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Design of an Agricultural Land Maintenance Robot

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Abstract: In the process of crop production, there are several obstacles such as growth of weeds, lack of labour to prepare the land, and expensive equipment. We have developed a prototype of the robot that can be used for weeding, leveling and ploughing tasks. The project has been developed keeping the poor farmers in view. Hence an affordable system has been proposed. smaller, cheaper and efficient robot that can perform. The system also detects obstacles and avoids collision by taking a detour. An user-friendly webpage is developed to interact with the farmers. The webcam relays a live stream of the video onto the webpage for remote monitoring and also clicks snapshots which are processed inorder to identify the unwanted weeds and determine the percentage of weeds present in each snapshot.

Keywords: Agriculture Robot, Weed detection, Collision avoidance, Raspberry Pi

I. INTRODUCTION

In recent years, the agricultural industry has begun adapting numerous technologies that help in improving the quality of crops grown. Most of these new technologies aim at large scale farming in the order of thousands of hectares. The equipment that already exists is expensive, huge and not preferable for farmers having smaller lands that are of a few acres in size.

The research and development in the field of agriculture is ever growing with new technologies that aim at improving the efficiency of the robots and reducing the size. The concept of precision agriculture has inspired the new age farmers to make use of the available technology to maximize their yield.

The current approach towards crop production and other farming practices are strenuous, time consuming and requires labourers to manually perform each task, repetitively. A solution needs to be proposed keeping in mind the tools and mechanisation available in the present technological landscape.

This is achieved by a robot that can perform multiple tasks efficiently and provides a user friendly interface for the farmer. The robot will mainly perform maintenance and monitoring activities which will eliminate human effort and increase work efficiency. This will result in more productivity and higher overall output from the agricultural land and from each of the practices.

II. RELATED WORK

An extensive literature survey has been carried out to understand the prior art in the role of robots in Agriculture. The findings are recorded as indicated below.

Redmond, et. al [1] have listed the latest developments in agricultural robotics, specifically those that are used for autonomous weed control, field scouting, and harvesting. The author has focussed on digital farming using sensors, actuators and data analysis. The major challenges faced in digital farming were object identification, task planning algorithms, digitalization and optimization of sensors. The paper helped us to understand the challenges of automation and the drawbacks of the existing systems. We have understood the challenges and have made an attempt to automate the Agricultural system.

An Agricultural robotic system which can be modelled using algorithms has been proposed by Nidhi, et. al [2]. Their model consists of Arduino boards and ultrasonic sensors. In their work the authors have employed a smart mechanization system using robots. The robot helps to disperse seeds, spray pesticides all over the field to kill the weeds.

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This is a random process wherein the pesticide is sprayed irrespective of the crop or weeds. They have used pesticides, which are harmful to health. But in our system, no chemicals or pesticides are used.

Amruta, et. al [3] have developed a prototype of a pesticide spraying robot that uses a wireless camera to determine the height of the target. This robot does not take into consideration the obstacles in the way. The robot will collide with any obstacle that is in front of it causing serious damage to the robot and the object it collides with. The robot developed by us has the ability to detect obstacles and take a detour around them.

The unmanned service units in agricultural environments are surveyed by Fernando, et. al [4]. A detailed analysis is presented and various algorithms and parameters that can be taken into account are mentioned. The collision avoidance techniques they have presented have been implemented in our model in a simpler manner.

The robot developed by Amrita, et. al [5] is capable of performing ploughing, seed dispensing, fruit picking and pesticide spraying using ultrasonic sensors for navigation. This helped us understand the mechanism behind automatic ploughing to implement the same in our project. Nonetheless, this robot does not take the growth of unwanted plants into consideration. Our model can differentiate weeds from crops and remove the same.

Usha, et. al [6] simulated the process of cultivating agricultural land without the use of manpower. The proposed model is a collision avoidance robot that has a seed dispenser and water sprinklers. But they did not take into account the growth of weeds. Whereas we have developed a working prototype of a robot along with the ability to identify weeds and remove them.

The use of microcontrollers and sensors for agriculture is emphasized by Abdullah, et. al [7]. They have simulated a model that can measure various parameters and display the result. This helped us understand the different sensors developed and used in farming practices. The implementation of this system in a greenhouse is also explained.

Nikesh, et. al [8] simulated and developed a system that aims at smart, automated agricultural activities such as weeding, spraying, moisture sensing and other monitoring activities. Pesticides which are sprayed irrespective of the presence of weeds can cause damage to the soil in the long run. The robot is not equipped with an obstacle avoidance system and hence it could collide with potential obstacles on the field.

The influence of shadows in recognition of weeds and insects is investigated by Zhao, et. al [9]. The model developed by them applies various transformations onto the image like erosion, gray transformation, threshold segmentation. A few of these transformations are applied in the weed detection process of the model we have developed.

Han, et. al [10] simulated an agricultural environment and applied the autonomous driving algorithm developed by them. They have also developed a model of the same which can control the movement and balance the robot. We have tried to achieve a similar result using a python program that determines the movement of the robot based on the output given by the sensor.

Fang, et. al [11] simulated a model that can enable agricultural robots to effectively operate on various farming practices on hilly areas and avoid obstacles in the process using 3D path planning. A partial implementation of the proposed functions has been done using the collision avoidance system itself.

A robot developed by David, et. al [12] consisting of an interlock drive system resulting in the robot to turn swiftly, follow straight rows and steer easily. They have used the number of rotations of the wheel to measure the distance moved by the robot from which we have derived a method to measure the distance moved by the robot in terms of the duration for which it was powered uniformly.

Yashaswini, et. al [13] propose a system to perform real time identifications of weeds in a farm using a deep learning method that works on real time farm crop images. The image captured by a webcam is processed by Raspberry Pi using OpenCV and deep learning techniques and eliminates the need to spray herbicides all over the field. This system only identifies the weeds but does not have the ability to perform the weeding activity. Our robot can remove the weeds in addition to identification of weeds.

The experiments conducted by Liu, et. at [14] on their robot for obstacle avoidance uses a Multi-sensor fusion algorithm. The robot can find the area around the obstacle with a fuzzy algorithm and remote monitoring is enabled through a camera which sends video over the internet. Our system implements a similar collision avoidance function along with various other functions.

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Stephen, et. al [15] have developed a system to perform real time identifications of weeds in farm crops by using a deep learning method. It accelerates the operation by eliminating the need to spray herbicides all over the field. The developed robot is bulky and cannot detect obstacles. It can also perform only one specific task of weeding. Our model is compact and can perform multiple tasks.

III. METHODOLOGY

A powerful processor is used for carrying out the task. A sensor to determine the exact distance of the object, which poses as an obstacle to the forward movement of the robot is sensed. Once the obstacles in the path are sensed, the robot takes a detour around the obstacle and resumes its main path.

Weeding is the most arduous process in agriculture. A lot of money, time and effort is spent in this activity, which is an indispensable one in agriculture. An attempt has been made to identify the weeds and without harming the main crop, the weeding is carried out. First the video streaming of the crops is done. Then snapshots at a frequency of one second are captured by the program. This information is stored on the Raspberry Pi. then the snapshot is accessed for carrying out weed detection. Weed detection is done using image processing techniques. OpenCV is employed to distinguish weeds from the crop. A Weeder attached as an end effector to the robot takes out the weeds effectively.

An active user-friendly webpage is developed using HTML and CSS softwares. This enables the farmers to choose the task to be performed.

IV. BLOCK DIAGRAM AND WORKING

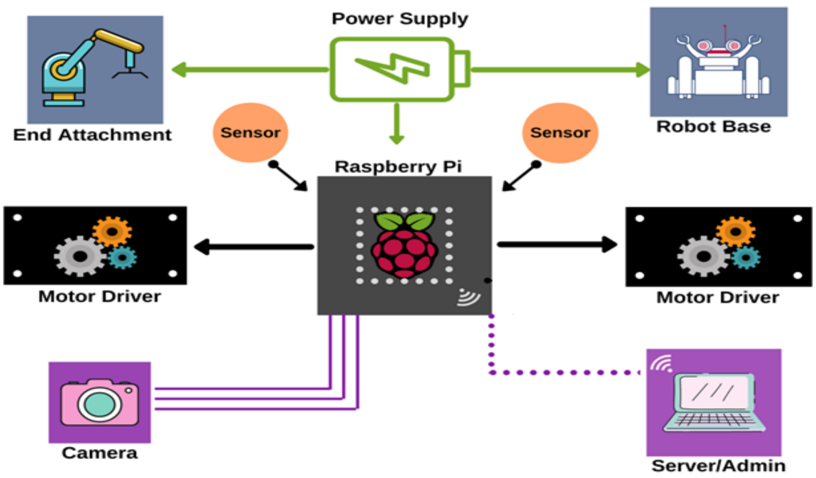

Figure 1. Block diagram of the proposed model

The system consists of a robot that is controlled by Raspberry Pi, a webcam, an L293D motor driver IC that controls two DC motors attached to the wheels, two servo motors that position the end attachments, an ultrasonic sensor that helps in obstacle detection and a robust software for collision avoidance.

Raspberry Pi 3B is used in our project due to its low cost, compact design, in-built ports and easy programmability. An external webcam of 720p/30Fps, wide angle view is connected through one of the USB ports. The camera is enabled through the motion library of python and a live stream of the video is relayed on the website for remote monitoring by the farmer. Snapshots are captured from the live stream and processed by the python program. Ultrasonic sensor HC-SR 04 used is a low cost sensor with a range of 2cm to 400cm and a 30 degree cone. It is mounted at the front of the robot.

The L293D motor driver module is used to control the speed of the two DC motors connected to the front two wheels of the robot. For mechanical support, an acrylic chassis set is used with a holder for an ultrasonic sensor, DC motors, wheels. The end attachments to perform different activities like ploughing, levelling are moved up and down using servo motors. The complete system is powered using two 3.7V, 2500mAh 18650 Lithium Ion Batteries.

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The various activities carried out by the robot are:
a. Weeding
b. Ploughing
c. Levelling

These activities are mentioned in the webpage as shown in Figure 5. The farmer chooses the activity that needs to be carried out by clicking on the web page developed for this purpose.The webpage has a livestream from the web camera on the robot for remote monitoring as presented in Figure 6.

On the click of the button on the web page, the control is transferred to the robot to carry out that particular activity. If the farmer clicks on the Weeding button, then the Camera will capture an image of the crops and store it on the Raspberry Pi. Image processing is performed on that image using OpenCV Python Library. This gives us the percentage of weeds present in the image. If the percentage of weeds is more than 70% then the weeder end effector is lowered and the weeding process is carried out. If the farmer clicks on Ploughing or Levelling, the robot lowers the respective end effector and the activity is carried out. With any of the above activities going on, the webpage keeps updating in real time and the farmer can view progress of the task on the web page as presented in Figure 6.

The movement of the robot and the process of collision avoidance is carried out using an ultrasonic sensor mounted at the front of the robot which is discussed in detail in the further sections.

The working of our prototype can be divided into three sections namely; Collision avoidance, Weed detection and User Interface.

Collision Avoidance

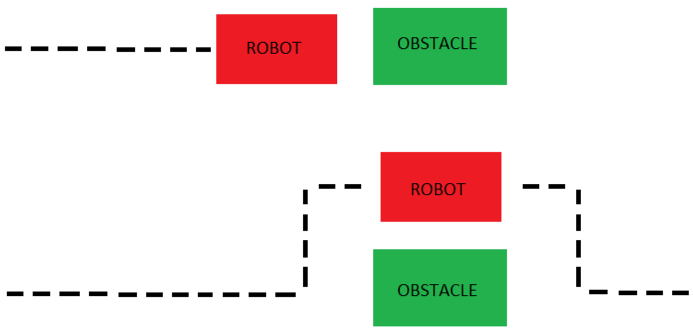

Figure 2: Collision Avoidance

An ultrasonic sensor is mounted on the robotic vehicle. The ultrasonic sensor measures the distance of an obstacle in front of the robot. The sensor can sense obstacles accurately within a range of 50 cms. Upto a distance of 15 cm to the obstacle the robot continues to move forward. If the distance is less than 15 cm then the robot stops, and moves backwards for 0.5 seconds (around 4cm) and turns to the left of the obstacle. If it still senses the obstacle then gets back to the previous position and then takes a turn towards the right of the vehicle and proceeds until it encounters no obstacle in its path.

To turn towards the left of the obstacle, the DC motor on the left wheel stops rotating and the right DC motor continues to rotate. Similarly to turn towards the right of the obstacle, the DC motor on the right wheel stops rotating and the left DC motor continues to rotate. In case there is an obstacle on both sides, then the robot moves backwards and covers a wider angle until no obstacle is detected.

Weed Detection

The Weed Detection process is carried out using OpenCV and image processing techniques. The camera captures the video stream of the plant along with the weeds. A snapshot is captured from the live stream and is stored on the Raspberry pi. The stored image undergoes a series of transformations such as RGB (Red, Green, Blue) to HSV (Hue, Saturation, Value) conversion, erosion and dilation. Parameters like colour and size are used to identify and differentiate the weed from the crop. The number of pixels occupied by the weeds was determined and the percentage of weed present was calculated.

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User Interface

The farmer interacts with the robot via a web page developed using HTML5 and CSS. The web page has 4 main tabs as presented in Figure 4. It opens on the Home Tab, the Task Tab enables the user to select the task that has to be performed by the robot. This tab has three options: Weeding, Ploughing and Levelling. The live stream of the video from the web camera is received by the port number 80 of Raspberry Pi. This live stream is displayed on the progress tab of the webpage along with the Progress bar which shows the percentage completion of the task .

V. RESULTS

We developed a prototype of the robotic vehicle along with required mounting. It was field tested to verify the functionalities of the robot. The findings are presented in the following paragraphs.

Weeding Task

We selected the weeding task from the web page. The control was transferred to the weeding section. The web camera mounted on the robot shot the live stream of the plant along with the weeds in the field of interest. This live stream is continuously displayed and monitored on the webpage. The snapshots of the live stream were stored on the memory of the Raspberry Pi. A Python weed detection program was run on the snapshots of the livestream, and the image was divided into 3 vertical sections and the percentage of weeds detected in each part was calculated. The average and mid section percentage values for the density of the weeds were considered. In our case, we found that the mid section percentage was around 85. Hence the weeding for those sections were carried out. The end effector was lowered from the mounting onto the ground for weeding.

Levelling Task

The leveling task was selected from the web page for another trial. The control was transferred to the levelling section. The ground is levelled for other practices to be carried out. The leveler implement attached to the end effector was lowered. The implement levelled the ground as the robotic vehicle moved forward. In order to ensure the functioning of the vehicle in case of obstacles on its path, an obstacle was placed on its path. The vehicle detected the obstacle and took a detour around it from the left side. Then it resumed position after the obstacle and continued forward movement.

Ploughing Task

The ploughing task was selected from the webpage for the last trial. The control was transferred to the ploughing section. The plough was attached as the end effector, and it was lowered for ploughing. The ploughing task was also carried out like other tasks, taking measures to avoid collision.

Figure 3: Weed detection

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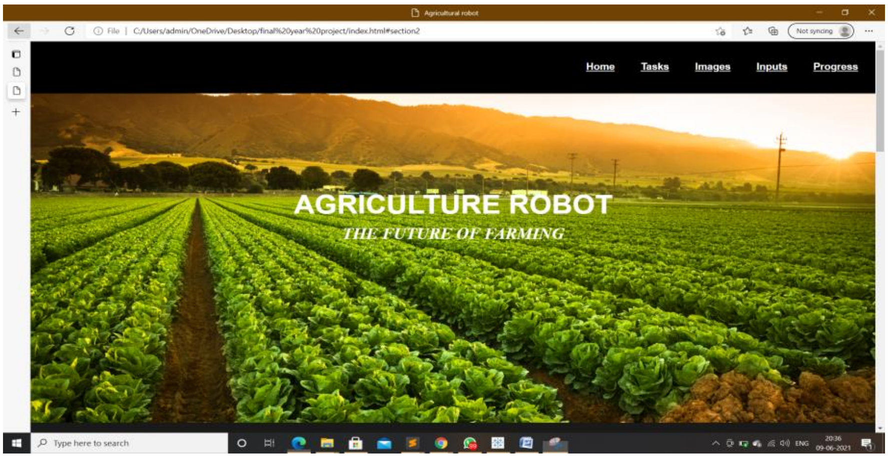

Figure 4: Agricultural Robot Webpage - Home

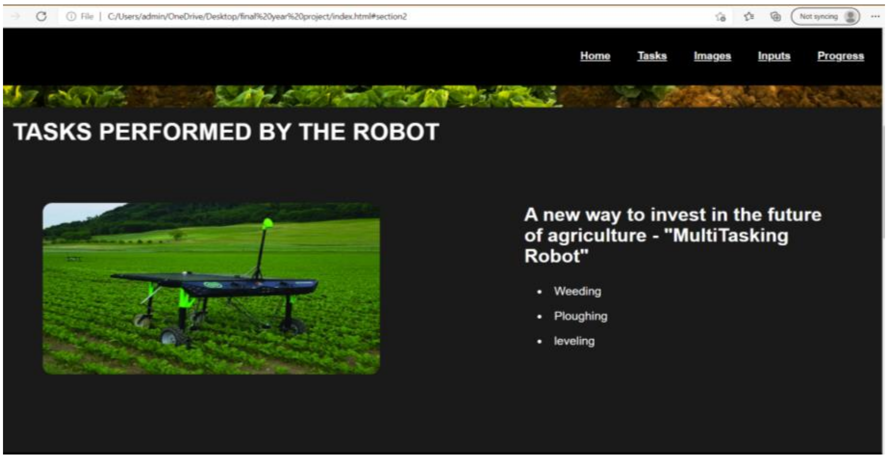

Figure 5: Agricultural Robot Webpage - Task Selection

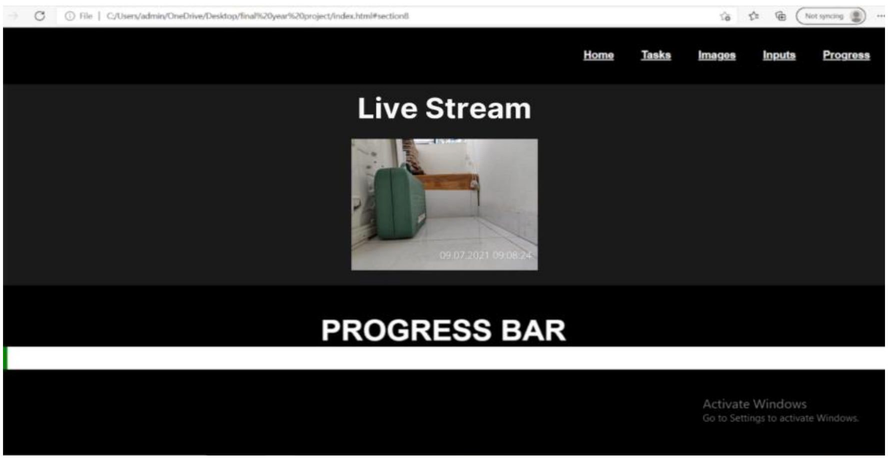

Figure 6: Agricultural Robot Webpage - Progress

VI. Conclusion

The Agricultural Land Maintenance Robot we have developed has the ability to perform routine maintenance tasks without much user intervention. This is a primary concern in the agricultural industry as the lack of labour causes loss of crops. This robot also helps to perform these tasks in a fraction of the time taken by humans. The comparative

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cost of the robot is significantly decreased by production using durable but inexpensive raw materials. The robot also avoids injury of labourers while working in the field.

Future Scope

This robot can further be modified to enhance its functionality by adding other end attachments, improving the user interface, adding more features to the webpage, increasing the accuracy of weed detection. GPS can be interfaced with Raspberry Pi inorder to track the exact location of the robot. Power is an important factor for the functioning of the robot. Solar Panels can be mounted on the robot vehicle in order to provide good battery backup as it moves through the field. Water sprinklers can be mounted to water the plants as the robot moves through the farmland. The movement of the robot in the field can be planned in advance using Novel Algorithms considering the dimensions of the agricultural land [16].

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