Design and Operation of Wi-Fi Agribot Integrated System

Gulam Amer[1] S.M.M.Mudassir[2] M.A Malik[3]

Deccan College of Engineering & Technology[123],
Darus-salaam, Hyderabad, India
hod_ie@deccancollege.ac.in[1]
smmmudassir@gmail.com[2]

Abstract—**Robotics in agriculture is not a new concept; in controlled environments (green houses), it has a history of over 20 years. Research has been performed to develop harvesters for cherry tomatoes, cucumbers, mushrooms, and other fruits. In horticulture, robots have been introduced to harvest citrus and apples. In this paper autonomous robot for agriculture (AgriBot) is a prototype and implemented for performing various agricultural activities like seeding, weeding, spraying of fertilizers, insecticides. AgriBot is controlled with a Arduino Mega board having At mega 2560 microcontroller. The powerful Raspberry Pi a mini computer is used to control and monitor the working of the robot. The Arduino Mega is mounted on a robot allowing for access to all of the pins for rapid prototyping. Its hexapod body can autonomously walk in any direction, avoiding objects with its ultrasonic proximity sensor. Its walking algorithms allow it to instantly change direction and walk in any new direction without turning its body. An underbody sensory array allows the robot to know if a seed has been planted in the area at the optimal spacing and depth. AgriBot can then dig a hole, plant a seed in the hole, cover the seed with soil, and apply any pre-emergence fertilizers and/or herbicides along with the marking agent. AgriBot can then signal to other robots in the immediate proximity that it needs help planting in that area or that this area has been planted and to move on by communicating through Wi-Fi.**

Keywords—Proteus Software; Agrirobot; Automation, GPS, Arduino

I. INTRODUCTION

Food is Man's most basic need. Throughout the ages men have strived to produce more and better food for growing populations. More land, Better tools, improved techniques, and technological advances however, all this progress has had one common element that has not changed "Man". Man has always been at the center of food production and has now become the limiting factor [1]. For 10,000 years, the primary focus of technological advancement has always been increasing the productivity and safety of the operator. But these incremental improvements will soon be outpaced by the exponential population increase that we are experiencing. Sometime in the near future, the population will exceed our ability to provide food for all of earth's inhabitants.

Automation Technology has proliferated in virtually every domain of human activity such as construction, manufacturing, communication, offices, households, transportation, warfare, exploration, and space travel. The investment in Automation Technology in agriculture is driven by various forces: The main motive for developing Agricultural Automation Technology is the decreasing labor force, a phenomenon common in the developed world. Other reasons are the need for improved food quality and security such as automated inspection of agricultural products for contaminants. Automation can also help solve problems with high volume seasonal labor such as harvesting of citrus fruits, grapes, and raisins. An important part of Automation is the use of robots [2].

Robotics in agriculture is not a new concept; in controlled environments (green houses), it has a history of over 20 years. Research has been performed to develop harvesters for cherry tomatoes, cucumbers, mushrooms, and other fruits. In horticulture, robots have been introduced to harvest citrus and apples. In dairy farming, milking robots are currently commonplace in the Netherlands. The pinnacle of highly automated crop production is without a doubt the Japanese ''plant factory,'' where vegetables are grown hydroponically under artificial lighting. Computers and robots control the process from out planting seedlings, to root cutting, packaging, and weighing, and the produce is free of any blemish, disease, or insect damage [3]. The automation level in plant factories is so high that over time they may become completely autonomous production facilities. The most important current abilities of automatic agricultural vehicles can be grouped into four categories:

- Guidance (i.e., the way the vehicle navigates within the agricultural environment)
- Detection (the extraction of biological features from the environment)
- Action (the execution of the task for which the vehicle was designed, e.g., radicchio harvesting [4].
- Mapping (the construction of a map of the agricultural field with its most relevant features) [5].

However, those four cores are not independent. For safe and successful navigation, the vehicle has to know its position within the field and the elements from the surrounding environment (mapping); bad detection could lead to an incomplete or unreliable map. Furthermore, if the elements from the environment are not properly located within the map, an agricultural vehicle may not be able to execute its tasks

successfully. In addition, an incomplete map should not be used for navigation purposes because of the risk of collision. As can be seen, the knowledge regarding the location of a vehicle within the environment and the location of the elements in an environment plays a crucial role in an automatic agricultural vehicle design. Slaughter et al. [6] propose the main abilities for designing robotic vehicles for weed control only, without addressing the localization issues associated with such a design. Growth in the world population has led to the need for an increasing level of sophistication in precision agriculture for both environment preservation and production optimization [7]. This need, in turn, has created a requirement for new methods, tools, and strategies for agricultural processes. Robotics and artificial intelligence achievements offer new solutions in precision agriculture to processes related to seeding, harvesting, weed control, grove supervision, chemical applications, etc. [8], to improve productivity and efficiency [9]. A service unit is an automatic vehicle for main or secondary tasks in the agricultural environment [10].

II. METHODOLOGY

A. Simulation with Proteus

1. Start the program by click the ISIS 7 Professional icon in Start Menu.
2. Designing the connections: For designing the schematic diagram of the robot it is necessary to know the components required while designing. All the components can be picked and place from the component library. The connections between the components can be given using wire pencil.

To select the components, click on Library > Pick Device/Symbol or just press "P". So the components used in this design are:

- At mega 328p micro controller. (AT MEGA 328P)
- Servo motor. (MOTOR-PWMSERVO)
- Capacitor. (CAP)
- Crystal oscillator. (CRYSTAL)
- Power source.
- Grounding

The selected component can be located on the left side window of the design diagram. To put the component to the design sheet, just left click the component and put it to the sheet. To move the components, simply right click on the component (the component will be red-lighted), and left click and drag the component to the desired location. For power terminal and ground, the component is NOT selected from the library. Select the "inter-sheet terminal" icon at the left-side toolbar. Select POWER for your Vcc and GROUND as ground. Each component need to be set according to the specifications. For example the servo motor or capacitor value need to define before any simulation can be done. To edit the component, select the component (right-click) and left-click to open the Edit Component dialog. The dialog is different according to the devices. Set the value of minimum and maximum angles in the box.

B. At mega 328p Parameter Settings

The most important part of Proteus simulation is setting up the microcontroller. The Configuration needs to be correct to cross out any setting error in time for program simulation.

To edit the parameter for PIC, right click on the PIC to select the component and then left-click. In this dialog, two things that need to set are: Program File: Your program's hex files location. Processor Clock Frequency: The oscillator frequency that you used At the Program File box, click the folder icon. Select the directory where you compiled your source code. Then select the corresponding hex file. Set the Processor Clock Frequency to 16MHz.

C. Simulation

After completing the circuit assembly and configuration, now its time to verify whether the source code compiled is virtually accurate or not. This is where the fun comes. Proteus offer a whole lot of variety virtual devices. In fact, simulation using oscilloscope and function generator can be done using Proteus. Even virtual HyperTerminal is provided to demonstrate how your code performs in real world without really doing the hardware section yet. To start simulation, press the play button at the bottom toolbar. The LEDs are ON initially. Then, when the push button is pressed, the LEDs will blink at a fast rate. To stop the simulation, press the stop button or press ESC. Bill of materials (BOM) the term used to describe the "parts list" of components needed to complete a saleable end-item. It generates a list of components needed to assemble the project. The file can be outputted in HTML or ASCII files.

III. MECHANICAL DESIGN

In this section we will list all components of the hexapod followed by a description for each component.

A. Body Chassis

Figure 1. Body Chassis of Robot.

The body has been designed with the lightest material for the body in order to decrease the load on the motors. The type of the material we choose was acrylic.

B. Leg Design

The main leg design was inspired by spider legs specifically " Theridion tepidariorum" and started by drafting the joint and links then using 3d modelling program to render the shape of the leg and then combining the aluminium brackets to create the required leg shape.
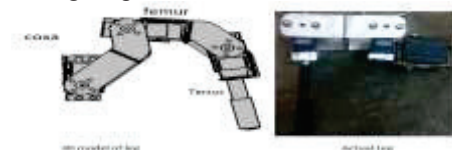

Figure 2. Leg design of robot.

C. Robot Description:

This section describes the robot, which is built by our team and it is an inline hexapod type robot, it has a costume design chassis, with 6 identical legs distributed evenly on the body. Each leg consists of 3 joints and 3 links. The joints can be manipulated by one servo per joint, providing 3 DoF for each leg. And a total of 18 DoF for the robot. One of the servos connects entire leg to the chassis through a vertical axis, allowing the leg to rotate sideways in relation to body. The three other servos manipulate the other joints of the leg with rotation about horizontal axes.

Figure 2. Six legs design of Robot.

D. Modelling of Robot

To be able to control the robot, model of the robot needs to be developed. First coordinate frames are defined for all important parts of the system, and to be able to move the robot in the environment a kinematic model is created. The kinematic model consists of the robot manipulators inverse kinematics solution. This makes it possible to calculate joint angles for robot legs for a given configuration.

E. Selection of Coordinate Frames

Before any modelling, the coordinate systems for all parts of the robot need to be identified. All coordinate systems will be Cartesian and called frames.

G. Leg Frame and Notations

The coordinate frames for the robot legs are assigned as shown in figure 3.3 .The assignment of link frames follows the Denavit Hartenberg notation. The robot leg is made of links and joints , different links of robot leg are called Coxa, Femur, Tibia and Tarsus.

A commonly used convention for selecting frames of

Link/parameter	α_i [degree]	a_i [mm]	d_i [mm]	θ_i [degree]
1 shoulder	90	30	-45	θ_1
2 Femur	0	74	0	θ_2
3 Tibia	0	70	0	θ_3
4 Tarsus	0	105	0	θ_4

reference in robotics applications is the Denavit and Hartenberg (D–H) convention which was introduced by Jacques Denavit and Richard S. Hartenberg. In this convention, coordinate frames are attached to the joints between two links such that one transformation is associated

with the joint, [Z], and the second is associated with the link [X]. The coordinate transformations along a serial robot consisting of n links form the kinematics equations of the robot.
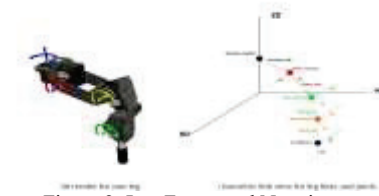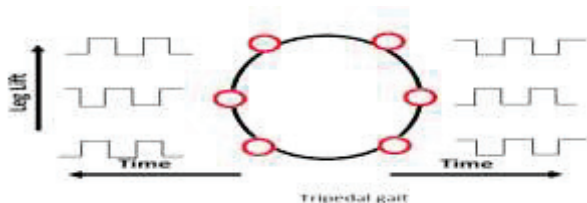

Figure 3. Leg Frame and Notations.

The robot leg frame starts with link 0 which is the point where the leg is attached to the body, link 1 is the coxa, link 2 is Femur, link 3 is Tarsus and link is the end effectors. The joints are located at the inner end of their respective link frames are attached to outer end of their respective links .this means that joint 2 rotates about the Z-axis of frame 1. The Y-axis of links are not shown in figure because they are irrelevant here.

H. Kinematics Mode

When all coordinate frames are defined, it is possible to describe the kinematic model of the legs of the hexapod. All units are in millimetres for distance measurements and degrees for angles.

I. Robot Leg Parameters:

The robots legs can be described by the following set of parameters which complies with the Denavit Hartenberg notation. The legs are placed in a local leg frame with a vertical z-axis through the rotational joint, which connects the leg to the body. The x-axis of the leg frame is defined to be perpendicular to the robot body, pointing away from the centre of the robot. In the leg frame, link frames are assigned to each link in the leg, as described in Figure 3.3.

The Denavit Hartenberg parameters are denoted α_i , a_i, θ_i and d_i.

• α_i is the angle between the z_i-1-axis and the z_i -axis about the xi-axis.

• a_i is the kinematics length of link i, e.g. the distance between the z_i-1-axis and the z_i -axis along the x_i-axis.

• d_i is the link offset, e.g. the distance from the x_i-1-axis to the x_i-1-axis along z_i-1-axis. 17

• θ_i is the joint angle or the joint variable. For the rotational joints in the robot legs, this is the angle

J. Tripedal Gait

This gait is the fast gait for the hexapod; it completes a cycle in two beats. In this gait the robot lift three legs simultaneously while leaving three legs on the ground, which keeps the robot stable.

Authorized licensed use limited to: NATIONAL INSTITUTE OF TECHNOLOGY CALICUT. Downloaded on January 29,2021 at 18:27:00 UTC from IEEE Xplore. Restrictions apply.

Figure 4. Tripedal Gait

IV. INTERFACING OF HARDWARE DEVICES

A. Legs Interfaced with Servo Controller

Initially the 3servo leg is being tested with various angles for proper functioning and then precise angles are provided for its effect on the motion of the hexapod. Then all the legs are interfaced synchronously to perform collective function .The 32 servo controller has ports connected to each leg in each different set of on board pins .The servo controller is provided with 6v of supply. The servos on the hexapod are supplied power from LiPo battery via BEC(*battery eliminator circuit*) which is connected to the 32 servo controller.
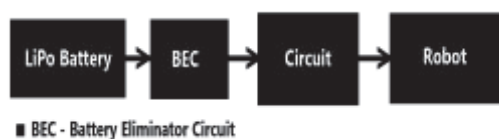

Figure 6. Leg interfaced with servo controller.
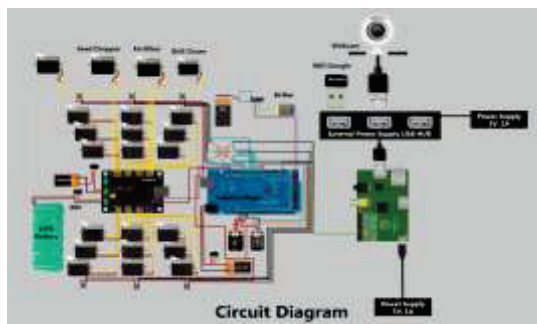
B. Circuit Connection Diagram

Figure 8 Circuit diagram of Complete robot.
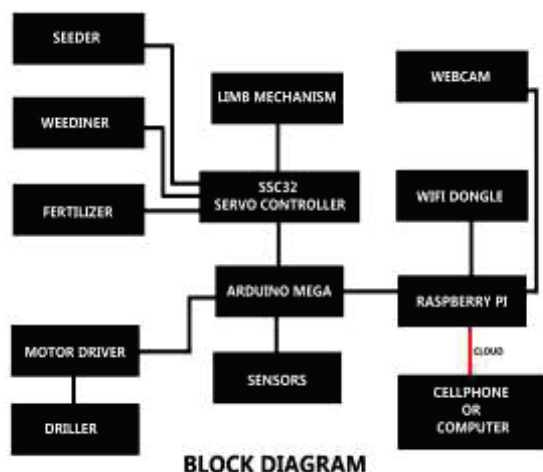
C. Block Diagram OF Agribot

Figure 9. Block diagram of Agribot

V. AGRICULTURAL PROCESSES

A. Seeding
It basically deals with two mechanisms one is drilling and other is dropping the seed.

B. Driller
The driller is attached below the surface of structure. The frontal part of the driller is a sharp spade that is attached to a dc motor with a shaft and performs the digging operation by the robot. The up-down motion of the driller is associated with the limbs of the bot. The digging varies from crop to crop.
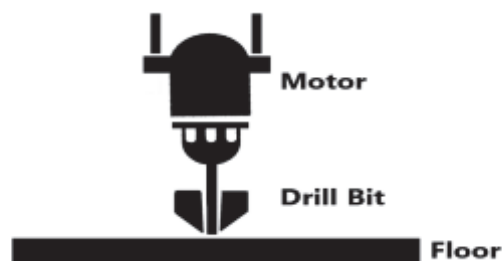

Figure 10. Drilling Action

C. Seed Dropper
There are three different approaches for this mechanism. The seed tank is attached to the dropping mechanism which performs the seeding process. The mechanism is designed in such a way that only one seed should drop at once.

Figure 11. Seed Dropping Mechanism

The mechanism is a servo dropping mechanism which takes the seed from the tank when in vertical position and turns 90 degree to horizontal position and releases the seed into the

D. Chemical Tank

Now this particular tank can be used for the fertilizers or insecticides. It is sprayed at the crop for its protection. This particular tank can also be used to spray herbicide with a more precise liquid ejector as the crop has to be avoided being sprayed.

Figure 12. Fertilizer tank.

E. Weeding

Weed mapping is process of recording the position and preferably density of different weed species .When the weed is identified , the proximity sensor follows any of the below processes and the weed is removed from the field. When the sensor detects any object at a certain defined level above the surface it will hold it and remove it. Around the robot six proximity sensors are placed and they follow are orderly fashion in performing their actions.

Figure 13. Weeding process

VI. CONCLUSION

Finally we have made an autonomous robot for performing all sorts of agricultural activities like drilling, seeding, weeding, and spraying of fertilizers. This bot has ability to work over half an acre. This project was conducted by both simulation and hardware structure. The hardware structure was designed it as a hexapod having its central body to be in a circular shape, having six legs and each leg having three servo motor for walking purpose. Drilling action uses a simple DC motor and a drill bit. Seed tank is placed on the bot to place the seed after drilling. Fertilizer tank is placed to pray the chemical after seeding operation. This robot also performs weeding operation when required.
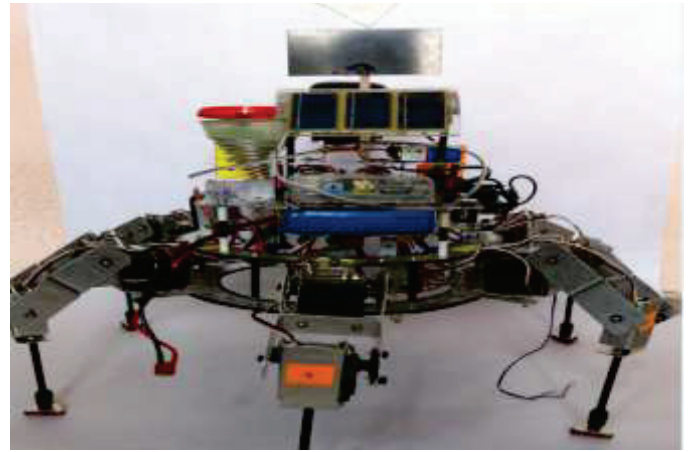
Fig. 14 Prototype of Agribot

It communicates through Wi-Fi with the operator and fellow robots. The on going process can captured and viewed through a camera attached on it. Walking mechanism was perfect on a flat surface. Then implementation was done on a rough surface and then on the field. In basic robotics we design machines to do the specified tasks and in the advanced version of it robots are designed to be adaptive, that is, respond according to the changing environment and even autonomous, that is, capable to make decisions on their own. While designing a robot the most important thing to be taken in consideration is, obviously, the function to be performed.

The levels of complexity of robots is defined by the members used in its limbs, number of limbs, number of actuators and sensors used and for advanced robots the type and number of microprocessors and microcontrollers used. Each increasing component adds to the scope of functionality of a robot. With every joint added, the degrees of freedom in which a robot can work increases and with the quality of the microprocessors and microcontrollers the accuracy and effectiveness with which a robot can work is enhanced.

AgriBot is limited to work for small piece of land say half an acre due its design and structure. We have designed under limited assumption and worked upon it task by task. Having control on leg movements and using Wi-Fi triangulation method precision for different operations was obtained. This basic design of autonomous robot can have advance changes and can be designed to work for large area of field. Much efficient agricultural activities can be performed.

REFERENCES

[1]   Abhinav Valada, David Kohanbash, George Kantor,   Design and Development of a Wireless Sensor Network System for Precision Agriculture, , *Robotics Institute Carnegie Mellon University Pittsburgh, Pennsylvania 15213.*

[2]   Simon Blackmore, Bill Stout, Maohua Wang, Boris Runov, Robotic Agriculture –The future of agricultural mechanisation? AgroTechnology *The Royal Veterinary and Agricultural University Agrovej 10 DK-2630 Taastrup, Denmark.*

[3]   Pavan.C, Dr. B. Sivakumar Wi-Fi Robot Video Surviellance Monitoring System *International Journal of Scientific & Engineering Research* Volume 3, Issue 8, August-2012 1 ISSN 2229-5518.

[4]   R. Eaton, J. Katupitiya, K. W. Siew, and B. Howarth, "Autonomous farming: Modeling and control of agricultural machinery in a unified framework," in *Proc. 15th Int. Conf. Mechatronics and Machine Vision Practice*, Auckland, New Zealand, Dec. 2008, vol. 1, pp. 499–504.

[5]   M. Foglia and G. Reina, "Agricultural robot for radicchio harvesting," *J. Field Robot.*, vol. 23, no. 6/7, pp. 363–377, 2006.

[6]   D. C. Slaughter, D. K. Giles, and D. Downey, "Autonomous robotic weed control systems: A review," *Comput. Electron. Agric*, vol. 61, no. 1, pp. 63–78, 2008.

[7]   C. Cariou, R. Lenain, B. Thuilot, and M. Berducat,"Automatic guidance of a four-wheel-steering mobile robot of accurate field operations,"*J. Field Robot.*, vol. 26, no. 6/7, pp. 504–518, 2009.

[8]   J. R. Rosell and R. Sanz, "A review of methods and applications of the geometric characterization of tree crops in agricultural activities,"*Comput. Electron. Agric.*, vol. 81, pp. 124–141, Feb. 2012.

[9] B. Astrand and A. Baerdveldt, "A vision based row-following system for agricultural field machinery," *Mechatronics*, vol. 15, no. 2, pp. 251–269, 2005.

[10] D. Bochtis, C. Sorensen, and S. Vougioukas, "Path planning for in-field navigation-aiding of service units," *Comput. Electron. Agric.*, vol. 74, no. 1, pp. 80–90, 2010.