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Research Article

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Design and Implementation of Automatic Paddy Drying Robotic System with Raspberry Pi Integration

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ABSTRACT

The process of drying rice paddies holds immense significance in rice production, profoundly influencing thequality of the final yield by ensuring the ideal moisture content. Among the conventional techniques for managing the solar drying process, manual tedding stands out-a labor-intensive procedure that entails the physical task of flipping and evenly dispersing the grains. This method remains widely practiced by Filipino farmers due to its cost- efficiency and minimal environmental impact. Nevertheless, there is an increasing demand for modernizing this process to enhance efficiency and elevate the quality of rice output. The focal point of this research is to engineer an automated tedding mechanism for sun- drying rice grains. Several forward-thinking designs were explored, encompassing a tossing mechanism, a plow- based configuration, a vacuum-assisted system, and a cutting-edge sweeper wheel concept. Following meticulous evaluation, a specific mechanism was chosen for production and subjected to rigorous testing. The findings unequivocally demonstrate the effectiveness of the chosen model in efficiently collecting and redistributing grains on the drying surface, achieving an impressively low margin of error, falling below 5%. This breakthrough holds the promise of streamlining the rice drying process, yielding time and resource savings, and ultimately elevating the overall quality of the rice harvest.

Keywords: Collecting, Sun Drying, Solar Drying Process, Tossing, Tedding

Introduction

Rice is a cornerstone of agricultural and economic stability in India, serving as a linchpin for food security within the nation. Despite substantial advancements in rice paddy production over the past decade, the overall yield has declined due to the prevalent inefficiencies in post-harvest practices, most notably in paddy drying. The drying stage is an absolutely critical facet of rice production, wielding substantial influence over the quality of the final output by ensuring the precise moisture content. Deviating from the recommended moisture threshold, which typically hovers around 14% as prescribed by institutions such as the International Rice Research Institute (IRRI), can lead to issues like breakage, discoloration, and spoilage. This underscores the pressing need for vigilant monitoring and management of the grain's temperature, consequently fueling the development of contemporary mechanical drying solutions. Yet, the high costs, rigorous maintenance demands, and technical complexity associated with these mechanical drying technologies have led to the continued popularity of the traditional practice of sun drying on pavements. This method prevails due to its cost-effectiveness and minimal environmental footprint, a testament to its practicality in the Indian context. According to IRRI, the recommendation is to ted the grains every half-hour during this process to ensure even drying.

Mechanization also holds great importance in streamlining the collection of paddies spread out on the expansive pavements. This challenge is exacerbated by the dearth of suitable technology for this task and the demand for expeditious handling, particularly when the monsoon season looms. Points out that manual collection can take over an hour, contingent on the field's dimensions, and necessitates a considerable workforce due to the prevailing method of grain sweeping. The pressing requirement is for an automated solution that not only streamlines the collection process but also outpaces the manual

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procedure in terms of speed and efficiency. Such an innovation promises to be of immense assistance to post-harvest operations in India, addressing the unique needs of the Indian agricultural landscape and benefiting local communities.

Objective

The primary aim of this research is to identify the most efficient mechanical design for grain turnover on pavements. This design will be tailored to meet the specific requirements of farmers and millers, while also aligning with the established tedding standards of the International Rice Research Institute (IRRI). A pivotal objective is to scrutinize multiple design options based on criteria such as accessibility, design intricacy, power demands, and adaptability/flexibility in real-world applications. The goal is to select a design that excels in these key aspects. The study intends to subject the chosen design to rigorous testing, with a primary focus on its effectiveness in tedding the grains and its ability to comprehensively sweep the grains. This thorough evaluation ensures that the selected design not only fulfills theoretical standards but also excels in practical, real-world scenarios.

Block Diagram

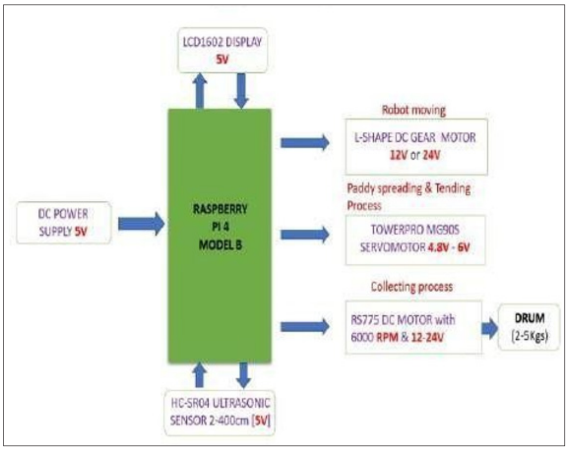

Figure 1: Block Diagram of Automatic Paddy Drying Robot

Components

- Raspberry Pi 4 Model B
- Permanent Magnet DC Gear Motor, Magnetic Hall Encoder
- TowerPro MG90S Mini Digital Servo Motor
- LCD1602 Parallel LCD Display with Blue Backlight
- IIC/12C Serial Interface Adapter Module
- 4x4 Matrix 16 Keypad Keyboard Module 16 Button MCU
- MPU6500 Gyroscope/Accelerometer/Digital Motion Processor
- RS775 12V 6000RPM High Speed DC Motor
- HC-SR04-Ultrasonic Range Finder
- B3950 10K NTC Thermistor Temperature Sensor

Methodology

Starting the Robot and Paddy Drop:

At the beginning of the project, we set up the robot's workspaceusing a display. Users choose where the robot will work by entering numbers for how far it should go left and right (x-axis) and forward and backward (y-axis). Once we've done this, the robot begins its work. It starts moving from a certain point and puts out Paddy as it moves. This way, we make sure that the Paddy is spread evenly along the path. This even spread is important for the next step, which is tedding.

Design Considerations

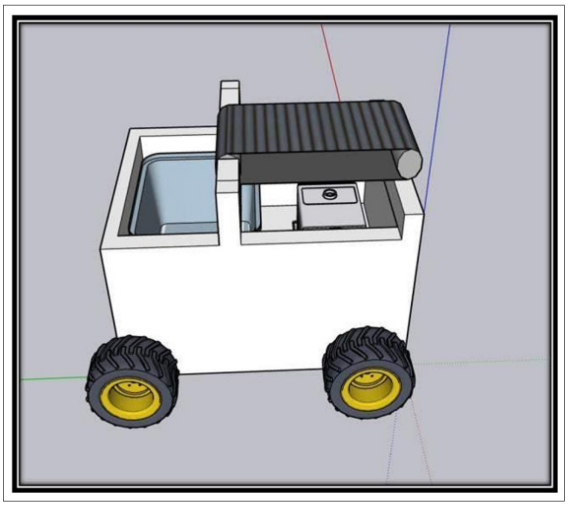

Figure 2: SideView of Robot Model

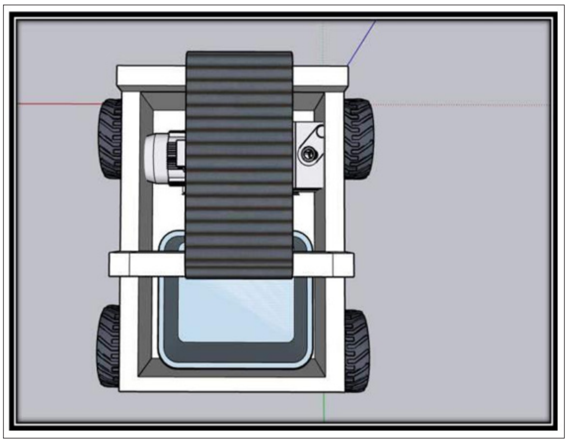

Figure 3: Top View of Robot Model

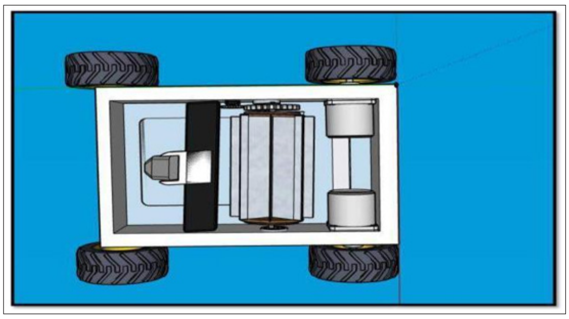

Figure 4: DownView of Robot Model

Tedding the Paddy

After waiting for about half an hour, the robot goes back to where it started. It follows the same path where it dropped the Paddy. This special method helps to make the Paddy better. It helps toseparate the grains and make them airy, which is important for drying.We do this several times, around 4 to 5 times, with each time taking about 30 minutes. This way, we make sure that all the Paddy gets treated well.

Collecting the Paddy

Once we're done with tedding, the robot goes back to where it started again. This time, it uses a vacuum to collect all the Paddy. It puts the collected Paddy into a small storage drum designed for this purpose. This is a good way to save Paddy and make use of the space efficiently.

```python
import RPi.GPIO as GPIO
import time

# Define the GPIO pins for the keypad rows and columns
rows = [17, 18, 27, 22]  # Replace with the actual GPIO pin numbers
cols = [23, 24, 25]      # Replace with the actual GPIO pin numbers

# Define the keypad layout
keys = [
    ['1', '2', '3'],
    ['4', '5', '6'],
    ['7', '8', '9'],
    ['*', '0', '#']
]

# Setup GPIO mode and pins
GPIO.setmode(GPIO.BCM)

# Initialize the rows as input and enable internal pull-up resistors
for row in rows:
    GPIO.setup(row, GPIO.IN, pull_up_down=GPIO.PUD_UP)

# Initialize the columns as output and set them high
for col in cols:
    GPIO.setup(col, GPIO.OUT)
    GPIO.output(col, 1)

# Function to read the keypad
def read_keypad():
    key = None
    for col in range(len(cols)):
        GPIO.output(cols[col], 0)
        for row in range(len(rows)):
            if GPIO.input(rows[row]) == 0:
                key = keys[row][col]
                while GPIO.input(rows[row]) == 0:
                    pass
        GPIO.output(cols[col], 1)
    return key

try:
    while True:
        key = read_keypad()
        if key:
            print("Key pressed: " + key)
except KeyboardInterrupt:
    GPIO.cleanup()  # Clean up the GPIO pins on Ctrl+C
```

Figure 5: Coding

Coding and Testing

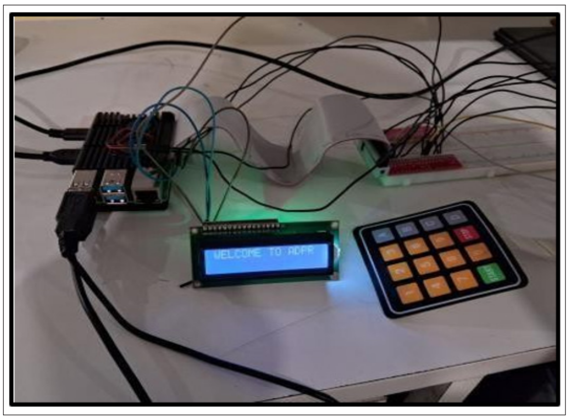

Figure 6: Interfacing with Raspberry pi

This Python code effectively manages a 4x3 matrix keypad interfaced with a Raspberry Pi via GPIO pins. It outlines the pin configuration, designating them as either input or output with pull-up resistors to facilitate key detection. The code employs a scanning mechanism within a function, systematically iterating through column and row pins to identify any pressed keys. When a key press is detected, the function returns the corresponding character; otherwise, it returns None. The main loop perpetually monitors the keypad, printing the pressed key on each iteration. The program runs until interrupted by Ctrl+C, at which point GPIO pins are cleaned up, ensuring proper termination and resource management. This comprehensive approach allows for seamless interaction with the 4x3 matrix keypad while maintaining the integrity of GPIO pin configurations throughout the script's execution.

Result and Discussion

Figure 7: Display Output

This Automatic Paddy Drying Robot (ADPR) that incorporates a user-friendly interface through an LCD display. The display greets users with a warm "Welcome to ADPR" message, setting the stage for a seamless interaction. To enhance user engagement, the system prompts users to input specific coordinates for the X and Y axes. These numerical inputs are conveniently entered using a number keypad connected to a Raspberry Pi, providing an intuitive and efficient means of communication with the robot.Once the user has entered the desired values, the system initiates the drying process and promptly updates the LCD display to reflect the ongoing operation, signaling the beginning of the automated paddy drying procedure. This user-centric interface not only simplifies the input process but also enhances the overall user experience by keeping them informed at every step of the robotic operation.

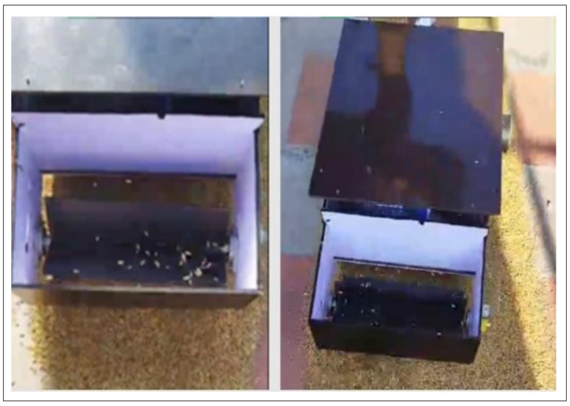

Figure 8: Field Testing Output

Commencing the robotic operation involves configuring the workspace through a display, allowing users to input parameters for the robot's lateral (x-axis) and longitudinal (y-axis) movements. Following this setup, the robot initiates its task, traversing from a designated starting point and dispensing Paddy evenly along its path to ensure uniform distribution. This uniform spread proves crucial for the subsequent step, which involves tedding. After a brief waiting period, the robot retraces its path, employing a specialized method to enhance the quality of the Paddy. The tedding process involves multiple iterations, typically around 4 to 5 times, each lasting approximately 30 minutes. This meticulous approach guarantees thorough treatment of all the Paddy, facilitating separation of grains and promoting optimal aeration, a vital aspect for the subsequent drying phase. Concluding the tedding process, the robot returns to its starting point, employing a vacuum to efficiently collect the treated Paddy. The collected Paddy is then deposited into a purpose-designed storage drum, ensuring both preservation and space utilization efficiency. This comprehensive workflow underscores the precision and efficiency of the robot in executing each phase of the paddy processing cycle.

Figure 9: Prototype Model

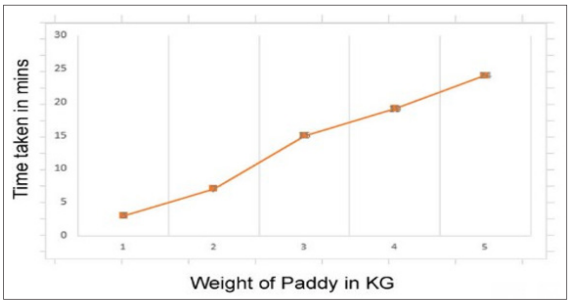

Figure 10: Paddy Drying Robot

In this Figure 10, imagine a graph where the Weight of paddy in Kg. As this axis increases, it signifies the forward march into the future, with each point marking a moment in the evolution of the Paddy Droping Processing Robot. Concurrently, the y-axis represents the ascending levels of Time Taken in mins, intelligence, and overall effectiveness in paddy processing. With the integration of the Raspberry Pi as the central intelligence hub, the trajectory of the y-axis steadily rises, mirroring the robot's ascent into a realm of enhanced capabilities. The graph captures a compelling narrative of the strategic transition from manual control to complete automation, showcasing how the symbiotic relationship between the Raspberry Pi and the robot leads to a continuous upward trend, illustrating a future where technological innovation propels agricultural practices to new heights.

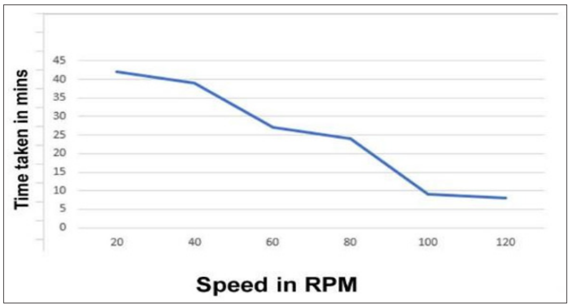

Figure 11: Tedding process

In this Figure 11, envision a chart where the x-axis represents the speed in RPM aspect of the Paddy Tedding Processing Robot. As the x-axis progresses, symbolizing the temporal journey or developmental phases, the y-axis takes a downward trajectory. The descending y-axis reflects Time taken by the robot. This visual narrative suggests that over time, with continuous advancements and refinements, the robot becomes more efficient in overcoming obstacles or streamlining its processes. The inverse relationship between the x-axis and y-axis showcases a scenario where the robot's performance steadily improves, leading to a decrease in specific operational complexities or inefficiencies.

Table 1: Output

SL NO	Product	Input for Drum (in kg)	Dropping Time in mins	Tedding time in mins	Collecting Time in mins
1	Paddy	2 Kg	5. 50	6. 15	4. 29
2	Paddy	4 Kg	11. 25	12. 56	9. 43
3	Paddy	5 Kg	13. 52	15	11. 47

The table outlines the performance metrics of our Automatic Paddy Drying Robot (ADPR) across different scenarios. For the initial category of Wheat Drying with a 5KG input, the drum loading is set at 5KG, followed by an initial tedding time of 3.5 minutes, subsequent tedding time of 4 minutes, and a total drying time of 30 minutes. The temperature collection time is noted at 14%, with a drum speed of 100Pa, and a final tedding time of 5 minutes. In the second scenario with a 10KG input, the drum loading increases to 10KG, with adjustments in tedding times and a final tedding time of 12 minutes. The third scenario involves Wheat Drying with a 15KG input, incorporating corresponding variations in tedding times and a final tedding time of 18 minutes. These comprehensive details offer a clear understanding of the ADPR's performance characteristics, emphasizing its versatility in accommodating diverse input conditions during the paddy drying process.

Conclusion

In conclusion, the examination of design considerations for a grain tedding mechanism aimed at sun drying has led to significant insights. The process involved the construction and testing of a functional prototype, guided by a commitment to practicality and the effectiveness of the chosen design. After evaluating four distinct designs, the sweeper wheel concept emerged as the most promising, thus warranting further analysis and testing. The preference for the sweeper wheel design stemmed from its remarkable resilience to grain breakage during operational use, surpassing alternative designs such as the Vacuum Design and Sweep and Catch Design. Notably, this design proved to be more practical in terms of the number of components required for manufacturing and the energy demands of the entire system. Extensive testing revealed that the selected design excelled in grain sweeping, with a minimal collection loss of only 2.88%. Nevertheless, there remains room for improvement in terms ofthe tedding efficiency, given that the mobile robot equipped with a vacuum had to traverse the grains thrice for optimal results. Nonetheless, these outcomes can be regarded as satisfactory, especially when applied in real-world grain sun drying operations, provided that they are accompanied by diligent monitoring and consistently timely tedding. This system has the capacity to perform partial tedding every 30 minutes and complete tedding every 1.5 hours, storing in drum up to 2- 5kg using vacuum, contributing significantly to the overall grain drying process [1-5].

Future Work

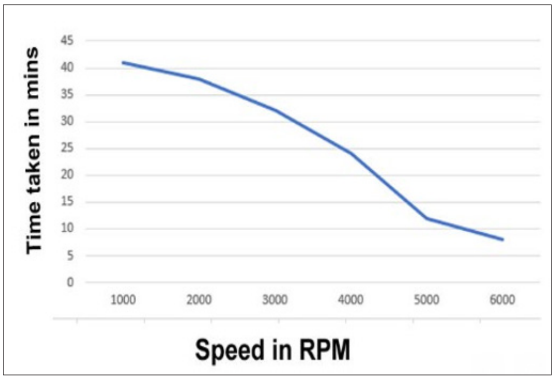

Figure 12: Collection Process

In this Figure :12, envision a chart where the x-axis represents the speed in RPM aspect of the Paddy collection Processing Robot. As the x- axis progresses, symbolizing the temporal journey or developmental phases, the y-axis takes a downward trajectory. The descending y- axis reflects Time taken by the robot. This visual narrative suggests that over time, with continuous advancements and refinements, the robot becomes more efficient in overcoming obstacles or streamlining its processes. The inverse relationship between the x- axis and y-axis showcases a scenario where the robot's performance steadily improves, leading to a decrease in specific operational complexities or inefficiencies. Envisioning the future evolution of the Paddy Processing Robot reveals a strategic transition from manual control to complete automation. At the forefront of this revolution stands the Raspberry Pi, positioned as the brain of the system, orchestrating a symphony of automated processes that promise to redefine the efficiency and intelligence of paddy processing. This miniature yet powerful computing device acts as the central nervous system of the robot, enabling it to process information, make informed decisions, and execute tasks with unparalleled precision [6-10].

The integration of the Raspberry Pi heralds a new era for the Paddy Processing Robot, empowering it with intelligent decision-making capabilities that elevate its functionality to unprecedented heights. No longer reliant on manual inputs, the robot becomes a self-sufficient entity, capable of adapting to dynamic environmental conditions. The Raspberry Pi's computational prowess facilitates real-time analysis of data, allowing the robot to navigate its surroundings seamlessly, optimizing its path and avoiding obstacles with remarkable agility [11-15].

In this envisioned future, the Paddy Processing Robot becomes a symbol of technological innovation, transforming the landscape of agricultural practices. The Raspberry Pi not only acts as the brain but also as the catalyst for increased productivity and efficiency. Its ability to process vast amounts of data in real-time ensures that the robot operates with a level of intelligence that surpasses human capabilities, resulting in more accurate and resource-efficient paddy processing [16-20].

The marriage of robotics and the Raspberry Pi extends beyond mere automation; it represents a paradigm shift in the way we approach agricultural tasks. The robot, guided by the computational prowess of the Raspberry Pi, is not confined by the limitations of human labor. It operates tirelessly, maximizing output and minimizing waste through its intelligent decision-making algorithms. Furthermore, the versatility of the Raspberry Pi allows for continuous updates and improvements, ensuring that the Paddy Processing Robot remains at the cutting edge of technology. As advancements in artificial intelligence and machine learning continue to unfold, the robot evolves alongside, constantly learning and adapting to new challenges in the ever-changing landscape of agriculture [21-25].

The strategic transition to complete automation, facilitated by the Raspberry Pi, holds the promise of revolutionizing the paddy processing industry. The robot's ability to process information, make decisions, and execute tasks autonomously not only streamlines operations but also enhances overall efficiency. This shift towards automation is not just about replacing manual labor; it is about ushering in a new era of precision agriculture, where every aspect of paddy processing is optimized for maximum output and sustainability.

The Raspberry Pi's role in this envisioned future goes beyond being a mere component; it becomes the cornerstone of the Paddy Processing Robot's success. Its open-source nature fosters a collaborative environment, allowing developers and researchers to contribute to the continual improvement of the system. The Raspberry Pi, as the central hub of intelligence, facilitates communication between different components of the robot, creating a cohesive and synchronized workflow.

In conclusion, the future evolution of the Paddy Processing Robot towards complete automation, driven by the capabilities of the Raspberry Pi, holds immense potential for revolutionizing the agricultural landscape. This strategic transition marks a paradigm shift in the way we approach paddy processing, unlocking unprecedented levels of efficiency, intelligence, and sustainability. As the Paddy Processing Robot embraces the power of the Raspberry Pi, it charts a course towards a future where technology and agriculture converge to create a harmonious and productive coexistence.

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