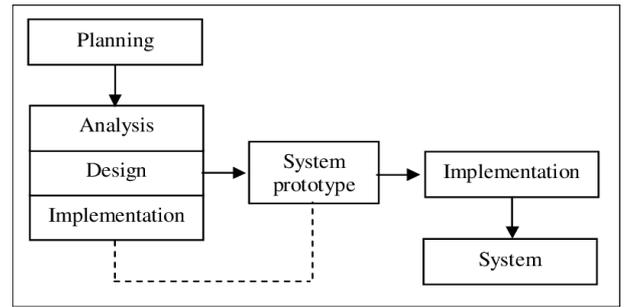


Figure 2. The Prototyping-base Model

An initial version of the system or product is constructed, tested, and improved depending on user feedback until an acceptable prototype is achieved. This process is known as the prototyping model. In order to improve the prototype iteratively, developers and users collaborate during this process.

The researchers use a prototyping-based strategy to create the system, starting with the planning stage in which they make plans for the system's requirements and results. The researchers then analyse the system's potential outcomes during the analysis phase. The researchers create the prototype model and system functionality in the design phase. Construction of the System Prototype for Testing and Implementation follows the Design phase. After the system has been tested and found to be error-free and revision-free, it moves on to project implementation, where it is made available to end users. The system prototype is then assessed in accordance with ISO 25010 evaluation requirements during the System Evaluation Test, which follows the Implementation Phase.

Requirement Analysis

Planning

The researchers designed the system's goal at this stage of planning: to lessen the amount of labour required to gather sun-dried rice grains in the sun's heat. Farmers may manage rice grain collection remotely thanks to an Android application that manages the hardware's operation. Based on the information acquired from their analysis, the researchers developed a concept for a particular type of technological innovation that would upgrade the standard rice grain collector. The grain collector would be controlled by an Android application.

Analysis

At this stage of the project, the researchers focused on gathering data that would help them understand the working of the rice grain collector robot. They collected various types of information related to how the robot functions, including technical specifications, operational efficiencies, and user needs. This data collection was crucial for ensuring that the final product would meet the requirements of those who would use it.

Once the necessary data was gathered, the researchers created visual representations of the information. This helped them interpret the data more easily and see patterns or insights that could influence their design choices. Analyzing the outcomes of their data allowed the researchers to assess the strengths and weaknesses of

different aspects of the system.

With a clearer understanding of the robot's function, the team organized the development process to align with the insights gained from their data analysis. They mapped out a structured plan that detailed each step required to build the system effectively. This plan included timelines, resource allocation, and specific goals for each phase of development.

The primary purpose of collecting this information was to innovate technology that would streamline the collection of sun-dried rice grains. By understanding the practical aspects and challenges of rice grain collection, the researchers aimed to create a robot that would simplify and improve this task. The integration of smart technology would not only enhance efficiency but also reduce the manual labor involved in harvesting rice grains.

Design

During the System Design Phase, the researchers focus on creating the key features, expected results, and visual aspects of the system. This involves deciding how the system will work, what it will achieve, and how users will interact with it. To structure the system's design, the researchers employ the Unified Modeling Language, or UML. This language helps visualize and organize the design process effectively.

The UML encompasses several important diagrams. An Activity Diagram illustrates the workflow of the system. It shows the various actions and the order in which they occur. A Use Case Diagram highlights the interactions between users and the system, defining the specific tasks the system should perform.

A Sequence Diagram maps out the order of messages exchanged among different parts of the system. This helps clarify how components communicate with one another. The Deployment Diagram outlines how the system will be set up in a physical environment. It provides a clear view of where different components will be located.

Additionally, a Block Diagram offers a high-level overview of the system's major components and their relationships. It is useful for understanding the overall structure. Finally, a Graphical User Interface Diagram shows how the system's interface will look. This diagram is crucial for designing a user-friendly experience.

Together, these UML diagrams provide a comprehensive framework for the system's design, ensuring that all functionality, outcomes, and visual elements are well thought out and interconnected.

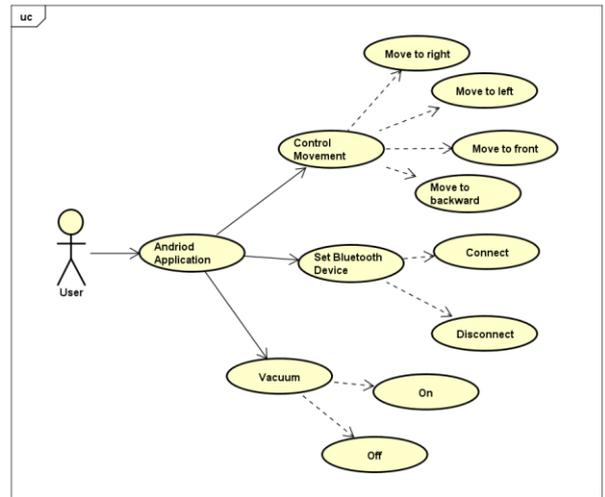


Figure 3. Use case diagram of the user and smartphone controlled rice grain collector robot

In figure 3 shows the use case diagram of android app controller rice grain collector robot. It has a Bluetooth buttons in order to connect and deactivate a Bluetooth device. The machine will move in all directions—left, right, forward, and backward—under using the control of the Android app. Furthermore, the Android app will manage the vacuum's features, such as turning it on and off.

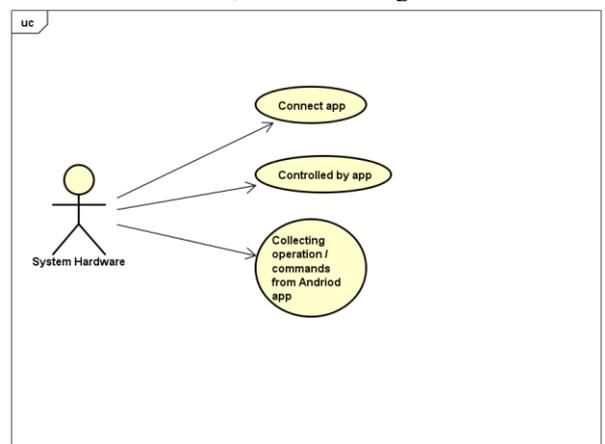


Figure 4. Use Case Diagram of the System of GrainBot: Smartphone Controlled Rice Grain Collector Robot

Figure 4 shows the use case diagram of GrainBot: Smartphone Controlled Rice Grain Collector. Through a Bluetooth connection, the Android app will establish a link with the system hardware, allowing the app to accept orders and operations from the Android app and use them to operate the system. There are four directions the system can move: left, right, forward, and backward. Pressing the on/off button on the Android app will activate its suction-generating vacuum.

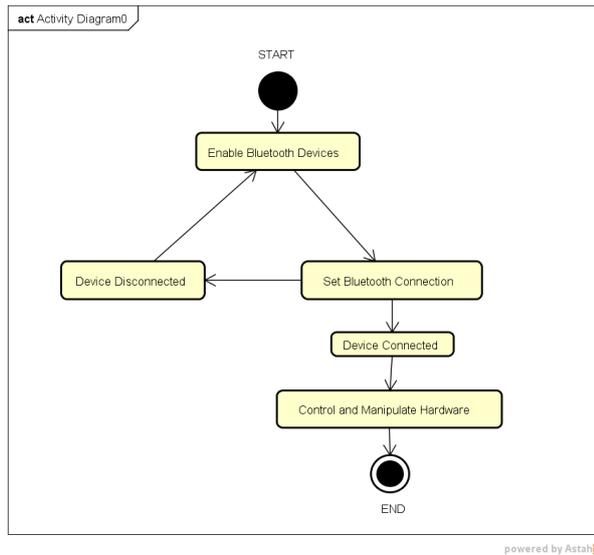


Figure 5. Android Application Activity Diagram

Figure 5 shows Android Application Activity Diagram of the System. The application must enable the Bluetooth connection and configure the Bluetooth device to connect to the hardware in order for the system to work effectively with a Bluetooth device. The user can now control and modify the device's movement and functionality after the application has been connected to the hardware.

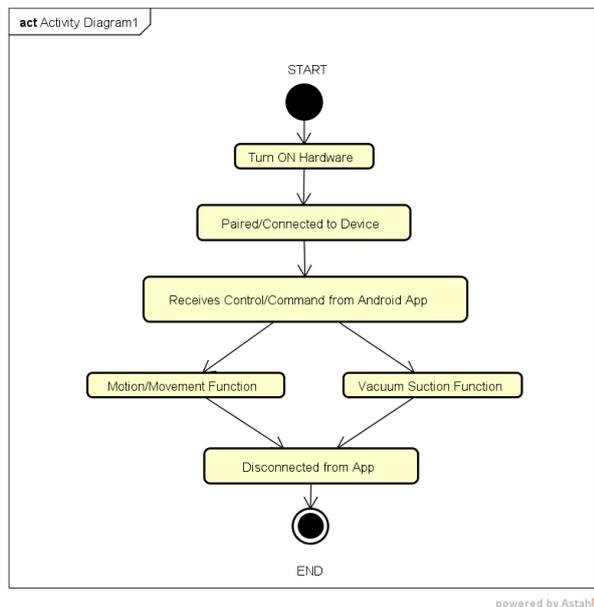


Figure 6. Activity Diagram of the System Hardware

Figure 6 shows Activity Diagram of the System Hardware. The hardware must be turned ON to Enable the Bluetooth module. Then the Application must pair the Bluetooth device of the Hardware. Once connected, the app can manipulate the function and movement of the hardware by sending commands to the Bluetooth module interpreted by the main microcontroller.

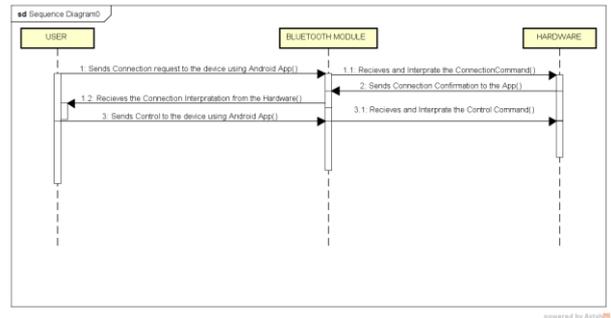


Figure 7. Sequence Diagram of the System.

Figure 7 show the Sequence of the Rice grain collector robot system. The process is that the user sends the connection request to the hardware using Android Application via Bluetooth connection. The Hardware receives the connection request and automatically connects to the Devices. Once the Device is Connected the user can now control the Hardware by pressing the button in the Android Application for movement and vacuum suction, where the commands are sent to Bluetooth module and interpreted by the main microcontroller of the System.

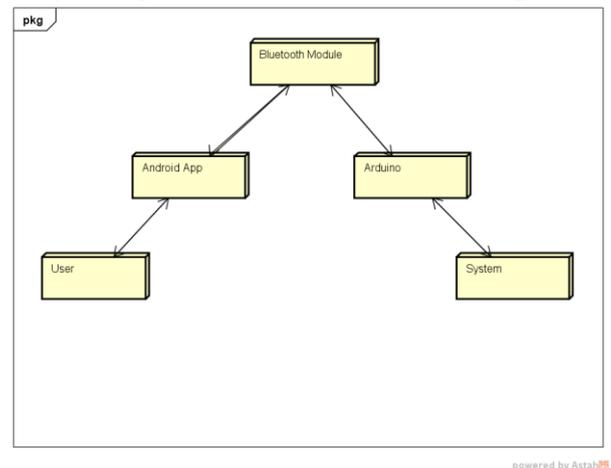


Figure 8. Deployment Diagram of the System

Figure 8 shows the deployment diagram of the system. In order to manage and operate the system's different operations, a user interacts with an Android app that connects wirelessly using a Bluetooth module. The Arduino microcontroller then receives and executes commands from the user.

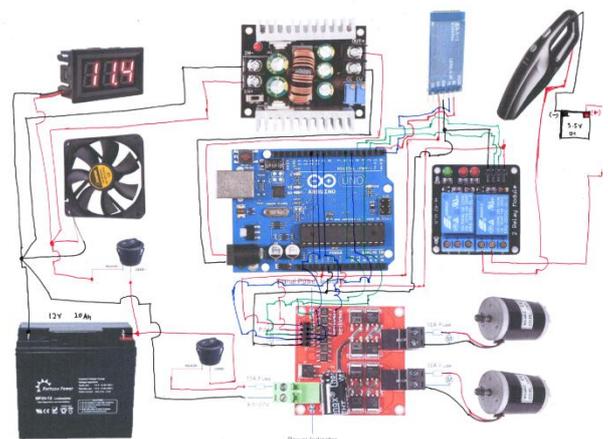


Figure 9. Circuit Diagram of the System Hardware

Figure 9 shows the Circuit Diagram Connection of the System Hardware.

The hardware circuit diagram for the system is displayed in the figure. where the switch is attached to the positive terminal line to turn the components ON and OFF, and the power source is a 12v DC rechargeable battery. A 12v DC battery powers the Arduino R3, voltmeter, cooling fan, DC Buck inverter, and 7A 160W motor driver module. While the cooling fan cools the parts to avoid overheating, the voltmeter measures the voltage supply from the battery. To provide the Arduino Uno with the proper current and voltage, the DC Buck inverter reduces the battery's voltage and amperes. The switch that turns the Vacuum on and off is the relay module. In order to send and receive command signals from Android phones, the Arduino Uno's RX and TX digital pins are also connected to the Bluetooth module. While the power is directly connected to the DC battery to provide sufficient current and voltage as required by its specifications to operate the DC motors, the Motor Driver Module Input Pins are connected to the Arduino Uno to initiate a command signal that turns the DC motors in both a reverse and an inverse direction.



Figure 10. Graphical User Interface (GUI)

The figure 10 shows the GUI of the rice grain vacuum controller robot. The Interface shows the three clickable Bluetooth icons the Enable Bluetooth, to turn On the Bluetooth of the device, the Bluetooth Connect, to send connection request to the hardware, and the Bluetooth disable, to disconnect and turn Off the Bluetooth connection of the Devices. It also has four arrow buttons for the maneuver control, to control the movement of the hardware such as forward, backward, left and right. Vacuum button to turn On and Off the vacuum suction of the Hardware.

Implementation

Implementation refers to the series of actions needed to launch a program successfully. This process begins with gaining support and acceptance from those involved. It is crucial to ensure that all stakeholders understand the purpose of the program and its potential benefits.

Implementation involves the activities of putting the program into place, from gaining acceptance for the program to making revisions when the program is not working as planned.

In summary, implementation is not just about starting a program. It is an ongoing process that includes gaining support, actively executing the plan, and making necessary revisions based on feedback and results.

Testing and Operation

Before deploying the system hardware, the researchers conducted extensive testing to ensure optimal performance and reliability. To make sure the system functions as intended, it is extensively tested throughout this phase. Plans for testing are created, user acceptance tests are conducted, and any flaws in the system are fixed. One step in identifying the application's flaws and mistakes is testing. These errors may occur at the system or unit level. You may avoid any bugs that might be harming your application by using so many testing phases.

Project evaluation

The system was evaluated using the International Organization for Standardization (ISO) 25010 standard. ISO/IEC 25010 is a widely recognized international standard that provides a framework for evaluating the quality of software products. It defines a set of quality characteristics, such as functional suitability, performance efficiency, usability, security, reliability, maintainability, portability, compatibility, and accessibility.

The smartphone-controlled rice grain collector robot was evaluated based on the ISO 25010. The study's evaluators were 30 randomly selected individuals composed of ten (10) farmers, ten (10) IT experts and ten (10) agriculturist.

The data was collected using survey questionnaires that was valid and reliable. The system was evaluated using 5-point scale, such as 5 Excellent, 4 Very Good, 3 Good, 2 Fair, and 1 Poor.

III. RESULTS AND DISCUSSION

This chapter presents and discusses the "Grainbot," an Android-controlled rice grain collector robot.

The system was designed to develop an Android-controlled robot collector that can collect rice grains, which is controlled using a mobile application via Bluetooth.

The grainbot has hardware that contains the chargeable battery to power the system, features a buck inverter to reduce current to the components' necessary levels, and guards against damage. It also has a programmable microcontroller that directs the motor driver module, which powers the DC motors attached to the wheels to control the robot's movement. Also, it includes a voltmeter to check the voltage and a relay module to turn the hoover on and off.

The software of the system has a feature that provides a Bluetooth connection where it enables connecting and disconnecting the Android app Bluetooth from the system hardware. It features a button switch for hoover control and a button for movement control.

Table 1. Result of the Functionality of the System

Functionality Sub-Characteristics	Farmers Mean	Agriculture Experts Mean	IT Experts Mean	Grand Mean Description
Suitability	4.8	4.67	4.8	4.75
Accurateness	4.87	4.5	4.6	Excellent
Interoperability	4.8	4.00	4.4	4.66
TOTAL Mean	4.82	4.39	4.6	Excellent 4.44 Very Good 4.61 Excellent

Table 1 shows the functionality of the system, the system got a grand mean of 4.61 or excellent, based on the evaluation of farmers, agriculture experts, IT experts. The four areas of functionality, the system got the highest mean of 4.87 in accurateness from the farmers. At the same time the lowest rating that the system got is 4.00 in interoperability from the agriculture experts.

System Performance in Terms of Reliability

Table 2 indicates that farmers (4.8), agricultural experts (4.5), and IT experts (4.4) all gave the system a very good rating for dependability. The outcome demonstrated the system's dependability as a tool in terms of its functionality, usefulness, maintainability, efficiency, and portability.

Table 2. Result of Reliability of the System

Reliability Sub-Characteristics	Farmers Mean	Agriculture Experts Mean	IT Experts Mean	Grand Mean Description
Compatibility	4.73	4.33	4.2	4.42 Very Good
Operability	4.87	4.67	4.6	4.6
TOTAL Mean	4.8	4.5	4.4	4.71 Excellent 4.56 Excellent

System Performance in Terms of Usability

Farmers, agriculture experts, and IT specialists evaluated the system and found it useful for using the mobile application as a controller. The outcome demonstrated that, in

terms of gathering the rice grains using the robot, the system satisfied the user's requirements.

Table 3. Result of the Usability of the System

Usability Sub-Characteristics	Farmers Mean	Agriculture Experts Mean	IT-Experts Mean	Grand Mean Description
Understandability	4.87	4.67	4.6	4.71
Operability	4.87	4.33	4.6	Excellent
TOTAL MEAN	4.87	4.5	4.6	Excellent 4.6 Excellent 4.66 Excellent

System Performance in Terms of Maintainability

The results of the system's maintainability are displayed in Table 4. With a mean rating of 4.51, the system received good ratings from farmers, agriculture experts, and IT specialists. Based on the evaluation rating, the outcome demonstrated that the system is maintainable. Errors in the system's software and hardware can be upgraded and changed to suit the farmers' desired system functionality.

Table 4. Result of the Maintainability of the System

Maintainability Sub-Characteristics	Farmers Mean	Agriculture Experts Mean	IT-Experts Mean	Grand Mean Description
Stability	4.73	4.33	4.5	4.52
Analyzability	4.8	4.67	4.5	Very Good
Changeability	4.8	4.00	4.75	4.66
TOTAL Mean	4.77	4.33	4.58	4.66 Very Good 4.51 Very Good 4.56 Very Good

System Performance in terms of Efficiency

The system's efficiency is displayed in Table 5. With an overall grand mean of 4.61, the system was assessed as excellent, according to the results. The system is producing as much as possible with the least amount of lost time in gathering sun dried rice.

Table 5. Result of the Efficiency of the System

Efficiency Sub-Characteristics	Farmers Mean	Agriculture Experts Mean	IT-Experts Mean	Grand Mean Description
Scalability	4.8	4.	4.6	4.59
Reliability	6	3	4.4	Excellent
TOTAL	4.8	3	4.5	4.64
Mean	6	4.		Excellent
	4.8	6		4.61
	6	6		Excellent
		4.		
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System Performance in Terms of Portability

The outcome of system portability is displayed in Table 6. Overall, the system received high ratings of 4.84 from farmers, 4.55 from agriculture professionals, and 4.73 from IT specialists. Because the user can simply utilize the app after connecting it to the system, the outcome demonstrated that the system is compatible.

Table 6. Result of the Portability of the System

Usability Sub-Characteristics	Farmers Mean	Agriculture Experts Mean	IT-Experts Mean	Grand Mean Description
Adaptability	4.8	4.6	4.6	4.70
Installability	6	6	4.8	Excellent
Compatibility	4.8	4.6	4.8	4.75
TOTAL	4.8	6	4.7	4.75
Mean	6	4.3	3	Excellent
	4.8	3		4.66
	4	4.5		4.66
		5		Excellent
				4.70
				Excellent
				4.70
				Excellent

Over all Evaluation of the System

The system evaluation demonstrated highly positive results, successfully achieving the primary objective of this study: developing a "GrainBot," a smartphone-controlled rice grain collector robot. This validated the GrainBot prototype's functionality and proved the feasibility of remotely controlling a rice-harvesting robot using an Android application. A key success factor was the farmer's ability to remotely control

the robot's movement via the application, enabling field navigation without manual intervention and significantly enhancing operational efficiency. While the evaluation identified some limitations, such as occasional malfunctions, these are typical of early prototypes and provide valuable insights for future iterations, guiding improvements in robustness, reliability, and overall system stability. Despite these minor setbacks, the successful demonstration of remote control capabilities and the overall positive evaluation underscore the GrainBot's significant potential to revolutionize rice farming by increasing productivity, reducing labor costs, and minimizing physical strain on farmers. Continuous refinement of the GrainBot will pave the way for the widespread adoption of this innovative technology, leading to increased efficiency and improved livelihoods for farmers.

Table 6. Over all Result of the System Evaluation

Characteristics	Farmers Mean	Agriculture Experts Mean	IT-Experts Mean	Grand Mean Description
Functionality	4.8	4.3	4.5	4.61
Reliability	2	9	4.4	Excellent
Usability	4.8	4.5	4.6	4.56
Maintainability	4.8	4.5	4.58	Excellent
Efficiency	7	4.3	4.5	4.66
Portability	4.7	3	4.73	Excellent
TOTAL	7	4.4	4.55	4.56
Mean	4.8	9		Excellent
	6	4.5		4.61
	4.8	5		Excellent
	4	4.4		4.70
	4.8	6		Excellent
	3			4.61
				Excellent

CONCLUSION

The researchers come to the conclusion that the system has effectively achieved its goals, producing a hardware and software solution that is both efficient and easy to use. This solution offers farmers with an intuitive and convenient approach for managing the movement of the robot use in gathering sun dried rice using Android Application in an Android Phone. (The research team confidently concluded that the developed system had successfully fulfilled its precise design parameters. Getting this done required a special set of hardware and software that was designed to work quickly and easily with the complicated process of collecting rice that was laid out to dry in the sun. The solution directly solves most of the issues faced during traditional sun-drying, giving farmers a fast and technological approach to the drying procedure. To this end, an Android-based application acts as the main control station, enabling farmers to remotely direct the movements of a purpose-built robotic unit. The robot tip toes close to the edge of the drying mats to carefully pick up the sun-dried grains of rice. This system essentially feels no longer ideal for conventional techniques as it

minimizes the manual works while maximizing the gathering process. The researchers noted that the system was specifically designed to be friendly to farmers, who can use their Android smartphones to track and make changes to the robot on the go, so that the all-important task of collecting on the sun-dried rice.)

RECOMMENDATION

The researchers are recommended to upgrade this system by incorporating features such as automated spreading of sun-dried rice on the drying mat, obstacle avoidance capabilities to enhance safety and navigation, increased storage capacity for collected dried rice, and a conversion to four-wheel drive for improved power and load-carrying capacity. These enhancements would significantly improve the system's functionality and broaden its applicability in real-world farming scenarios. (The system can be further improved by: maximizing sun-dried rice spreading on the drying mat; implementing obstacle avoidance for enhanced safety and navigation; increasing the volume of collected dried rice; and upgrading to a four-wheel drive system for improved power and carrying capacity. These enhancements would significantly improve the system's functionality and broaden its applicability in real-world farming scenarios.) (The current system, researchers say, should be updated to become a one-stop agricultural solution. They deliver rice automatically by spreading it to ensure evenness in sun-drying and obtaining excellent grain quality. Your training also indicates advanced obstacle avoidance for safe ground across varying field conditions. Increasing the onboard storage capacity for harvested dried rice is important to help reduce downtime and increase efficiency. A four-wheel drive system would enhance power and load-carrying capacity, allowing passage through rugged terrain and improving productivity. These upgrades are designed to move the grid from just a specialized collection device to a general-purpose tool, increasing productivity and lowering labor costs.)

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