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Development of an automated inter and intra-row weeder for efficient and precise weed control in small-scale farming in India

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Abstract
Weeding is an essential practice in crop cultivation as it removes unwanted plants that compete with cultivated crops for resources. In India, small-scale farmers rely heavily on manual labor for weeding due to the high costs of herbicides and weed management equipment. To address these challenges, the agricultural sector is adopting mechanization and herbicide usage. However, small landholding sizes and cost factors hinder the adoption of these technologies. Intra-row weeding, which involves removing weeds within crop rows, is currently done manually and requires improvement to make it more efficient and less labor-intensive. Automated or semi-automated weeding technologies can reduce time and effort. Advancements in machine learning and computer vision can accurately identify and target weeds, minimizing damage to crops. The development of an automated inter and intra-row weeder aims to minimize plant damage and increase productivity. The weeder utilizes a frame, tines, inter and intra-row blades, ultrasonic sensor, D.C. motor with drivers, microcontroller, battery, wooden box, and sensor and motor holders. Ultrasonic sensors differentiate between crops and weeds based on their height, allowing precise weed removal without damaging crops. The weeder significantly reduces manual labor, covers large areas quickly, and integrates easily with existing farm machinery. It offers a cost-effective, efficient, and precise solution for weed control in agriculture, improving crop yields and reducing labor costs.

Keywords: Weeder, mechanization, robotics

Introduction
Weeding is an essential practice in crop cultivation as it involves the removal of unwanted plants that grow near or alongside cultivated crops. Weeding is required in crop fields to minimize competition for nutrients, water, and sunlight between the crop plants and the weeds. It helps in promoting optimal growth and development of the cultivated crops, leading to higher yields. In the Indian scenario, weeding is crucial due to the predominance of small-scale and marginal farmers practicing agriculture. These farmers depend on heavily on manual labor for weeding purposes since they usually cannot afford expensive herbicides or weed management equipment.

Weeding is typically done using manual hand tools, such as hoes, sickles, or mechanical weeders, which are affordable and easily available. Indian farmers utilize various methods for weeding, including hand weeding, intercultural operations, and mechanical cultivation. This method is labour-intensive and requires skilled labourers who can differentiate between weeds and crop plants. Intercultural operations involve using implements like cultivators, harrows, or weeders to mechanically remove weeds from the crop fields, saving time and labour.

To address these challenges, the Indian agricultural sector is increasingly adopting mechanization and herbicide usage for weed control. Farm machinery like power weeders and rotary weeders are being introduced to reduce the labour-intensive nature of weeding. However, the adoption of these technologies is hindered mainly by the small landholding size and the cost factor for small and marginal farmers.

Inter-row weeding refers to the process of removing weeds that grow in between rows of plants or crops. On the other hand, intra-row weeding involves removing weeds that grow within the rows of plants or crops. This is done to prevent the weeds from affecting the growth of the cultivated plants by competing for resources or interfering with their development.

Both inter and intra-row weeding are important practices in agriculture to maintain the health and productivity of crops. Intra-row weeding performed manually by hand-weeding and inter-row weeding through the use of tools and equipment.

Clark *et al*. (1981) [3] reported that an optimum swept angle for minimum draft occurred at approximately 40°. For the same cutting length a 20° increase from this swept angle resulted in a 9% increase in draft whilst a 10° decrease in swept angle resulted in an increase of draft of 4%.

Intra-row weeding is currently carried out manually, which is a time-consuming and physically demanding task. There is a need for improvement and research in the field of intra-row weeder to make the process more efficient and less labour-intensive. By developing automated or semi-automated weeding technologies, the time and effort required for this task can be significantly reduced. Furthermore, advancements in machine learning and computer vision can be utilized to accurately identify and target weeds, minimizing damage to crops (R. G. Jakasania *et al*. 2019) [5].

When the crop is detected by a computer vision guidance (Aastrand and Baerveldt, 2002) [1], the rotating wheel is lifted up by a pneumatic cylinder and lowered down when it has passed the plant. Aastrand and Baerveldt (2005) [2] evaluated the system in greenhouse experiments with sugar beet plants at intra row plant spacing of 170 mm and reported that the robot was able to recognize all the plants and the weeding tool worked well. No information is given for working speed and weed control efficacy.

The weeding tool is attached via a shaft to the motor and the working height of the whole assembly is adjustable (Gobor and Lammers, 2007) [4]. The system has only been tested in a virtual environment.

This research and improvement in intra-row weeders can help farmers save time and resources, leading to increased productivity and sustainability in agriculture. So based on this challenge the objective of the study was to developed automated inter and intra raw weeder with minimum plant damage.

Materials and Methods

The development of automated inter and intra row weeder was conducted at the Workshop of the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University.

During the process of designing and developing the tractor-operated automated inter- and intra-row weeder, the following factors were prioritized: ease of fabrication, utilization of locally accessible materials, and minimal fabrication expenses. Easy assembly and disassembly for maintenance and inspection were appropriately taken into account. The main parts of the machine are:

Frame: It provides the structure and support for the machine.

Tines: The blade is attached or fixed onto a tine, and multiple tines are then attached or fixed onto a cultivator.

Inter row blade: It is a blade that is used to create furrows or pathways between rows of plants.

Intra row blade: This blade is used to remove weeds or unwanted plants within a row of crops.

Ultrasonic Sensor: It is a device that uses ultrasonic waves to measure distance and detect obstacles in front of the machine.

D.C. motor with drivers: The motor provides the power to drive the machine's movement, and the drivers control the speed and direction of the motor.

Microcontroller: It is the central processing unit of the machine, responsible for controlling and coordinating the different components.

Battery: The battery supplies the necessary electrical energy to power the machine.

Wooden box: It is a container or housing that holds and protects the electronic components of the machine.

Sensor holder and Motor holder: These are brackets or mounts that hold the ultrasonic sensor and D.C. motor securely in place on the machine.

Circuit diagrams are important in an automated weeder as they provide a visual representation of the electrical connections and components in the system. This helps in understanding the wiring layout, troubleshooting any issues, and ensuring correct installation and operation of the weeder. Circuit diagram of automated inter and intra row weeder is shown in Fig. 1.1. Trigger pin of the ultrasonic sensor is connected to digital pin 2 of the arduino. Echo pin of ultrasonic sensor is connected to the digital pin 3 of the arduino. Were, VCC and GND are connected to the 5 V and GND of the arduino. Arduino and ultrasonic sensor get power from 9 V battery. Motor driver is required to separate high current and high voltage device from logical device. D.C. motor is a high voltage and high current device which are controlled though driver. Driver is connected to digital pins 5 and 6 in arduino.

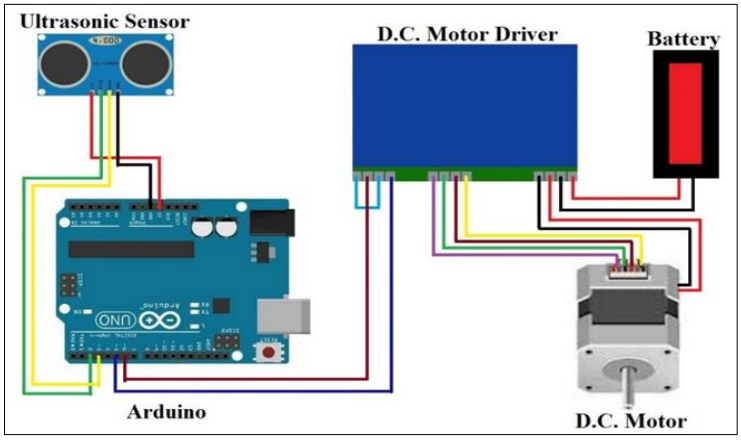

Fig 1.1: Circuit diagram of automated inter and intra row weeder

Arduino IDE is programming environment that allows the user to draft different kind of programs and load them into the arduino microcontroller. Arduino uses user-friendly programming language, which is based on programming language called processing. After the user has written his code, IDE compiles and translates the code to the assembler language. After translating the code, the IDE uploads the program to the arduino microcontroller. After testing the program it can be uploaded to the arduino by USB cable. Fig. 1.2 shows a screen capture of java-based arduino IDE.

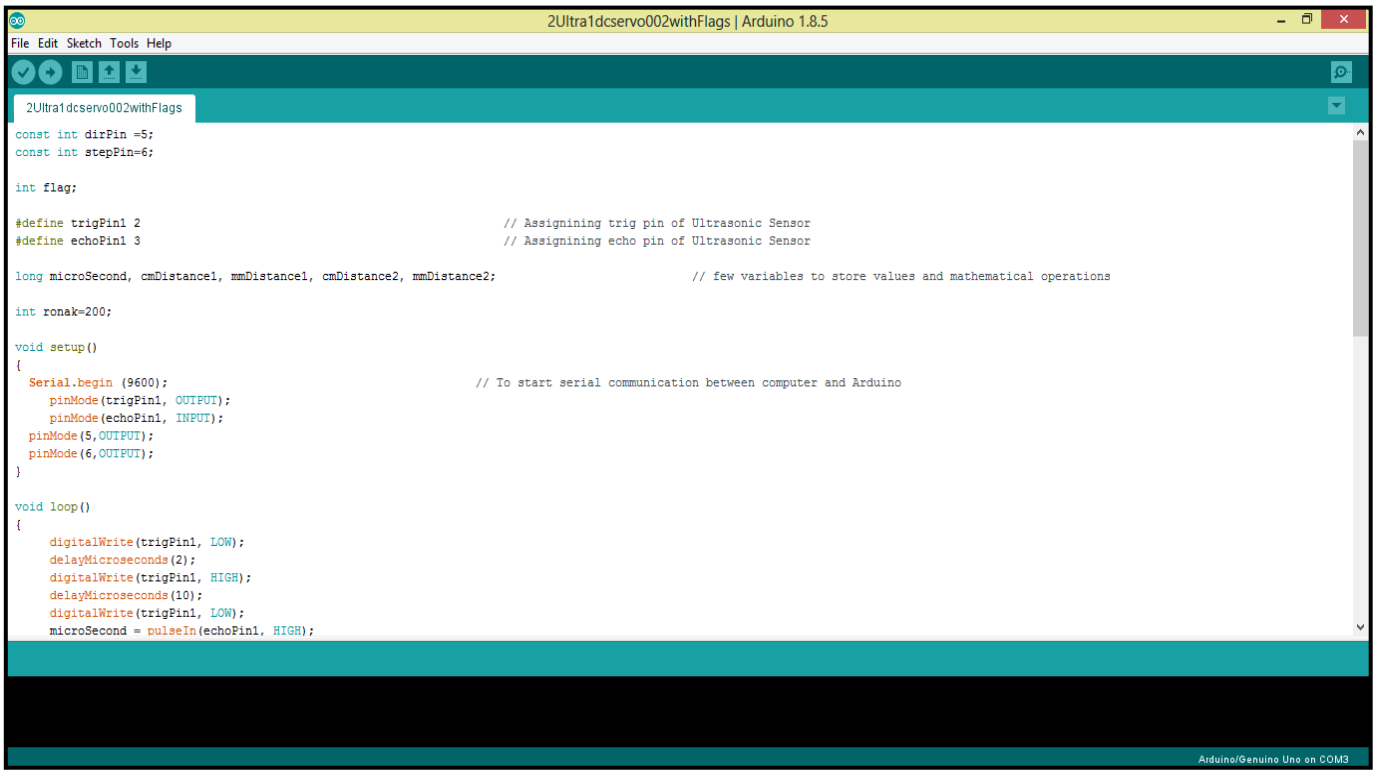

Fig 1.2: Arduino IDE

Results and Discussion

The automated ultrasonic sensor based inter- and intra-row weeder is a novel solution for agricultural weed control. The results from our experiments show promising potential for this technology.

In terms of the inter-row weeding capability, Differentiating plant and weed height based on ultrasonic sensor detection involves measuring the distance between the sensor and the ground. By setting a threshold value, plants below this height are identified as weeds. The weeder successfully eliminated the weeds present in inter- and intra-row spaces, reducing competition for resources and enhancing the overall growth of the crops.

Furthermore, the intra-row weeding capability of the automated system proved to be equally effective. The ultrasonic sensors were able to detect the presence of weeds within the crop rows, allowing the weeder to precisely target and remove them. This targeted approach minimized the chances of damaging the crops while eradicating the weeds. The weeder consistently achieved high weed removal rates, ensuring that the crops were protected from weed infestations.

The use of ultrasonic sensors contributed to the precision and accuracy of weed detection and removal. The sensors were able to distinguish between crops and weeds based on their height and shape, ensuring that only the targeted weeds were removed. This precision minimized crop damage and enhanced the overall efficiency of the weeder. The automated weeder significantly reduced the labor requirement for manual weeding. With the ability to cover large areas quickly, the weeder eliminated the need for manual labor, saving time and reducing costs for farmers. This automation also minimized the potential for human errors during weed removal.

The automated weeder was designed to be easily integrated with existing farm machinery such as tractors. This allowed farmers to adapt the technology without making significant modifications to their current setup. The weeder could be attached to a tractor and operated simultaneously with other farming activities.

Conclusions

In conclusion, the tractor-operated automated inter- and intra-row weeder is a cost-effective and efficient solution for weed control in agriculture. The prioritization of ease of fabrication, utilization of locally accessible materials, and minimal fabrication expenses ensure that it can be easily constructed and maintained by farmers. The main parts of the machine, including the frame, tines, inter and intra row blades, ultrasonic sensor, D.C. motor with drivers, microcontroller, battery, wooden box, and sensor and motor holders, work together to provide effective weed removal and minimize crop damage.

The use of ultrasonic sensors in the weeder greatly improves precision and accuracy in weed detection and removal. By differentiating between plants and weeds based on height, the weeder can target and remove only the unwanted plants, minimizing crop damage and enhancing overall crop growth. The weeder consistently achieves high weed removal rates, protecting crops from weed infestations and reducing competition for resources.

The automation provided by the weeder significantly reduces the need for manual labor, saving time and reducing costs for

farmers. It can cover large areas quickly, eliminating the potential for human errors during weed removal. Additionally, the design of the weeder allows for easy integration with existing farm machinery, making it convenient for farmers to adapt and incorporate into their current setup.

Overall, the tractor-operated automated inter- and intra-row weeder is a promising technology that offers a novel and effective solution for weed control in agriculture. Its cost-effectiveness, ease of use, precision, and efficiency make it a valuable tool for farmers seeking to improve their crop yields and reduce labor costs.

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