

Development of an Arduino-Based Paddy Transplanting Mechanism

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ABSTRACT

Transplanting of paddy in rice farming presently is done manually, which is costly, time-consuming, and inefficient, especially for small-scale farmers in Malaysia. To overcome these challenges, this research proposes a prototype of paddy transplanting mechanism with the help of Arduino technology to mechanize and improve the transplanting process. The operations of seedling spacing and timing are controlled by ultrasonic sensors, motor microcontrollers, and a pulse width modulation direct current (PWM DC) motor speed controller in the prototype. The findings revealed that the mechanism was successfully developed. The mechanism also ensured a planting depth of 1 cm and a spacing between seedlings of 16 cm, as opposed to the conventional method, where the depth ranged from 0 cm to 3 cm and the distance between seedlings was 13 cm to 15 cm. Therefore, the system is a viable solution for improving the efficiency of rice farming in Malaysia. In this way, this technology can enhance food security, as well as economic development by improving accuracy and decreasing labour dependency. Future research should be directed to enhance the accuracy of the sensors, reduce energy consumption, and expand the mechanism for extensive use in agricultural fields.

1. Introduction

Rice is the most important essential food for more than half of the world's population and has considerable socio-economic value, especially in Asia. In Malaysia, the government has outlined a policy on the production of rice to attain a level of producing its rice [1]. However, the current practices of rice farming in Malaysia have the following challenges: 1) Low productivity, 2) High cost of labor, and 3) Health risks affecting the farmers due to manual transplanting. Transplanting of paddy involves moving the rice seedlings from the nursery to the main field which is a tiresome activity and also takes a lot of time [2]. This traditional method is one of the causes of the causes of poor planting patterns, low yields, and high operating expenses. In addition, farmers are at risk of getting diseases and other health complications including spinal injuries and chemical exposure.

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These challenges have been tackled by innovations in agricultural technology through mechanized and automated procedures. However, current mechanized solutions are expensive, complicated, and not very adaptable to the smallholder farmers' scale [3]. This research seeks to fill this gap by designing a cheap, easy-to-use automated paddy transplanting mechanism through the use of Arduino technology. In the proposed prototype, the ultrasonic sensors, motor microcontrollers, and pulse width modulation (PWM) direct current (DC) motor speed controller are used to transplant the seedlings with high accuracy and at the right time.

Therefore, the objective of this study is to design and develop a paddy transplanting mechanism and operate the parameters to control the speed of the motor and the accuracy of the distance between the paddy seedlings. This will combine system and mechanical mechanisms to transplant paddy seedlings by small-scale farmers in the country. The mechanization of paddy planting will enable farmers to plant paddy. This is because it can help to reduce the time needed for planting, the amount of labor required, and the overall process of planting paddy seedlings.

2. Methodology

This section describes the method employed in the development of the prototype of the project with emphasis on the hardware and software aspects. The project is divided into the following phases to provide a systematic approach towards the design, development, and evaluation of the prototype:

2.1 Schematic Diagram

Figure 1 illustrates the schematic diagram that shows an integrated system where the Arduino Uno is the control unit that communicates with the sensors, actuators, and communication modules to perform the transplanting function. The ultrasonic sensor is used to calculate distance, the Bluetooth module is used as a switch to turn on or off the machine, the relay and the motor controller are used to control the motor, and the buzzer is used to give out sound signals. The whole system is driven by a 12-V battery to make it portable and easily usable in agricultural fields.

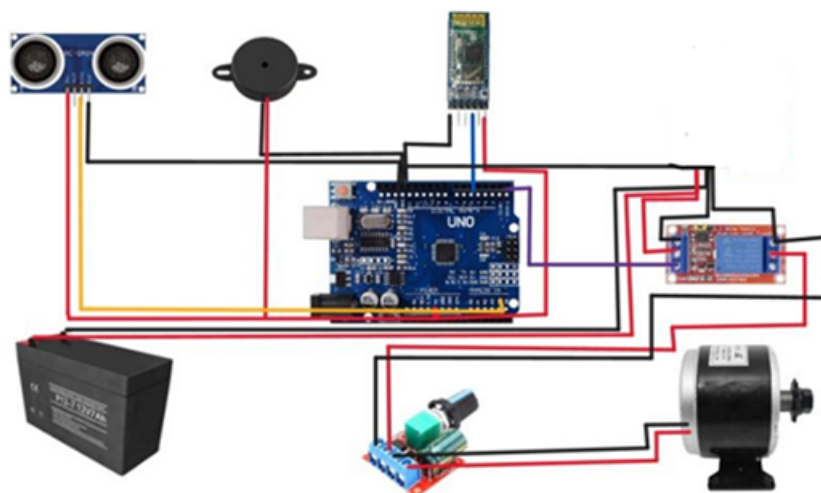


Fig. 1. Schematic diagram of the project

2.2 Block Diagram

Figure 2 shows the block diagram of the project which consists of the Arduino Uno microcontroller as the core. The Arduino Uno communicates with an ultrasonic sensor to measure the distance for proper seed positioning in the tray, and it uses an HC-05 Bluetooth module for remote control of the device. Then, a 5V relay controls the power supply to the direct current (DC) motor and the latter is operated by a pulse width modulation (PWM) DC motor controller for smooth movement. In order to increase operational consciousness to the overall system of the project, a buzzer is used to give audible signals of different system conditions. The overall system is also run by a 12V supply which makes the configuration of the setup quite efficient and effective.

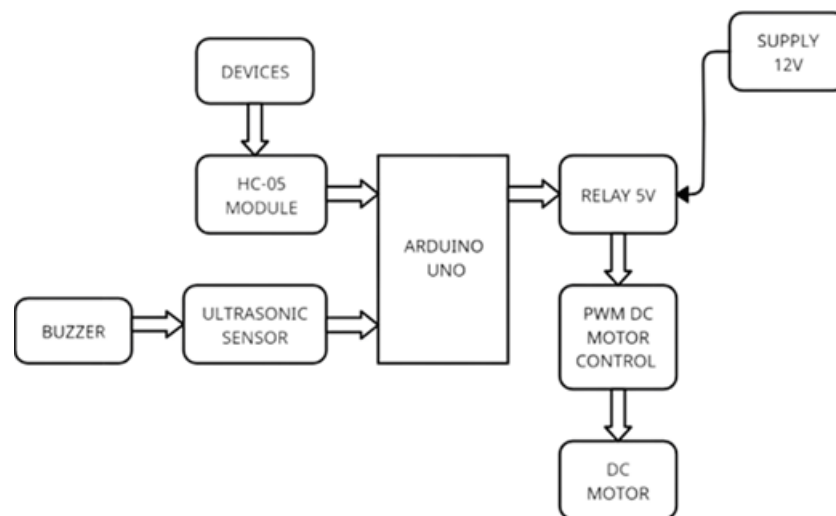


Fig. 2. Block diagram of the project

2.3 Flowchart

The flowchart shown in Figure 3 illustrates the working mechanism of the project. It starts by turning on the Arduino and motor driver. Subsequently, the HC-05 Bluetooth module gets a signal of “START”. The ultrasonic sensor measures the quantity of paddy seedlings. If the quantity is sufficient, the relay then turns “HIGH,” and the motor driver powers the PWM DC motor to move the wheel and finger bar for transplanting. Otherwise, the buzzer sounds and the relay executes “LOW”. The transplanting continues accordingly. A decision point defines whether to proceed or not to proceed with the activity. In case of receiving a “STOP” signal, the system stops all activities and guarantees the proper and mechanized transplanting of paddy.

2.4 Design Consideration

The design of the machine in this study is based on the design of a planting unit, paddy seedling tray, and power transmission system and attachment. When designing the planting mechanism, the following aspects were considered: 2.4.1 Moving Pathway; 2.4.2 Plant Catching Mechanism; 2.4.3 Depth of Planting; 2.4.4 Designing of the Tray; and 2.4.5 Power Transmission System and Attachments.

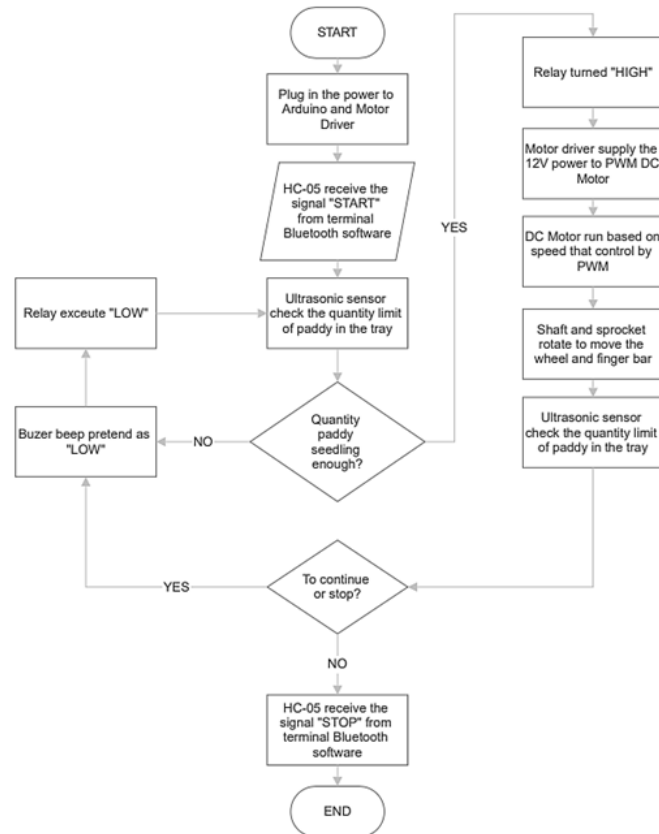


Fig. 3. Process flowchart of the project

2.4.1 Moving Pathway

The moving pathway of the finger arm is designed in three parts and is made of iron brackets connected by nuts and screws. The upper part is slidably connected to the shaft for movement, the middle part engages the paddy for planting, and the lower part is connected to a back bracket, the finger can turn without changing its position. This design provides a firm base and accurate rotation like a tire with the length of the bracket varying with the rear trunk support. Free play can be a problem if the shaft is too long. This is shown in Figure 4.

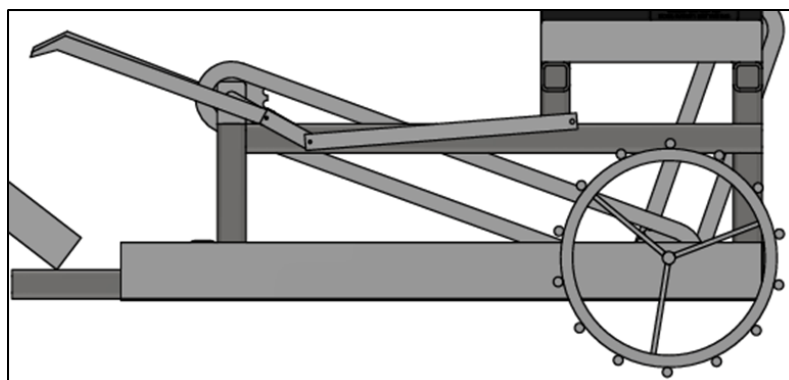


Fig. 4. Moving mechanism

2.4.2 Plant-Catching Mechanism

The plant-catching mechanism design considers several parameters such as: the place of catching, number of plants per catch, distance travelled, releasing point, tension on plants, and angle of planting. The mechanism helps to avoid any harm coming to the plants during the catching and releasing of the paddy [4].

The speed, position, and angles of the mechanism were adjusted to ensure proper planting of the seeds [5]. The travelling distance was calculated by the walking speed of a person and the motor speed. The planting arm and fingers are made of steel bars. Fingers were welded to the arm to keep the right tension and angle for planting. Figure 5 shows the design of the finger, while Figure 6 illustrates the rotation cycle for finger.



Fig. 5. Finger of the planting arm mechanism

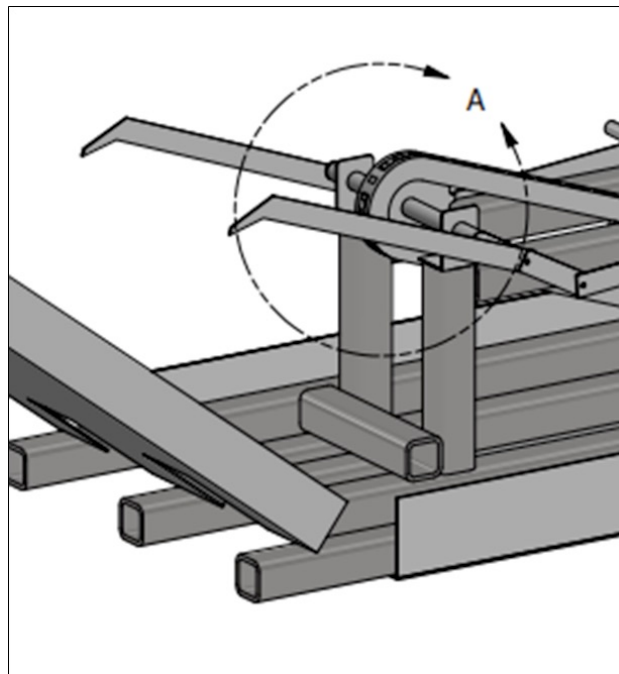


Fig. 6. Rotation cycle for finger

The following formula (Eq. (1) and Eq. (2)) were used to determine the planting distance between two rows based on the intended parameters.

$$\begin{aligned}\text{Distance travelled in 1 minute} &= \pi \times \text{diameter of the wheel} \times \text{rotation (RPM) of the wheel} \\ &= \pi \times 0.07 \text{ m} \times 120 \\ &= 26.39 \text{ m}\end{aligned}\tag{1}$$

$$\begin{aligned}\text{Distance between 2 planted rows} &= \frac{\text{Distance travelled for one minute}}{\text{Planting cycles per minute}} \\ &= \frac{26.39}{12} \\ &= 2.20 \text{ cm}\end{aligned}\tag{2}$$

Therefore, the distance between 2 rows is approximately 2.20 cm. However, this is not the practical space value. The practical value is always less than the calculated value. The reason is that the wheels are rotated in the mud and due to the slipping and etching of the wheels, the traveling distance of the machine is always less than 2 cm.

2.4.3 Depth of Planting

The depth of the soil for planting paddy was controlled by the rotation designed on the mechanical part [6]. If the bracket on the shaft rotates well without any obstacles, it will plant well at the predetermined depth which is 2-cm deep.

2.4.4 Designing of the Tray

The tray is capable of holding approximately 40 paddy seedlings, 2 plant rows at a time, with the width being twice the plant spacing. As shown in Figure 7 and Figure 8, the tray has two blank areas for the finger arm to slide and place the seedlings. The tray design depends on the ground wheel rotation speed and must accommodate the finger's jaw adequately. Two flexible iron plates are used to support the seedlings. Also, an ultrasonic sensor is placed on the tray to determine the volume of seedlings and to know when the tray is full or empty for planting.

2.4.5 Power Transmission System and Attachments

As shown in Figure 9, the power transmission system in the project prototype is used to plant the seedlings with a within-row spacing of 16 cm and plant 2 plants of paddy per wheel revolution. The system employs 14-teeth sprockets and chains that are attached to the motor, tire shaft, and finger arm. The ground wheel rotates and in turn, rotates the primary sprocket which through a chain rotates the secondary sprocket and the planting arm (Figure 10). This arrangement enables the planting arm to oscillate in harmony with the wheel so that seedlings are planted at a 2-cm depth. The system employs reliable sprockets and chains for power transmission, low wear and tear, and variable planting rate and depth to suit the soil type [7]. This calculation measures the total gear reduction between the ground wheels, and it should be equivalent to 1, as demonstrated in Eq. (3):

$$\begin{aligned} \text{Gear reduction between 14-teeth sprocket and 14-teeth sprocket wheel} &= 14/14 \\ &= 1 \end{aligned} \quad (3)$$

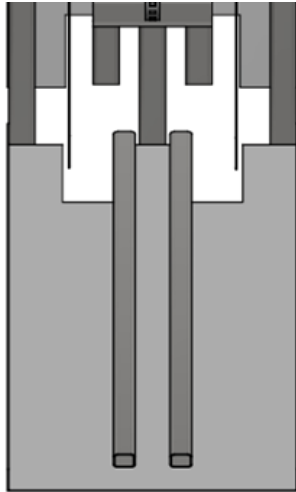


Fig. 7. Tray design

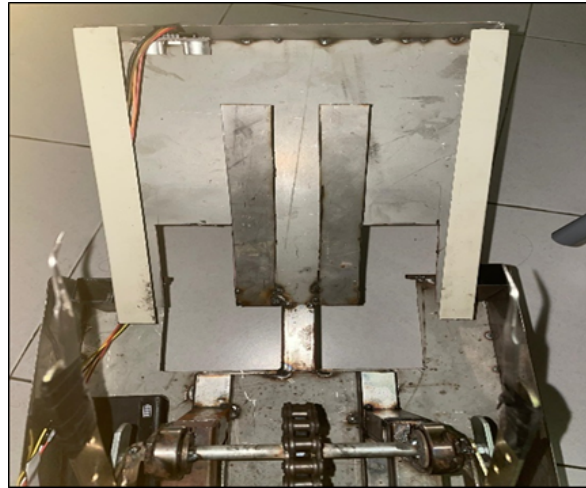


Fig. 8. Tray final design

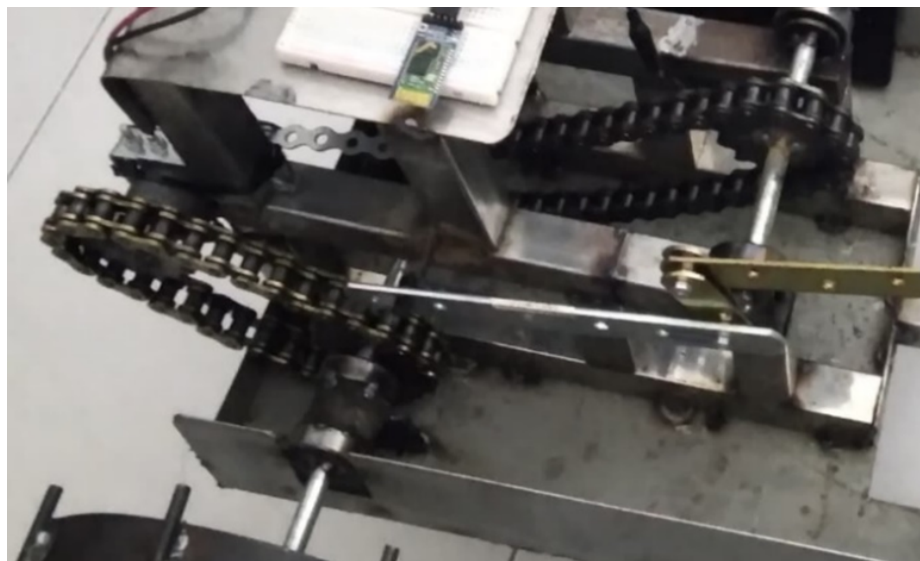


Fig. 9. Power transmission to planting arm

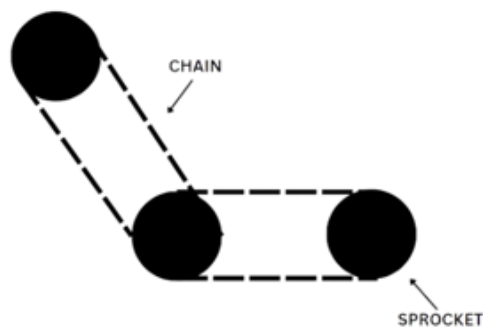


Fig. 10. Sprocket mechanism

2.5 Prototype Design

For the conceptual design of the project prototype, Figure 11, Figure 12 and Figure 13 illustrated the isometric view, front view and side view of the prototype respectively.

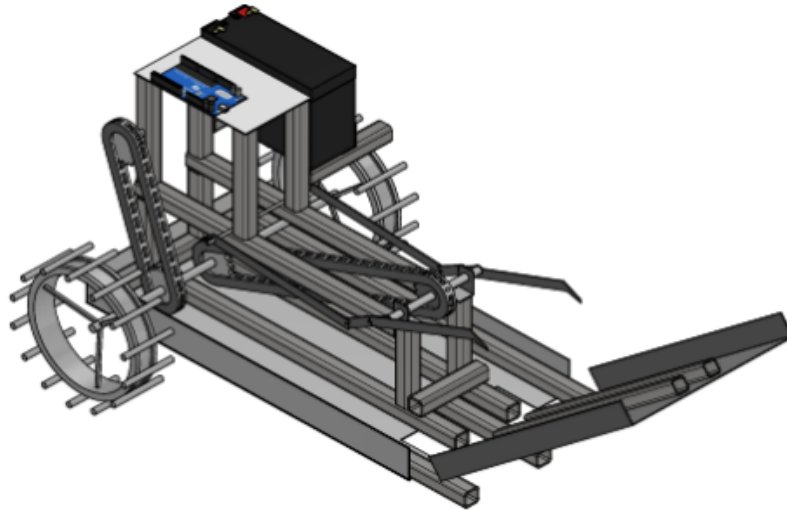


Fig. 11. Isometric view of the prototype

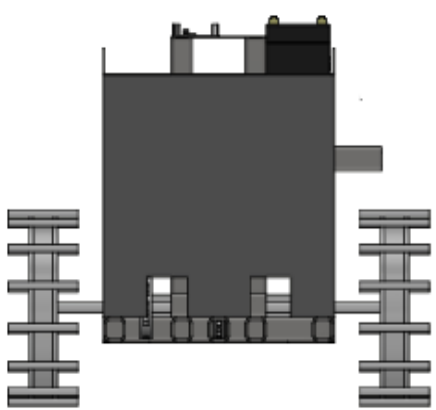


Fig. 12. Front view of the prototype

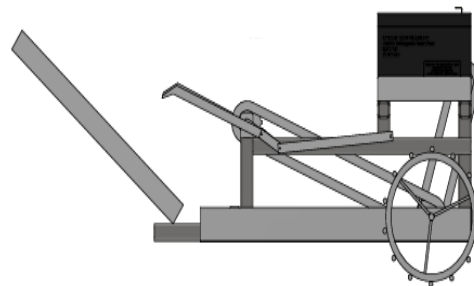


Fig. 13. Side view of the prototype

3. Results

3.1 Development of Paddy Transplanting Mechanism

Figure 14 shows the developed prototype of the project. The design of the prototype is relatively basic and this makes it easy to repair and maintain. All the spare parts of the machine can be produced locally, and this has made the cost of producing the machine much cheaper than the commercially available transplanting machines [8].

Using Arduino as a microcontroller, the paddy transplanting mechanism can be automated where the sprocket that is directly connected to the motor provides a proper transfer of rotational movement, which in turn controls the key aspects of the transplanting system. Also, the new fingering mechanism that is located in a position to come into contact with the paddy seedlings improves the delicate handling of young plants. This subsequently enhances the general transplanting accuracy since it helps in spacing and placing of the seedlings in the field appropriately.

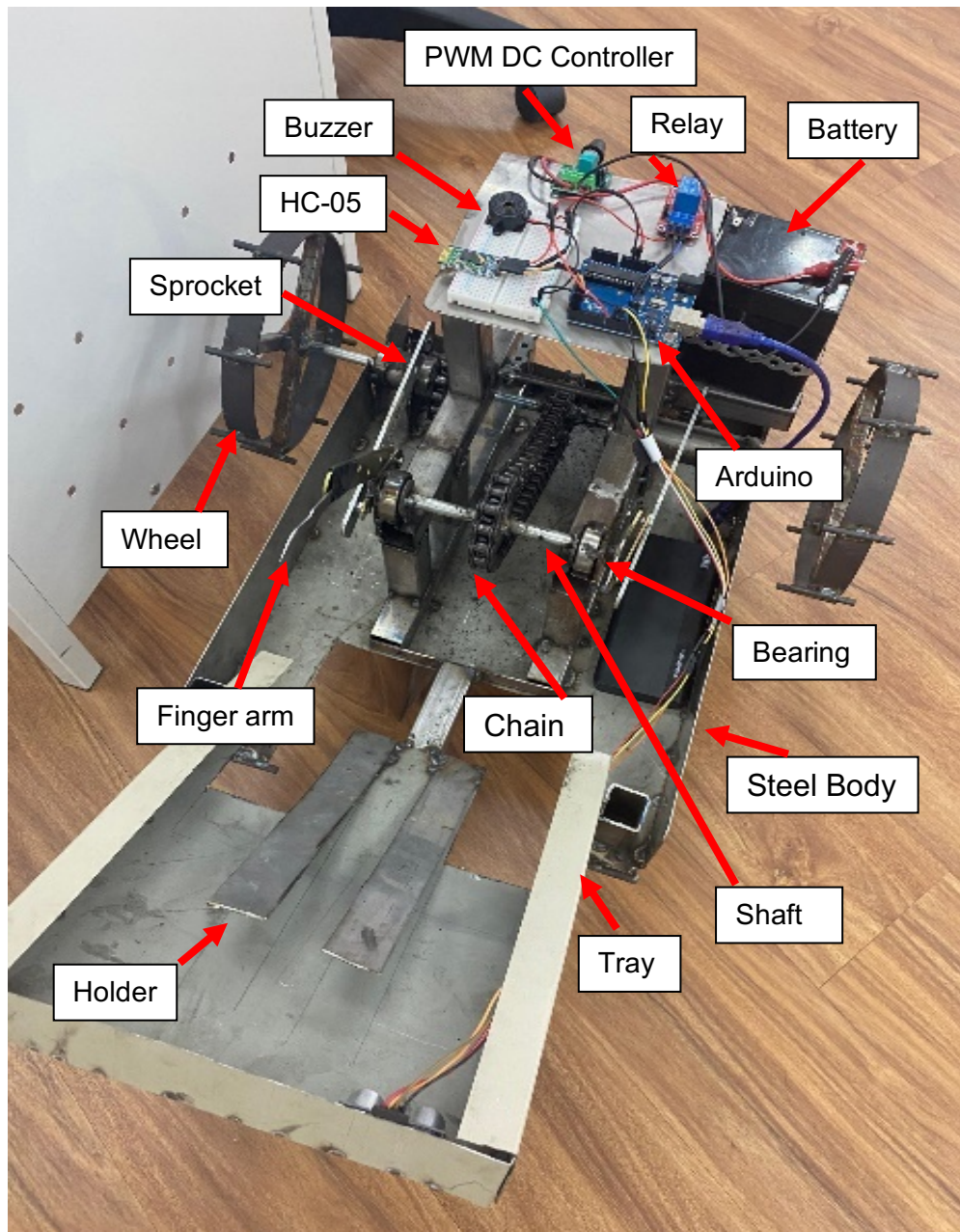


Fig. 14. Prototype of the project

3.2 Consistency of Paddy Seedling Spacing

Planting the paddy seedling using the automated mechanism of the prototype resulted to a spacing of 16 cm between paddy seedlings (Figure 15). On the other hand, transplanting using manual method lead to inconsistency as shown in Figure 16, where distances of 13 cm and 15 cm were seen between the seedlings.

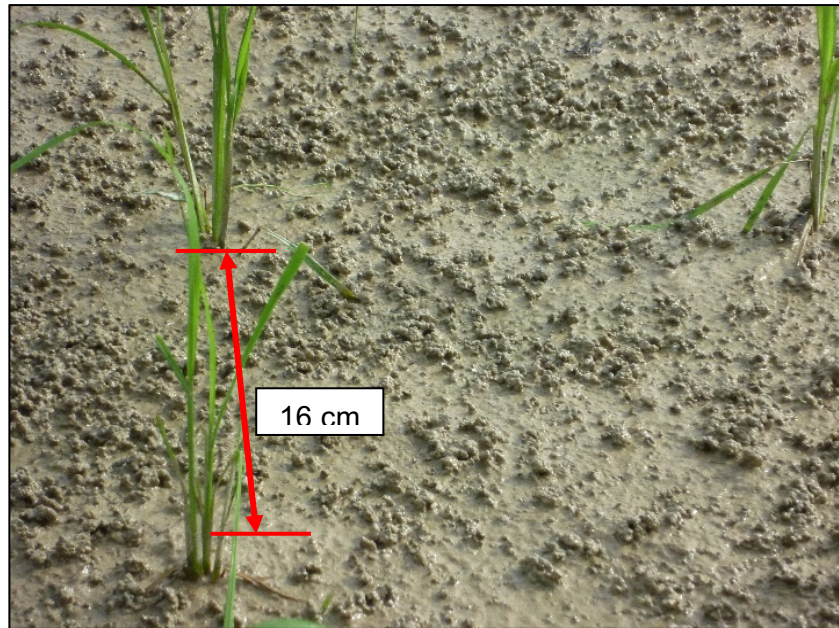


Fig. 15. Spacing of the paddy seedling using automated system

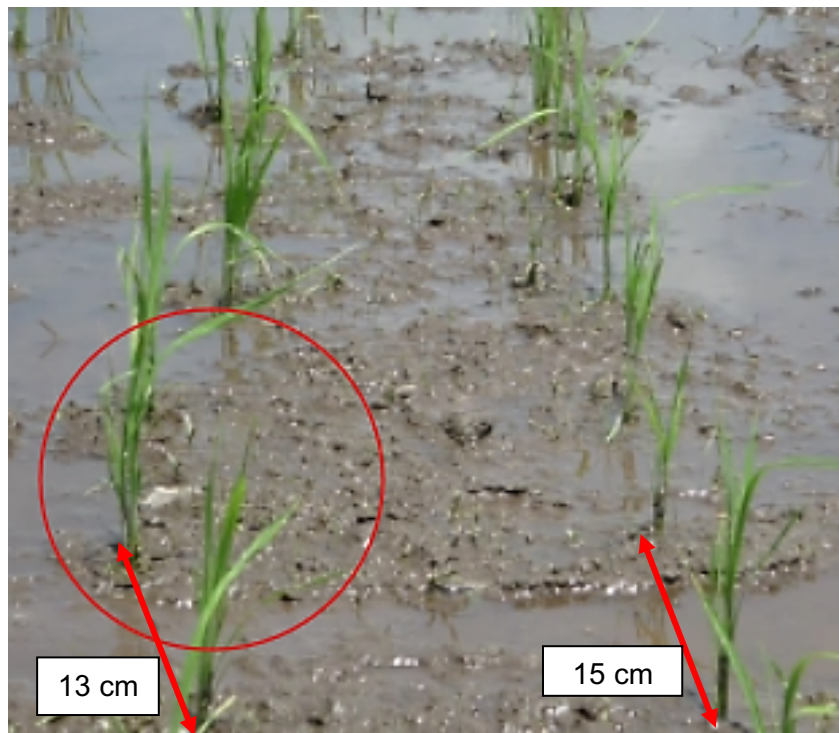


Fig. 16. Spacing of the paddy seedling using manual method

3.3 Consistency of Transplanting Depth for Paddy Seedlings in Soil, at Various Speed

The automated mechanism of the prototype was able to do transplanting at 2-cm deep in soil regardless of transplanting speed, as shown in the graph of Figure 17. The graph also shows that at different speed values ranging from 1.0 km/h to 5.5 km/h, the system consistently achieved a transplanting depth of 2 cm. This contrasts with the conventional planting method, which typically varies from 0 cm to 3 cm at similar speed ranges.

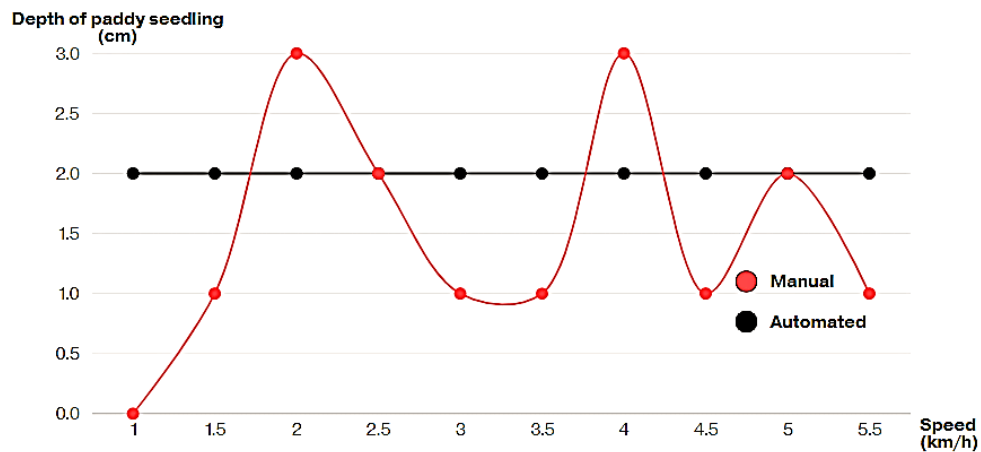


Fig. 17. Depth for Paddy Seedlings in Soil, at Various Speed of Transplanting

3.4 Comparison Between Manual and Automated Methods of Transplanting Paddy

Table 1 shows the comparison of various parameters between the manual and automated methods of transplanting paddy. This comparison shows that the automated method yields better result compared to the manual method, in terms of the transplanting spacing and depth in soil for the paddy seedlings. The accurate control of the planting depth and spacing of the automated system is beneficial to the growth of the plants [9]. Proper placement of seeds is important for growth and distribution of resources which are important determinants of crop productivity [10]. The use of the automated method also minimizes the chances of planting wrong or missing seedlings which are very costly to the yields [7].

Table 1

Comparison of various parameters between manual and automated method of transplanting paddy

Parameter	Manual Method	Automated Method
Spacing between seedlings	13 cm – 15 cm	16 cm
Spacing accuracy between seedlings	68%	100%
Depth in soil for seedlings	0 cm – 3 cm	2 cm

4. Conclusion

The main objective of the study which is to develop a paddy transplanting mechanism that is controlled by Arduino was successfully achieved. This is demonstrated in section 2. Methodology, and section 3. Result, where a motor-driven sprocket mechanism controlled by an Arduino microcontroller is included in the system. The system demonstrated good control over rotational motion, which allowed for accurate transplanting of paddy seedlings into the soil. The newly designed fingering mechanism also contributed to the gentle handling of young plants, which improved transplanting efficiency and field placement.

The study's other objective which is to control the speed of the motor and to ensure the accuracy of the distance between the paddy seedlings, was also achieved. As discussed in section 3. Result,

these parameters were well managed by the system, with a planting depth of 1 cm and a seedling spacing of 16 cm. In contrast, manual transplanting exhibited less precision.

Overall, the study has the potential to reduce labour dependency, which in turn would be able to promote sustainable farming practices. Subsequently, agricultural productivity can also be enhanced. From this point onward, improving sensor accuracy and energy efficiency, applying the system to larger farming units, and using it with different crops are identified areas for improvement from the study. This may require additional optimization and validation.

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