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Greenbot: A Solar Autonomous Robot to Uproot Weeds in a Grape Field

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Abstract: *Greenbot, an initial step towards automation of agricultural practices in India, is an autonomous robot that is designed solely to help farmers by identifying the weeds automatically and uprooting them from the agricultural field, especially grapevine field. The power source for this robot is provided through a solar panel along with a rechargeable battery, making it an environment friendly device. The primary actuator of the proposed system is a high speed blade known as a "Rotavator" that uproots the weed and buries it back into the soil from where it is uprooted. Weed identification through image processing techniques, controlling the rotavator based on image processing output and guiding navigation through Global Positioning System (GPS) and obstacle identification sensor are the important components of the proposed intelligent system. Raspberry Pi 2 board is used to implement these components, which is based on Broadcom BCM2836 SoC and includes a quad-core Cortex-A7 CPU running at 900 MHz and 1 GB RAM using Windows 10 IOT core. MATLAB software is used to implement the system.*

Keywords – *Autonomous Robot, Solar Energy, Image Processing, GPS, Obstacle Identification, Raspberry Pi, MATLAB.*

I. Introduction

As farms grow in size, together with the size of the equipment used on them, there is a need for ways to automate processes, previously performed by the farmer himself, for instance, irrigation, applying fertilizers and pesticides, de-weeding fields, etc. These tasks are perfectly suited for autonomous robots, as they often require numerous repetitions over a long period of time and over a large area. The use of robots is a rather new development as most of the existing solutions for automatic supervision [1, 2], is designed for standard farm equipment, such as tractors, combines and rotary tillers. One of the problems faced by the farmers is the process of removing weeds from the field. The aim of this project is to reduce manual labour and entirely automate this process. As an initial step, grape vines have been chosen as the field for implementation. This is so because, the process of weed identification is easier as the only crops which grow on these fields are weeds. Moreover, the navigation of the proposed system is simpler with the crops arranged in rows and columns [3]. The proposed system is environment friendly as the power for the functioning of the device is provided through a solar panel and a rechargeable battery. Image segmentation and analysis are two important processes involved in the system [4]. Vegetation indices are used for greenness identification and the proposed system is implemented in Raspberry Pi 2 processor, which acts as the brain of the entire system. The detection of weed activates the embedded rotavator, which uproots the weed. The navigation of the prototype is done using GPS. Ultrasonic sensors are used to identify the presence of obstacles.

II. Literature Survey

2.1 Current Scenario of Indian Agriculture

In spite of the large scale mechanism in the field of agriculture in some parts of the country, most of the agricultural operations in larger parts are carried on by human hand using simple and conventional tools and implements like wooden plough, sickle, etc.Little or no use of machines is made in ploughing, sowing, irrigating, thinning and pruning, weeding, harvesting threshing and transporting the crops. This is specially the case with small and marginal farmers. It results in huge wastage of human labor and in low yields per capita labor force. There is urgent need to automate the agricultural operations so that wastage of labor force is avoided and farming is made convenient and efficient. Agricultural implements and machinery are a crucial input for efficient and timely agricultural operations, facilitating multiple cropping and thereby increasing production. Some progress has been made for mechanizing agriculture in India after Independence. Need for mechanization was specially felt with the advent of Green Revolution in 1960s. Strategies and programs have been directed towards replacement of traditional and inefficient implements by improved ones, enabling the farmer to own tractors, power tillers, harvesters and other machines.

2.2 Factors affecting agriculture in India

- Scarcity of capital
- Economic Cost
- Ineffective agricultural practices
- Damage to natural systems
- Non-Environment friendly existing systems
- Hidden costs of Industrial agriculture

2.3 Existing Automations in Agriculture

2.3.1 Autonomous Robot Tractor in Belgium

From Belgium comes one of the most advanced self-steering tractor designed by the ability for a wide range of maneuvers and working the ground with high accuracy [5]. They pass the problems with uneven and inconsistent terrain that can change the direction of the tractor. Autonomous system component includes a system to act the acceleration and steer, processing unit, and sensors to locate the position including GPS system. Sensors and a powerful computer is not enough to keep the tractor on the right path. The development team creates an application where the user calibrates the robot according to each terrain type [6].

Fig. 1. Autonomous Robot Tractor in Belgium.

Fig. 2. Hortibot in Denmark

2.3.2 Hortibot in Denmark

Hortibot was born in the labs of Aarhus University in Denmark and was built by combining the Spider remote controlled robot with research platform AgRobot designed by the Danish agricultural engineers. The result is an autonomous vehicle for farming, a robot used to remove weeds manually, spraying or cutting with flames or laser.Row by row, the robot navigates the entire field using vision system and positioning system. Using an ECO-DAN camera, GPS system, and a gyro sensor, Hortibot can reduce the herbicide usage by 75 percent since it can recognize up to 25 different kinds of weeds and can use up to three methods to remove the weeds from the land. The system uses a camera for taking continuously picture of the ground and based on images analysis the system locate the crops and weeds. Once the weeds are located the system sprayed on a limited surface.This method is very expensive in terms of time, this could be a big disadvantage, but is very friendly with the soil while this is not affected.

2.3.3 Vitirover - Solar Robot For Cutting Grass

Green, friendly with the nature, Vitirover is an autonomous robot designed to cut the grass and weeds between grape vines. Built by a French company, the little robot uses a solar panel to produce energy to power the electric motor and electronic parts [7]. Using a battery to store energy is not the best solution since the robot has to navigate on large areas. As long as the sun is up the robot can work without pause and cut the grass and weeds at a speed of 500 meters in an hour. For farmers, it is very important to use technology friendly devices in the grape vines. Vitirover uses sensors and GPS system that keeps the robot away from grape vines.

Fig. 3. Vitirover in New Zealand

2.3.4 Gripper

The gripper is a grasping device that is used for harvesting the target crop. Design of the gripper is based on simplicity, low cost, and effectiveness. Thus, the design usually consists of two mechanical fingers that are able to move in synchrony when performing their task.. For example, in a procedure that required plants to be cut for harvesting, the gripper was equipped with a sharp blade. The manipulator allows the gripper and end effectors to navigate through their environment. The manipulator consists of four-bar parallel links that maintain the gripper's position and height. The manipulator also can utilize one, two, or three pneumatic actuators. Pneumatic actuators are motors which produce linear and rotary motion by converting compressed air into energy. In the last decade so many researchers have been carried out to analyze the quality of the soil [8].

III. Field Study

A detailed field study has been conducted by visiting a grapevine field situated in Rangasamuthiram, Coimbatore. The observations are noted down below:

(i) Orientation of Grapevine
The vines are arranged on stone pillars, in columns with an average area of the field being around 1 acre.

(ii) Row Length
The average length of each row in a grape field is about 50 to 100 metres.

(iii) Row Spacing
There is an interval of 2-5 metres between two consecutive rows of the grapevine.

(iv) Vine Spacing
An interval of 5 to 10 feet exists between two stone pillars.

(v) Average Height
Average height of stone pillar is about 5 feet.

Fig. 4. Grape field at Rangasamuthiram, Coimbatore

IV. The Proposed System

4.1 Components of the Proposed System

The proposed system has the following components:

4.1.1. Raspberry Pi

A small credit card sized computer, the Raspberry Pi processor helps in autonomous functioning of the robot. It controls all the processes of the system. The latest model Raspberry Pi 2 B+ board is used in the proposed system. It has a RAM with 1 GB storage memory. The 8 GB micro SD card acts as the secondary memory storage. The power supply from the rechargeable battery is provided to the system through the micro USB port. The HD camera used for image processing and the GPS antenna are plugged into the USB 2.0 ports.

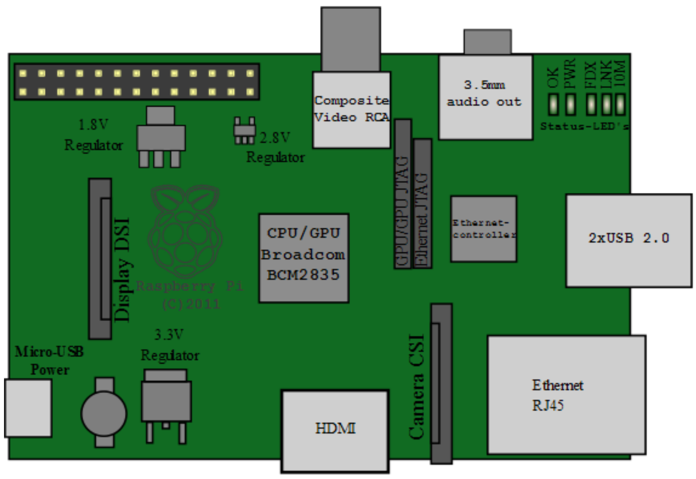


Fig. 5. A Raspberry Pi 2 Board

4.1.2. Solar panel

A 100 W solar panel is used to provide power supply to the machine.

A solar panel is a panel designed to absorb the sun's rays as a source of energy and provide DC supply. A photovoltaic module is a packaged, connected assembly of typically 6×10 solar cells. Solar cells work based on photovoltaic effect. A solar cell is a solid-state electrical device (p-n junction) that converts the energy of light directly into electricity (DC) using the photovoltaic effect.

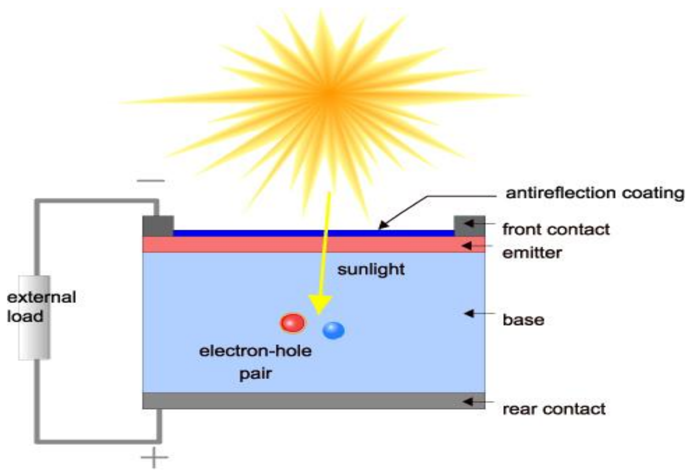


Fig. 6. Solar Cell Structure

Photovoltaic effect: The collection of light-generated carriers does not by itself give rise to power generation. In order to generate power, a voltage must be generated as well as a current. Voltage is generated in a solar cell by a process known as the "photovoltaic effect." The collection of light-generated carriers by the p-n junction causes a movement of electrons to the n-type side and holes to the p-type side of the junction. Under short circuit conditions, the carriers exit the device as light-generated current.

4.1.3. Input Devices

4.1.3.1 *HD Camera*

A high definition camera with 720 x 576 pixel resolution is used for detecting the presence of weeds using image processing. The video is converted into frames and the occurrence of green colour denoting the presence of weeds is detected. Signals are sent from the processor to turn on the rotavator.

4.1.3.2 *Ultrasonic sensors*

The occurrence of obstacles during navigation of the robot is identified using the ultrasonic proximity sensors. Sensors transmit rays up to 30 cm. When an obstacle is detected, the transmitted rays are reflected back to the receiver and signals are sent to the processor to deviate the path of navigation.

4.1.3.3 *GPS Antenna*

The coordinates for navigation of the robot is provided by the GPS antenna. A GPS antenna is a device that helps boost the reception signal to a GPS unit, whether it is a standalone unit or an embedded unit. GPS, or the Global Positioning System, is a satellite system that utilizes more than two dozen satellites orbiting the Earth to allow receivers on the ground or in the sky to tell exactly where they are, by receiving heads off of multiple satellites. Using this location, devices can detect not just latitude and longitude, but also altitude, and even heading and speed.

4.1.4. Actuators

4.1.4.1 *L298 Motor Driver*

This is a microcontroller that acts as an interface between the processor and the Dc motor. It helps in turning the motor on or off based on directions from the processor.

4.1.4.2 *DC Motor*

A set of three motors with a rating of 60 W are used in design of the system. One of them is used to motor the rotavator to uproot the weed and bury it back to the soil from where it is removed. Two other motors are used for the navigation. When both the motors are turned on it moves the robot in forward direction. When the motor for the right wheel is turned off, it facilitates the turning of the robot in left direction. Similar is the case for the movement in right direction.

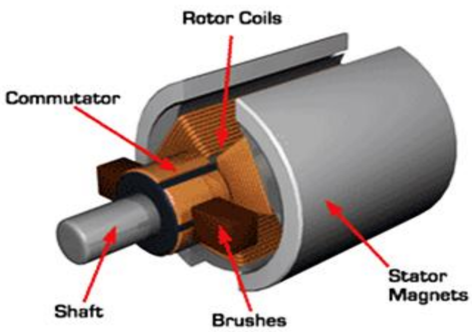


Fig. 7. Structure of a DC motor

4.1.4.3 *Rotavator*

A special purpose blade called Rotavator has been fabricated to uproot the weed detected during the navigation of the robot.

4.2 The Proposed Architecture

The Raspberry Pi 2 processor acts as the ‘brain’ of the entire system and controls all the processes. A high definition camera is used for the purpose of image recognition. Image processing using MATLAB is done to sense the presence of weed and send command to the processor to activate the rotavator to uproot the weed. GPS is used for the navigation of the proposed system. A GPS antenna is set up to receive GPS coordinates from the satellite. Ultrasonic sensors are placed at the front of the prototype in order to identify the presence of obstacles during navigation. Appropriate signals are sent to the processor to divert the device to avoid the obstacle. A set of three DC motors are used for the motion of the system in the agricultural field. One of the motors is used for the uprooting mechanism. Two other motors are used for driving the robot. L298 motor driver is used in each of the motor to switch it on or off. A solar panel and rechargeable battery are used to provide power supply to the entire system.

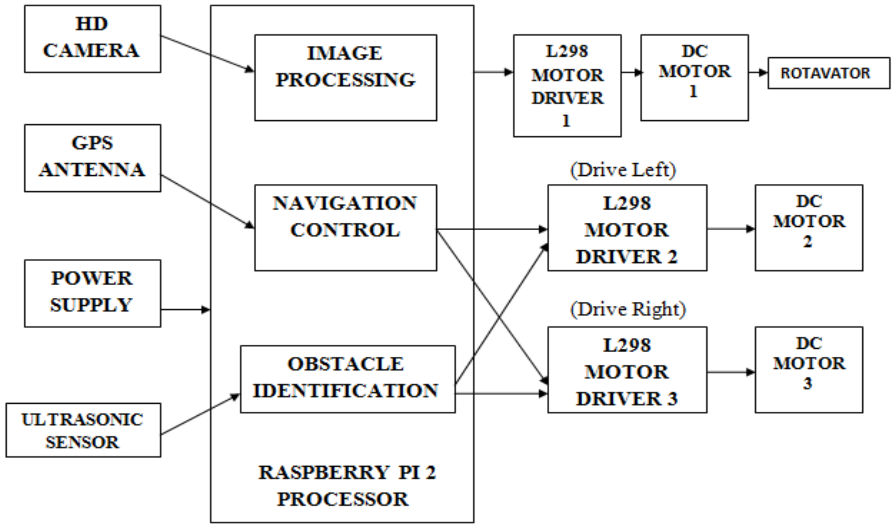
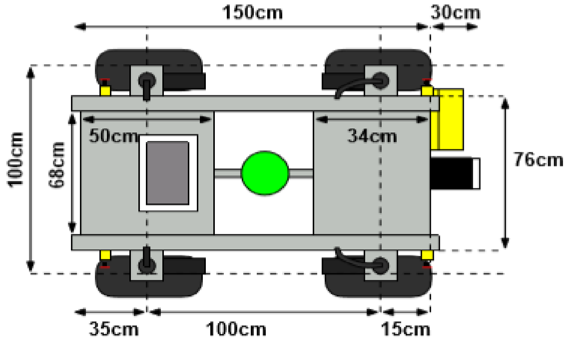


Fig. 8. Architecture of the proposed system

4.3 Design of the Hardware Model

The hardware model has been fabricated with respect the dimensions specified in the figures below. The designing has been done in such a way that it incorporates the internal components of the system such as the DC motors, the rechargeable battery and the rotavator.



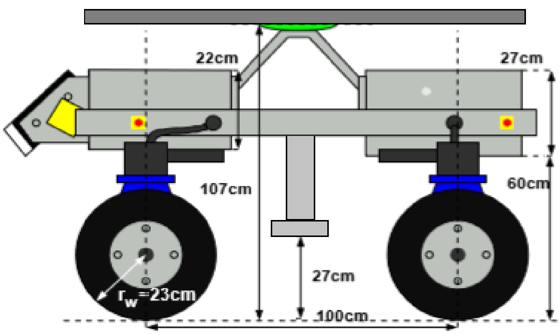


Fig. 9. Top View of the prototype

Fig. 10. Side view of the prototype

V. Experimental Results

The proposed system has to concentrate on three different operational areas such as image processing, image analysis and image understanding. Image processing is quite low-level operation, which transforms or enhances the original image by performing some pixel-level manipulations. Subsequently, image analysis operates at the middle-level and deals with classifying, segmenting the target based on its features. Color, texture and shape are the significant features that describe the uniqueness of the object. Image understanding mainly performs high-level operations, in order to execute the decision making process and consequently activate the control systems associated with the intelligent machines. Vegetation indices based thresholding technique [9] is used to detect weeds real time during the navigation of the device. Morphological operations are performed to identify the location where the rotavator has to start its process. Experiments are conducted in grapevine field in three lighting conditions (morning, noon and evening) and three different climatic circumstances (sunny, rainy and cloudy).

Fig. 11. Block Diagram for Image processing

(a) 5.1 Image Acquisition

A high definition color camera with resolution of 720 x 576 pixels is used to capture the images in the grapevine. All the images are taken in same height by placing the camera beneath the device which moves between the rows in the field. Images are collected at morning, noon and evening times in a day. Different climatic conditions such as sunny, cloudy and rainy days are chosen to perform image acquisition. The database used in the proposed work consists of 300 images taken in outdoor environment with different lighting conditions. The experiments are conducted on images of 10 different species (1grape + 9 weed species) and there are 30 images in each species.

(b) 5.2 Greenness Identification

The first stage in a typical weed identification procedure is segmentation of vegetation from the soil background. Color based vegetation indices (consisting of Red-Green-Blue or R, G, B components) are frequently considered in this stage because of the fact that vegetation pixels have a strong green component in comparison to background pixels. It is near impossible to achieve a 100% segmentation rate especially without manual thresholding, due to uneven illumination (even in the laboratory environment) and color variation among weed species or even among the same species at various growth stages and environment conditions. Thus the objective of this step to eliminate more than 99% of soil and residuals from the image and to retain the pixels of fresh vegetation in which the textural properties are not spoiled. A simple color index which fully eliminates the blue channel is utilized in the proposed approach. This index is based on the fact that the pixel which appears more green is the plant and the soil which slightly masks the green leaves also reflects more green light, which it obtains from its neighborhood pixels. The direct sunlight which appears whiter on the leaves also identified as leaf in this approach and at the same time the white light on the soil is identified as soil which is required for the proposed work.The index used in this approach is qE x G = G-R . Where qE x G is quantized Excessive Green; G,R are Green and Red values of a color pixel respectively. The system incorporated a simple image segmentation algorithm, based on global threshold to binarize the color field images for subsequent image processing and feature extraction procedures. This algorithm binarizes the raw color images with a correct segmentation rate of 98%.

(a) (b) (c)

Fig. 12. Results of Color Segmentation

Figure 2(a) shows the input color image (I). Figure 2(b) presents the segmented image, where the black and white image (BW) obtained is multiplied with input image (I). Figure 2(c) shows the output of the segmentation algorithm in which the pixels are distributed, in the tri-dimensional RGB color space. Pixels labeled in red are patterns belonging to soil and residual class i.e., black pixels in the segmented binary image. On the contrary, pixels labeled as blue are patterns belonging to vegetation class, i.e., white pixels in the obtained binary image.

VI. Future Enhancements

The proposed system can further be developed to perform advanced operations like identifying and killing pests, spraying herbicides, applying fertilisers, sowing seeds and harvesting the field. The system can further be enhanced to irrigate the field effectively. Moreover, the proposed model can be scaled up to perform such operations in all types of agricultural fields. The system could also be incorporated with ZigBee technology for effective interaction with the peasants who are the end users of the device.

VII. Conclusion

Greenbot- A fully automated agricultural robot, designed to uproot weeds in agricultural field using the concept of image processing has been presented in this paper. The proposed system is also designed to avoid any obstacles in its path all the while being conscious to its distance from the crop and providing no threat to it. This robot will definitely be one of the biggest breakthroughs in agriculture aids proving to soon become a farmer's best friend that takes out his worst enemy. Its advanced intelligence system also proves to be very easy to operate making it very friendly in every possible way. The proposed model is environment friendly with the use solar power for its functioning. The use of low cost materials benefits farmers of all economic conditions as a result of being easy to produce and purchase while at no instant compromising on performance at any level.

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