Agricultural Robot for Automatic Ploughing and Seeding

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Abstract: This paper strives to develop a robot capable of performing operations like automatic ploughing, seed dispensing, fruit picking and pesticide spraying. It also provides manual control when required and keeps tabs on the humidity with the help of humidity sensors .The main component here is the AVR At mega microcontroller that supervises the entire process. Initially the robot tills the entire field and proceeds to ploughing, simultaneously dispensing seeds side by side. The device used for navigation is an ultrasonic sensor which continuously sends data to the microcontroller. On the field the robot operates on automated mode, but outside the field is strictly operated in manual mode. For manual control the robot uses the Bluetooth pairing app as control device and helps in the navigation of the robot outside the field.

The field is fitted with humidity sensors placed at various spots that continuously monitor the environment for humidity levels. It checks these levels with the set point for humidity and alerts the farmer. The alerting mechanism is GSM module that sends a text message to the farmer informing him about the breach in set point. The farmer then responds via SMS to either switch on the water sprinklers or ignore the alert. The water sprinklers, if on, bring down the humidity level thus providing an ideal growing environment to crop. The concept of fruit picking and pesticide spraying is described under the process domain. Farmers today spend a lot of money on machines that help them decrease labor and increase yield of crops but the profit and efficiency are very less. Hence automation is the ideal solution to overcome all the shortcomings by creating machines that perform one operations and automating it to increase yield on a large scale.

Keywords: Agrobots, Advanced Virtual Risc (AVR), Bluetooth, Humidity sensors, Machine vision system

I. Introduction

Farmers today spend a lot of money on machines that help them decrease labor work and increase yield of crops. There are various machines that are available for ploughing, harvesting, spraying pesticides etc., however these machines have to be manually operated to perform the required operations and moreover separate machines are used for every functions. The yield and profit returns from employing this equipment are very less as compared to the investment. Another issue is the growing demands of the world's population. The World Health Organization estimates that Earth's population will touch 9 billion in 35 years which will lead to a staggering demand in increase of growth of food crops. Automation is the ideal solution to overcome all the above mentioned shortcomings by creating machines that perform more than one operation and automating those operations to increase yield on a large scale. XUE Jinlin, XU Liming [1] published a paper on "Autonomous Agricultural Robot and its row Guidance", at the International Conference on Measuring Technology. The objectives of this paper are:

- To enable the farmer to plough large areas of land in minimum amount of time.
- To perform automated ploughing and simultaneous seeding process using Advanced Virtual RISC (AVR).
- To provide manual control with the help of Bluetooth.
- To measure and control humidity in the field using humidity sensors and water sprinkler.

1.1 Robots in Agriculture - Agrobots :

Agriculture is humankind's oldest and still important economic activity, providing the food, feeder, fiber and fuel necessary for our survival. The current trend in agricultural robot development is to build more smart efficient machines that reduce the expense of the farmer while still providing one more services and higher quality which is precisely what we have done in this paper. Development of a robot that can perform automated ploughing and seeding operation can be manually navigated by the farmer and stabilizes the humidity in the environment.

Robotics and automation can play a significant role in enhancing agricultural production needs. Automation can be done by man in operations such as pruning thinning and harvesting, as well as mowing, spraying and weed removal. We can also implement with the advancement in sensors and control systems that allow for optimal resource and integrated disease and pest management. Alijanobi, A.A [2] published a paper titled "A set up of mobile robotic unit for Fruit harvesting" at the 2010 19th International workshop. Yan Li, chunlei Xia, Jangmyung Lee [3] published a paper titled "Vision based pest detection and automatic spray in green house plant", page no 920-925.Once the concept of Automation and agriculture is accepted the adoption rates will become high and the costs of technology will come down. Autonomous machines will be safer, more consistent with more efficient plant agronomy. The robot in the fig 1 shows how a robot is used in the agricultural fields. With the help of robots, autonomous agricultural operations such as spraying, mechanical weed control, fruit picking, watching the farm day and night, allowing farmers to reduce the environmental impact, increase precision in an effective manner.The Advantage of Automated techniques are

- Robots can work nonstop and in hazardous environment.
- Robots can detect presence of diseases, weed, insect infestations and other stress.
- Due to the light weight of the robots they do not compact the soil as large machinery does.

Fig 1 Robot in Agricultural field

1.2 Image Processing:

In engineering that makes use of digital signal processors, image processing is one form of signal processing for which the input is an image, such as a photograph or video frame. The output of image processing may be either an image or a set of characteristic related to the image. Most of the image-processing techniques treat the image as a two-dimensional signal and applying standard signal processing techniques to it like noise rejection, gray scaling etc. An image is an array or a matrix of square pixels that are picture elements arranged in columns and rows. It can also be defined as a two dimensional function f(x, y) where x and y are spatial coordinates, and the amplitude at any pair of coordinates (x, y) is called the intensity or gray level of the image processed at that point.

II.RELATED WORKS:

Several Projects like User friendly fuzzy logic based farm automation using arduino and Lab view using x bee controller are being undertaken. Also automatic milking systems, irrigation and harvesting systems, Tank farming automation using several meter designs are practised in most of the western countries.

III.SYSTEM ARCHITECTURE

3.1 Existing System

Robotics in agriculture has been a target for agricultural aspirants for many years. The first report was published from the February 1934 Modern Mehanix journal. This concept tries to establish crisis that a farmer could be separated from a machine's field operation where initially there was only little progress in the automation of Agrobots or indeed an automotive sector. It was after this gradual development in the field of agriculture began to take place. Also unlike in the present scenario which requires large manpower and investment for fruit picking process we can replace it with few numbers of this device, thus paving way for precision agriculture.

3.2 Proposed system Configuration

The farming using this kind of device is called precision farming. The main parts of the robot are the tiller, plougher and the wheels section. Three cameras are present for praying pesticides and for fruit picking. The tiller is a horizontal bar with a number of jagged teeth's fixed on it to aerate or loosen the soil bed. Cong Ming, in Ligang and Fag Bo [4] published a paper titled "Intelligent robot Mowers: A review", Robot, Vol. 29, no 4.From this we can say that the plougher is similar to a tiller but has sharper and longer blades to turn over the soil. Both the tiller and plougher are crafted of sheet metal for the prototype model. The robot section consists of 7 motors out of which 5 are dc motors and 2 are servo motors.

Four dc motors are attached to wheels strung on either side such that each side is driven by two motors each. The plougher is attached with another dc motor which aids polar movement in the plougher. However the tiller is fitted with more sophisticated servo motor for precise angular movement of the tiller. The servo motor serves its optimum purpose in the speed dispensing box where it is placed to slide the opening exactly for few inches in order to let the seeds fall in the soil. The AVR microcontroller and the other interfacing hardware are all mounted on the robot for convenience.

On the field navigation mechanism of the robot is guided by the signals being sent out from the AVR microcontroller in coordination with ultrasonic sensor placed on the robot. The ultrasonic waves are emitted and received continuously by the sensor which on encountering a wall or any obstacle sends signals to the microcontroller that further conveys the robot to stop, else keeping moving. They help in determining how much more distance is yet to be covered by the robot, this is done with the help of echo pulse which in simple terms means measuring the time taken for the pulse to leave and return to the sensor. If the waves come across a boundary wall then it immediately takes 180 degree turn to proceed to the next column of the field and so on till the last boundary all is reached. The distance to be covered is shown on a LCD display that is mounted on the robot. In this manner the entire field is ploughed and seeded.

3.2.1 AVR Microcontroller:

The AVR has Harvard Architecture where program and data memory are separately placed with an 8-bit RISC single chip microcontroller. It is the heart of the agricultural robot here. It is one of the first microcontroller families to use on-chip flash memory for program storage while other controllers used programmable ROM, EPROM or EEPROM. RISC-Reduced Instruction Set Computing, this is a CPU designed strategy based on the insight that simplified instruction can provide higher performance. AVR is most appropriate for battery powered appliances. The main advantages of using this ATmega16 are its 8-bit high performance with low power consumption and that it is based on enhanced RISC architecture with 131 powerful instructions of which most of the instructions execute in one machine cycle. For the applications, Atmega16 can work on a maximum frequency of 16MHz.It has a programmable flash memory of 16Kb and a digital to analog comparator. The controller is interfaced with the motor, water sprinkler, camera, display, Bluetooth and gsm and functions these devices.

3.2.2 DC Motors:

DC Motors fall into the category of Electrical motors that converts electrical energy into mechanical energy. There are several kinds of DC Motors. They work on the principle that when a current carrying conductor is placed in a magnetic field, it experiences a torque and has a tendency to move which is known as the motoring action. If the direction of electric current in the wire is reversed then the direction of the rotation is also reversed. When magnetic field and electric field interact they produce a mechanical force which causes the direction of rotation of this motor to change and is given by Fleming's left hand rule which states that if the index finger, middle finger, and thumb of your left hand are stretched mutually perpendicular to each other and if the index finger represent the direction of the magnetic field, middle finger represents the direction of the electric current the then the thumb represents the direction in which the force is experienced by the shaft of the dc motor.

3.2.3 Servo Motor:

Servo motor is commonly used as an error sensing feedback control which is used to correct the performance of a system. They are equipped with a servo mechanism for precise control of angular position. These motors usually have a rotation limit from 90 degree to 180 degree or to even 360 degree. But servos do not rotate continually. Their rotation is restricted in between fixed angles.

A servo motor primarily consists of a DC motor, gear system, a position sensor which is a potentiometer, and some of control electronics. The DC motor is connected with a gear mechanism and provides feedback to the sensor which is the potentiometer and from the gear box, the output of the motor corresponds to the current position of the motor. So the change in resistance produces an equivalent voltage from the potentiometer. The pulse width modulated signal is fed through the control wire where this pulse width is then converted into an equivalent voltage that is compared with that of signal from the potentiometer using an error amplifier.

3.2.4 Global System for Mobile Communication (GSM):

A GSM/GPRS module assembles a GSM/GPRS modem with standard communication interfaces like RS232 (Serial port), USB etc., so that it can be easily interfaced with a computer or a microprocessor or microcontroller based system. The power supply circuit is also built in the module that can be activated using suitable adaptor. Thus it is basically an open, digital cellular technology used for transmitting mobile voice and data services and supports voice calls and data transfer speeds up to 9.6 kbps, together with the transmission of SMS. Terrestrial GSM networks now cover more than 90% of the world's population. A GSM satellite roaming has also extended service access to areas where terrestrial coverage is not available.

3.2.5 Bluetooth:

Here Bluetooth is used as a basic universal Remote control for Bluetooth enabled serial devices such as Bluetooth modules connected to the microcontroller. It is a short-range wireless networking technology and is used to link (or pair) two devices, such as smart phones and headsets, cameras and printers, and keyboards and computers, it is sometimes called a cable-replacement technology. Both devices must support Bluetooth in order to be paired, if they do, though paring the paring is designed to happen automatically, with little to no user interaction. The Bluetooth module used here is a HC-05 based on SPP support. HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. In our idea we have made use of blue tooth Control App available on Android as controlling software more like a remote control for the manual operation of the robot.

3.2.6 LCD Display:

LCD abbreviation of Liquid Crystal Display screen is an electronic display module which is found in a wide range of applications. A 16 digit display is the very basic module and is very commonly used in most of the devices and circuits. (1)NUMERIC LCD: displays only numbers. E.g.: old calculators. (2)ALPHANUMERIC LCD: displays numbers and alphabets. E.g.: Scientific calculators. (3)GRAPHICAL LCD: displays pictures. E.g.: mobile displays. These modules are preferred over seven segments and other multi segment LEDs. The reasons are due to the LCDs being economical, easily programmable, having no limitation of displaying special characters or animations have comparatively better brightness. A model of the display placed on the device is given in fig 2.

Fig 2 LCD display

3.2.7 Ultrasonic Module HC-SR04:

The HR-SR04 ultrasonic sensor uses sonar emission technique to determine distance with an object just like bats or dolphins do. A model of the HC-SR04 Ultrasonic Module is given in the fig 3. It offers excellent range detection without contact but with high accuracy of stable readings to use the package in an easy manner. Its operation is not affected by sunlight or black material like Sharp rangefinders but acoustically soft materials like cloth can be difficult to detect. It comes with a complete ultrasonic transmitter and receiver module.

Fig 3 Ultrasonic sensor

3.2.8 Humidity Sensors:

Humidity is defined as the presence of water in air. The amount of water vapor in air can affect human comfort as well as many manufacturing processes in industries. The presence of water vapor influences various physical, chemical and biological processes. In agriculture, measurement of humidity is important for plantation protection, dew prevention, soil moisture monitoring etc.

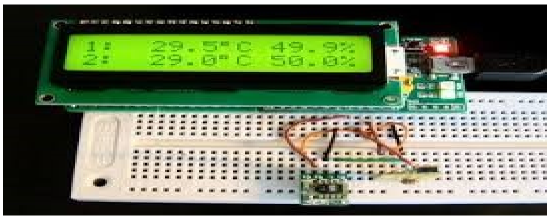

Fig 4 humidity sensor

With the development of science a chemical technology, the humidity sensor begins to use a thin piece of lithium chloride or other semiconductor devices and measuring the resistance which will be affected by water vapor. The resistive humidity sensor can use this feature to gather the humidity information. The main advantage of this sensor is that it can work in the high temperature up to 212 degrees Fahrenheit. Fig 4 shows a humidity sensor with its circuit connections.

3.2.9 Water sprinkler:

The type of water sprinkler used here is E-JET905F. This water sprinkler comes in use when the humidity level goes below the set point.

3.2.10 Camera:

The cameras used in robots are commonly used as an image sensor. These cameras are sensitive to IR light and have an IR filter placed in front of the lens. Cheap webcams may not have such a filter, which makes them very sensitive to sunlight. Camera calibration has always been an essential component of photogrammetric measurement. Self-calibration has become essential for high-accuracy close range measurement. The sensor that is used in the camera has a highly integrated cmos constructed array with extraction and enhancement facilities built in the space. It also performs extracting any extra edges from the image but the microcontroller has to process it. The two extreme types of calibration approaches are named as the photogrammetric calibration and pure auto calibration techniques. Traditionally the methods of calibration were used to resolve a pack of non-linear equations based on triangle measurement principle. Using servo, we can control the tilt angle of the camera in the device.

IV. PROCESS DESCRIPTION

The process is broadly classified into robot section and field section. The robot section comprises of components that take care of the automated ploughing, seed dispensing while the field section comprises of the humidity measurement and control, pesticide spraying and fruit picking operations. The two sections are discussed elaborately below.

4.1 Robot Section:

The fig below describes how different parts in the robot section are interfaced with the controller. The robot's controlling technology is the AVR microcontroller. A.Gollakota[5], Srinivas published a paper titled "Agribot: A Multipurpose agricultural robot", INDICON, vol.1, no.4, pp.16-18(2011) which explains here that the movement of the robot is guided by the ultrasonic sensor that is fixed on the robot's body which continually sends ultrasonic waves at long distances. If these waves hits any object in their path then the send back signals to the AVR informing the robot about the obstacle thus prompting it to behave according to the operation programmed in it. As the robot moves the AVR calculates the distance yet to be covered on that strip of field and displays it on the LCD display present in the robot.

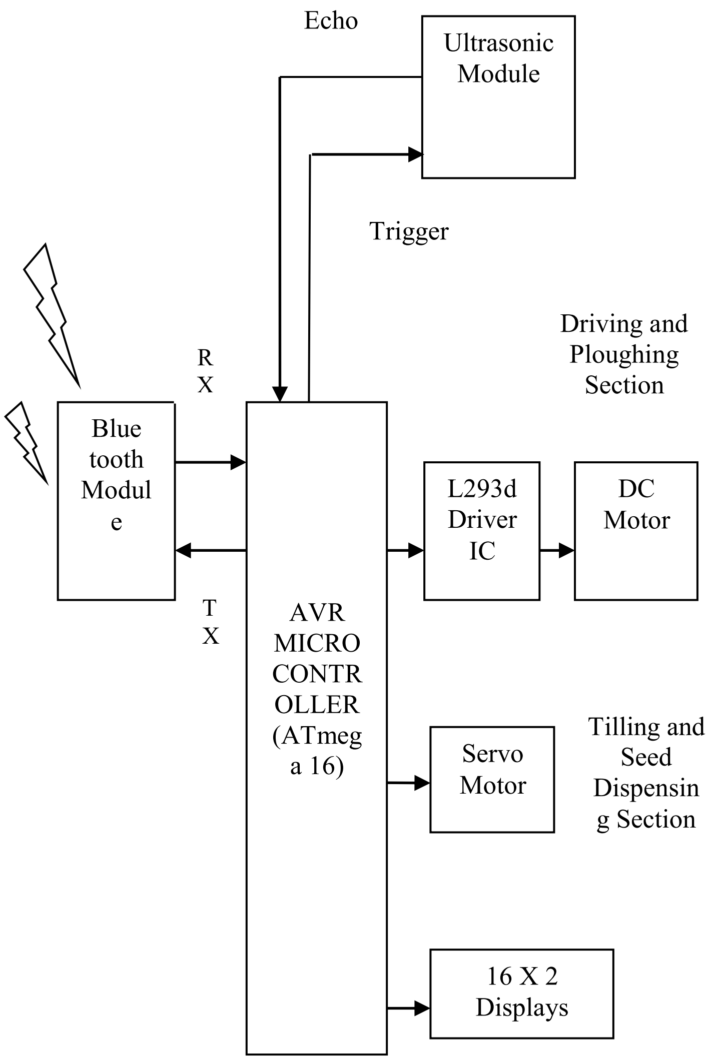

Fig 5 Interfacing diagram 1

The process begins with the scraping of the top surface of the soil using the tiller fixed to the front of the robot. The entire field is tilled first. The tiller loosens the soil bed enough for the plougher to be driven deep into the soil in order to turn the soil effectively. The plougher is accompanied simultaneously seed dispensing. The tiller is controlled by a servo motor that is driven by a motor driver l293D which allows for precise polar configuration in the robot's movement. The plougher is raised and lowered using a DC motor, which is also driven by a L293D motor driver IC.Gwoninso [6] published a paper titled "Autonomous Technology", Vol 51, No.3, 2011. The arrangement is such that when the robot lowers the tiller, it raises the plougher and holds it there until the tilling process is completed and vice versa. DC motors are used for the rotation of the wheels of the robot. All the above processes are automated. For manual control, an Android phone consisting of the Bluetooth application is paired with Bluetooth on the robot and used for navigation.

<u>*4.2 Field section:*</u>

The fig below describes how the different components on the field section are interfaced with the AVR microcontroller.

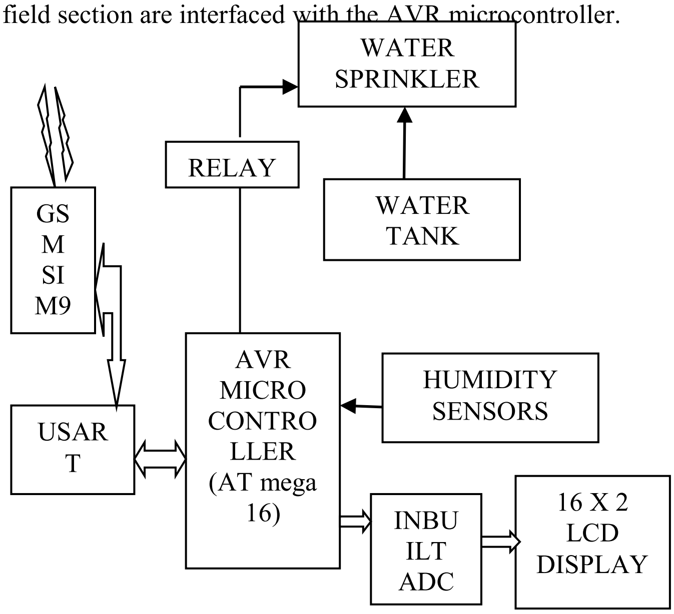

Fig 6 Interfacing diagram 2

4.2.1 Humidity measurement:-

Humidity sensors and water sprinklers are placed in fixed spots on the field which are interfaced with an AVR controller. A resistive type humidity sensor is used here. The AVR controller has an inbuilt ADC that converts the analog values coming from the humidity sensor to digital signals. An LCD display attached to the AVR control, displays the current humidity value along with the set point. Here, the ADC plays an important role in converting the analog values to digital values so that the LCD displays the measured values in readable and understandable terms. The humidity sensor continuously checks for the humidity in the environment and if it is below the set point value alerts the farmer informing him about the compromise in set point through GSM module. The farmer instantly receives a text message informing him about the disturbance in set point. The GSM module is interfaced to the AVR through the USART that helps perform the above function. The farmer can choose to turn on the water sprinklers or not through simple commands that can be communicated to the AVR through GSM module via text message. The communication rate is controlled using USART which is an inbuilt function of AVR.The AVR instructs the water sprinklers to either turn on or off as per the farmer's requirement thereby controlling humidity. Humidity is mainly being controlled to provide an ideal environment for growth of the crops so as to get maximum yield and produce good quality crops.

4.2.2 Fruit picking:-

For the process of fruit picking we use image processing along with a hydraulic arm. By the technique of image processing the cameras locate the fruits and hydraulic arm picks the fruits. All these action are controlled by the AVR microcontroller.

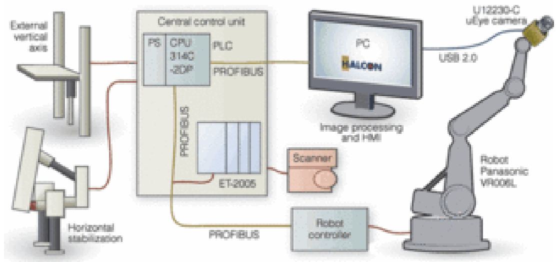

Fig 7 Fruit picking mechanism of the robot

Fig 5 shows how fruit picking is done using a hydraulic arm and image processing. Here we are in need to use a camera for capturing images and we also need a fruit gripper which is an arm tool to pick the fruit with intensive care. The position of the camera is fully controllable because it is fixed to the arm of robot and also because the camera is placed inside the gripper. The camera can point its optical axis at the fruit, reducing image distortion and eliminating calibration steps that take place repetitively during apple picking. A convincing advantage is that the camera is protected against collisions or bad weather conditions, as well as against direct sunlight. The camera scans the tree from 40 pre-programmed positions thus each tree is divided into 40 sectors or images.

Fig 8 Image Processed after capture

The programmed location and orientation of the robotic arm is stored with each image. For each sector, all ripe fruits are identified by the image processing software, listed, and picked one by one in a looped task. To improve the therapeutic effect of the image processing in finding and locating the apples on the tree, the platform was designed to control the lighting conditions to the greatest extent possible, using a canopy to cover the entire tree. The AFPM platform is also used to reduce the effects of changing ambient lighting conditions and provide a uniform background (blue) to ease locating the (red and green) fruits. The output of image processing is given in fig 6. Image processing is better performed on an industrial PC with 2 GHz featured Pentium IV microprocessor and 1 Gbyte featured RAM provisions running Windows XP.

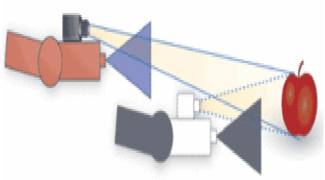

Fig 9 Distance calculation to pick the fruit

During system calibration, the first step is to train the system on the color of the fruit tree's leaves and the blue background canopy. A series of color thresholding steps are used to filter out these unwanted features. First the blue is filtered out of each of the 40 images that represent one side of the tree, and then the leaves are filtered out. The green and the red parts of the apples' surfaces are located via color thresholding. After noise reduction and filling holes in the images, the fruit's positions are clearly emerged .To pick one fruit, the robot has to determine the distance between the camera and the apple and the path to get there. The camera measures this distance by triangulation. The measuring is done in several steps. The camera first acquires an image, and then the camera is turned so that the fruit is situated in the center .The camera then acquires a second image, and finally the diameter is calculated by processing these two images. At this point, the vision system determines if the fruit falls within the acceptable size range. If so, a signal is sent to the robot controller, and the robot arm is allowed to continue to approach towards the fruit.

While approaching the fruit, several images are processed to calculate by triangulation method the remaining distance to the apple while air is blowing through the gripper at a speed having value about 300 m^3/min to free the fruit from leaves that might disrupt the clarity to focus it. With each image acquired, the system calculates the remaining distance using a formula. When the selected fruit is approached, air blows through the picking device to clear the apple from leaves. Once the apple is within a well-defined range of the gripper, the vacuum device is activated. If a vacuum around the fruit is detected, the fruit is rotated and tilted softly, picked and then put beside. Fig 7 shows a setup to calculate distance the machine has to move in order to pick the fruit.

4.2.3 Pesticide Spraying:

Camera and nozzle are installed on the end of robot arm. When the robot moves, on finding a plant the robot stops moving and the arm inspection of the plant from bottom to top is done using binocular stereo vision system using one camera. Teruaki Mitsui, Toshiki Kagiya, Akio Inaba and Shinya Ooba [7] published a paper titled, "Verification of a Weeding Robot", Journal of Robotics and Mechatronics, Vol 20, no.2, pp.228-233, 2008.Using image processing similar to fruit picking, i.e. (a) Original images obtained by camera (b) Gray-scale adjust (c) Image segmentation and area based matching (d) The results of fig, we can detect the weed and also the location of it. Image analysis is usually applied for the following purposes: 1.To detect a diseased leaf, stem or a fruit. 2. To spot the affected area by disease. 3. To find the extremes upon which this area is affected. 4. To determine the color of the affected area. 5. To determine size and shape of leaf, stem or fruit. 6. To identify the Object correctly. Fig 8 shows how a robot inspects the status of the leaf and an output of gray scaling. Using the above method, the information of pest could be calculated in detail. Through the depth of information obtained, robot can control the arm and to how much distance it should extend to focus the pest in the scope of the spray nozzle. A DSP board is used to control the spray nozzle. Also transfer of data can take place by RS-232-C fixed between chip and computer at the robot.

Fig 10 Processed image of the infected plant

A sprinkler similar to the water sprinkler is used to spray the pesticides in the field. The spraying of pesticides is done after the seeds are placed in the soil.

V.FUTURE WORKS

This paper is a small scale effort but the same can be implemented with enormous results in a large scale that benefits all farmers of the world. Apart from ploughing, seed dispensing, spraying pesticides and fruit picking other farming process like harvesting, irrigation etc. can also be implemented in one robot thus making the machine capable of multi-tasking. Also looking forward to learn about and implement agricultural based agrobots like Nursery bot, Herder bot, Wine bot, Bee bot, and Hamster bots that would qualify the standards from the current precision to autonomous farming methodologies.

VI.CONCLUSION

An initial outcome of this study indicates that most of these systems that which work autonomously are more flexible than traditional systems. The benefits of reduction in labor costs and restrictions on the number of daily working hours significantly improved. Thus it has made possible to automate the most significant working routines. However some have failed due to the requirement of accuracy of specific tasks. In addition, at this stage of development, the initial investment and annual costs of expensive GPS system are still relatively high but it seems possible to design economic viable robotic systems for grass cutting, crop scouting and autonomous weeding. Findings show that there is a significant potential for applying these systems if it's possible to impose adequate control and safety regulations systems at reasonable costs. Moreover, a comparison between different European countries indicates that labor costs, cost rotation and farm structure may have a tremendous impact on the potential use of these systems.

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