AgriBot: An Autonomous Weeder Robot

Aya Sherif, Ibrahim El-Abasy, and Mohamed Osama
Kafr El-Shiekh University, Egypt, aya.sherif1698@gmail.com, himaelabasy@gmail.com,
Mohamed.osama.abuseada1999@gmail.com
Supervisor: Prof. Ghada Hamissa, Lecturer in Electrical Engineering Department.
Kafr El-Shiekh University, Egypt, ghada.hemesa@eng.kfs.edu.eg

***Abstract*—For thousands of decades, agriculture has been one of the most important sectors in the development of Egyptian civilization. And with the recent advancement of technology and the need for increasing sustainability autonomous robots will play a huge role in the future of agriculture—especially in weeding applications.**

Weeding is necessary because weeds compete with the main crop plant for different factors such as water, sunlight, nutrients, and space, hence affecting plant growth. Traditional weeding methods usually use chemicals in an excessive way that causes lots of damage to the crops and has a negative impact on both, the environment, and human health. In addition, it requires a lot of manpower and unnecessary costs.

Modern technology must be applied to solve such issues while keeping farmers competitive. A design of a robot is proposed to reduce herbicides input in the field to its minimum while in parallel trying to provide cost, time, and fuel economies.

Our project—in the form of an autonomous robot that aims to get rid of weeds with the use of a micro-dose of herbicides— robot represents a major innovation in weeding methods.

It is 100% autonomous. It can detect the weed with high precision in order to spray the herbicide on them directly without affecting the crops. Furthermore, it uses less herbicide to reduce the costs and the environmental impact. Plus, the robot will be powered by a renewable source of energy—solar energy—to help reduce carbon emissions and improve sustainability.

***Keywords*—Autonomous, Robot. Smart Agriculture, Weeding, Sustainability.**

I. INTRODUCTION

A. Problem Statement

Weeding is one of the most important practices that can never be understated. It can defined be as the removal of weeds (unwanted plants) from the field. Weeding is necessary because weeds compete with the main crop for the different factors such as water, sunlight, nutrients, and space and hence affect plant growth.

The most common method used for removing weeds is through mass spraying of herbicides; however, herbicides can cause deleterious effects on organisms and human health if used heavily.

Moreover, excessive use can create weed resistance to the chemical. If resistant, the weeds will no longer respond to the herbicide’s active properties. Plus, excess herbicides can persist in the soil and cause lasting effects on future vegetation growth, and heavy treatment of soil with herbicides can cause populations of beneficial soil microorganisms to decline

In addition, the harmful effects of direct contact with herbicides on human health can be detrimental—and sometimes, fatal. The recorded number of worldwide deaths and chronic diseases due to herbicide poisoning is about 1 million per year, according to the Environews Forum, 1999. [1]

From this, we can deduce that prolonged exposure to herbicides can lead to several health effects, including the induction of diseases such as cancer and neurodegenerative, reproductive, and developmental changes, and respiratory effects.

B. Proposed Solution

There are two main factors to look at when trying to solve the main issue that was brought up. The first one is the total area covered by a conventional herbicide sprayer (generally the whole field), versus the actual area covered by weeds. Using advanced technology, a device that would effectively spray patches of weeds individually can be designed, which will be able to reduce the area to be covered. Also, a substantial economy can be achieved with less use of herbicide and associated time and energy costs. And not only the load of chemicals reaching the soil would be reduced, but also there will be no need for direct human contact due to the autonomous properties that the device will be equipped with, a function that will result in avoiding the negative impacts of herbicides on human health.

Furthermore, the ability to detect weeds and spray them directly with a micro-dose of herbicides will result in more organic and healthy crops, and there will be no active herbicides in the soil itself, meaning that the organic life of the soil will be preserved. Plus, this will also prevent herbicides from spreading into the atmosphere and contaminating the air.

And to achieve even more sustainability and help reduce carbon emissions, the device can be powered using a clean and renewable energy source.

C. Goals and Objectives

Our project's main aim was to design such a device in the form of a weeding robot. The robot as to be able to navigate through rows of different crops, recognizing and systematically targeting the weeds patches along the way, spraying them with precision. Also by giving the weeding robot navigation abilities, it will be able to position itself precisely and effectively, all while avoiding obstacles in its way.

Also, we aimed to make the project eco-friendly, hence why, we thought reliance on solar power was the best option, as it made the robot completely autonomous in terms of energy, reducing both costs and carbon emissions.

Our project also aims to help the national economy through the production of healthier crops that can be exported. Furthermore, the project will reduce the need for manpower, as well as energy, and time, thus reducing costs and increasing efficiency.

Finally, we aimed to gain hands-on experience through designing, manufacturing, and implementing a project that is multi-disciplinary in nature.

II. SYSTEM DESIGN AND IMPLEMENTATION

A. Mechanical System

The mechanical system connects the wheeled robot that works and moves on the agricultural lands and the delta robot arm that provides the flexibility of movement for reaching and spraying the weeds precisely.

The main components of our mechanical system were:

1. The chassis: It is the metal frame on which the parts of an electronic device together with the circuits connecting them are mounted. It is the base of the robot which contains the main components of the project like the solar units, battery, and microcontroller. It weighs 14 kg.

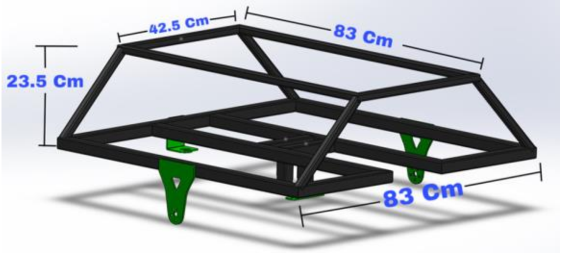


Fig 1: Chassis

2. Rocker Bogie Mechanism: A suspension arrangement, consisting of two arms with a wheel mounted to each of them. Both arms are connected through a movable joint. This enables having a suspension-based mechanism that allows the chassis to climb over any obstacles and distributes the vehicle load as evenly as possible even on bumps and irregular surfaces. The design consists of a spring-free suspension-based differential drive system that allows the bogie to move over rocks, and pebbles with ease, making it perfect for agricultural lands.

Fig 2: Rocker-Bogie Mechanism

3. Delta Robot: The second robot which carries the injector to spray herbicides on the weeds. It has been designed to cover the area needed and to be lightweight. We used three NEMA 23 stepper motors, but the torque wasn't quite enough to carry the Delta Robot Parts, so we used a 1:3 Geared System to increase the torque but decrease the speed; however, that doesn't affect our application. The area covered: max (±25Cm in X & Y direction), and the maximum torque load: 39 Kg.cm.

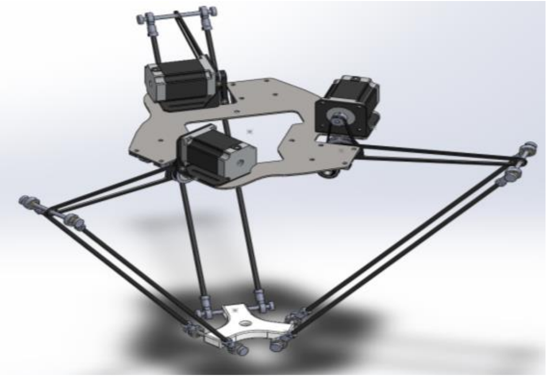


Fig 3: Delta Robot

B. Electrical System:

The electrical system connects the motors, the batteries, the pump, and the solar power system.

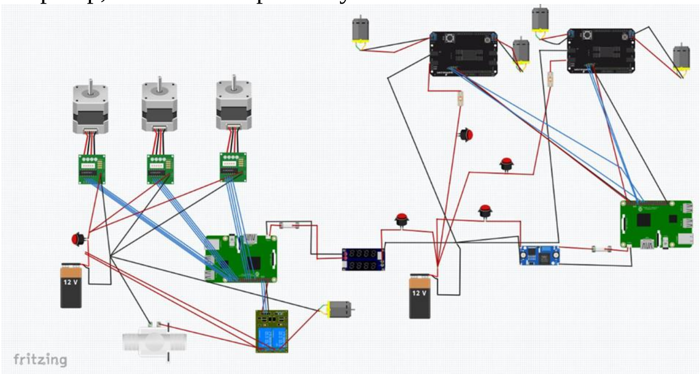


Fig 4: Electrical System Design

- Parts in Mobile Robot:
  - Battery
  - Raspberry Pi4
  - Camera
  - 4 DC motors
  - 3 Drivers for DC motors
  - Converter
  - PCB board
  - Fuses
  - Switches
  - Wires
  - Heat Shrink
- Parts in Delta Robot:

  - Battery
  - Raspberry Pi4
  - Camera
  - Stepper motors
  - 3 Drivers for Stepper motors
  - Limit switches
  - Converter
  - PCB board
  - Switches
  - Wires
- Parts in End Effector:
  - Relay
  - Valve
  - Pump

III. CONTROL AND AUTOMATION

A. *Mobile Robot*

- Steps of Operation:
  1. Computer Vision and Image Processing.
  2. Motor Drivers.
  3. Integration of Computer Vision and Motor Drivers.

Step (1): Computer Vision and Image Processing: [2]

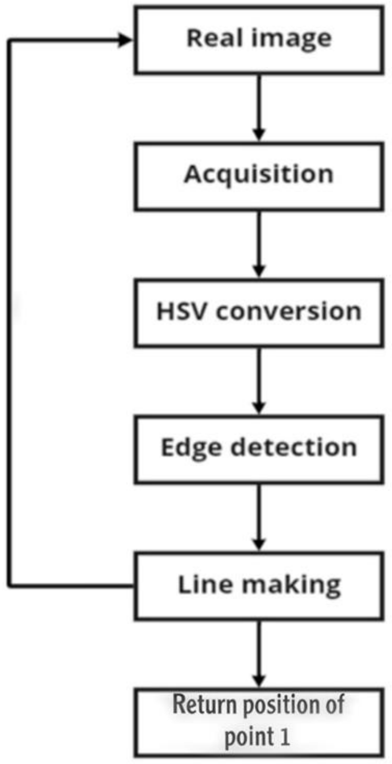


Fig 5: Computer Vision and Image Processing Algorithm

Step (2): Motor Drivers: [2]

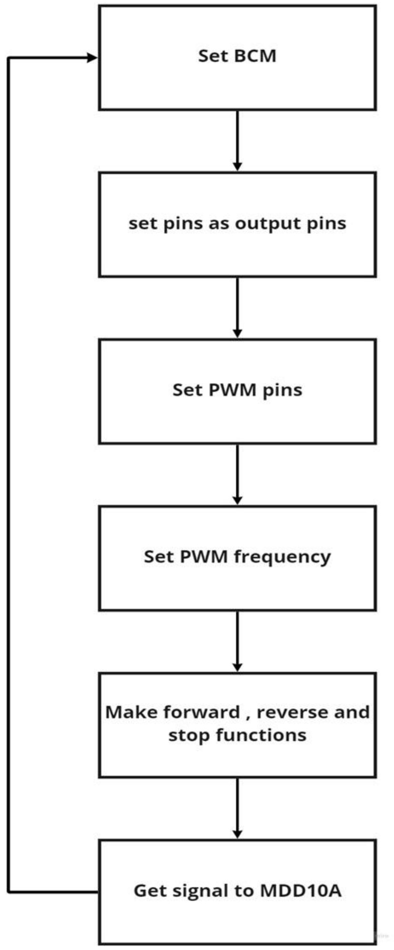


Fig 6: Motor Drivers Algorithm

Step (3): Integration of Computer Vision and Motor Drivers: [2]

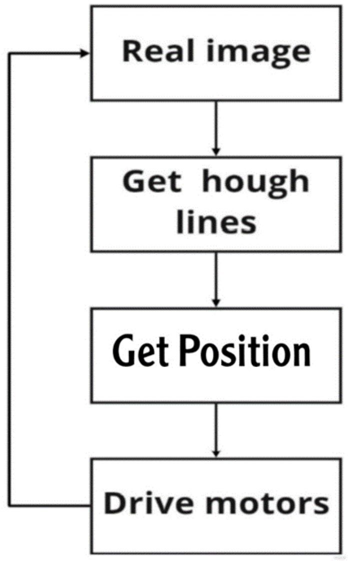


Fig 7: I

B. Delta Robot

- Steps of Operation:
  1. Weeds Detection
  2. Inverse Kinematics of Delta Robot
  3. Motor Drivers
  4. Integration of the Three Steps

Step (1): Weeds Detection: [3]

By using the camera, which is connected to raspberry pi4, we were able to detect the weeds and their position. Then transfer this data to the raspberry pi4 to control and move stepper motors.

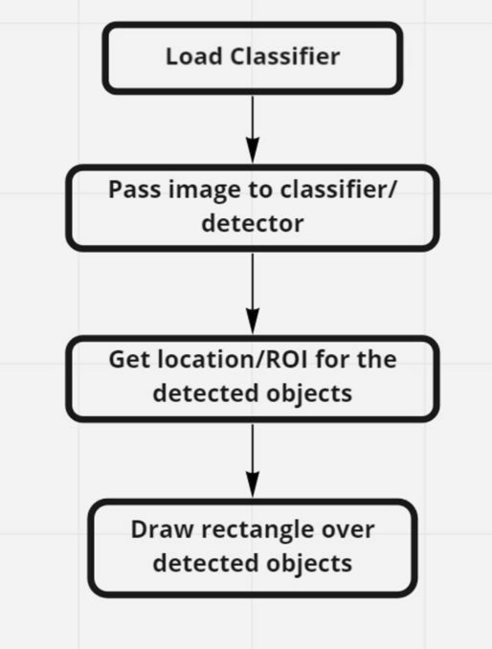
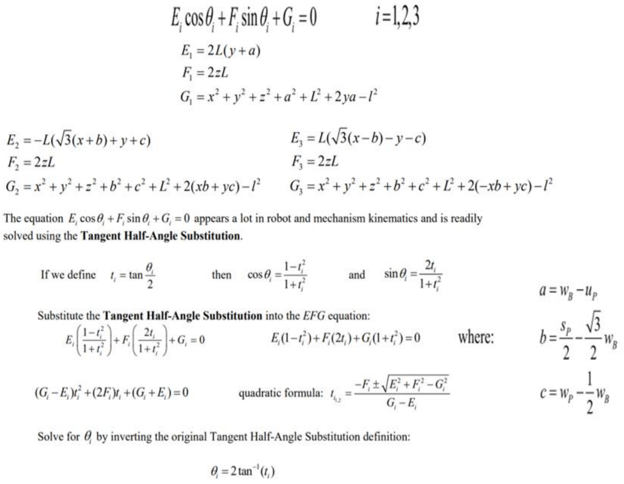


Fig 8: Weeds Detection Algorithm

Step (2): Inverse Kinematics of Delta Robot:

The three-DOF Delta Robot is capable of XYZ translational motion, to control the delta platform motion within its workspace, the following equations are used to calculate its inverse kinematics. [4]



$$E_i\cos\theta_i + F_i\sin\theta_i + G_i = 0 \qquad i=1,2,3$$

$$E_1 = 2L(y+a)$$
$$F_1 = 2zL$$
$$G_1 = x^2+y^2+z^2+a^2+L^2+2ya-l^2$$

$$E_2 = -L(\sqrt{3}(x+b)+y+c) \qquad E_3 = L(\sqrt{3}(x-b)-y-c)$$
$$F_2 = 2zL \qquad F_3 = 2zL$$
$$G_2 = x^2+y^2+z^2+b^2+c^2+L^2+2(xb+yc)-l^2 \qquad G_3 = x^2+y^2+z^2+b^2+c^2+L^2+2(-xb+yc)-l^2$$

The equation $E_i\cos\theta_i + F_i\sin\theta_i + G_i = 0$ appears a lot in robot and mechanism kinematics and is readily solved using the **Tangent Half-Angle Substitution**.

If we define $t_i = \tan\frac{\theta_i}{2}$ then $\cos\theta_i = \frac{1-t_i^2}{1+t_i^2}$ and $\sin\theta_i = \frac{2t_i}{1+t_i^2}$

Substitute the **Tangent Half-Angle Substitution** into the *EFG* equation:

$$E_i\left(\frac{1-t_i^2}{1+t_i^2}\right)+F_i\left(\frac{2t_i}{1+t_i^2}\right)+G_i=0 \qquad E_i(1-t_i^2)+F_i(2t_i)+G_i(1+t_i^2)=0$$

$$(G_i-E_i)t_i^2+(2F_i)t_i+(G_i+E_i)=0 \qquad \text{quadratic formula: } t_{i_{1,2}} = \frac{-F_i \pm\sqrt{E_i^2+F_i^2-G_i^2}}{G_i-E_i}$$

where:

$$a = w_B - u_P$$
$$b = \frac{s_P}{2}-\frac{\sqrt{3}}{2}w_B$$
$$c = w_P - \frac{1}{2}w_B$$

Solve for θ_i by inverting the original Tangent Half-Angle Substitution definition:

$$\theta_i = 2\tan^{-1}(t_i)$$

Fig 10: Inverse Kinematics Equations

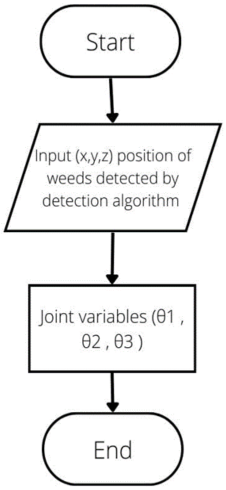


Fig 9: Inverse Kinematics Algorithm

Step (3): Motor Drivers: [3]

Raspberry pi4 controls motors that move the end-effector to the weed position, this control action is based on the data that is received from the detection camera. In the coding process, we start by setting the input and output signal pins, then we define the functions to move the steppers by steps per angle required, then we define functions to move the steppers by the angles required, then we define the function to move the three steppers concurrently by using threading module, and finally, we define the function to move the steppers in the CW direction (upward) until it hits the limit switches.

Step (4): Integration of the Three Steps Through the Following: [3]

1. Detecting weeds and their position by using the camera.
2. Transferring data and its position to raspberry pi4.

3. Controlling and moving motors to the position of weeds.
4. Turning on the pump and spray weeds with the herbicide.
5. Returning the delta robot to the home position.
6. Returning this cycle.

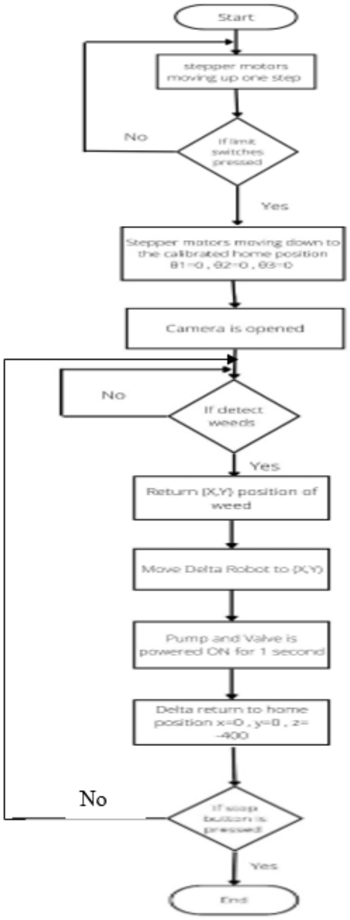


Fig 11: Integration of the Three Steps Algorithm

IV. CONCLUSION

- Weeding is one of the most important practices because weeds compete with the main crop for different factors such as water, sunlight, nutrients, and space and hence affect plant growth. The most common method used for removing weeds is through mass spraying of herbicides; however, herbicides can cause deleterious effects on organisms and human health if used heavily.
- Our AgriBot's essence is harnessing technology for both the environment and human wellbeing. The robot has the unique ability to distinguish the slightest differences between the crops and weeds, then it targets the latter with the help of a nozzle that is both accurate and precise..
- The robot offers a completely autonomous process using a built-in camera, using computer vision technology. Also, our solar-powered AgriBot can operate for longer times and improve sustainability. Moreover, it is designed to follow crop rows and detect the presence of weeds in and between the rows, then it targets each individual weed with a micro-dose of herbicides. This will help reduce costs and preserve human health.
- When coming to the mechanical part of the solution, we made integration between two robots one is the mobile and the other is the delta robot. Chassis is made of steel and wood so we can reduce its weight as much as possible. And for maintaining the robot's stability, we chose the suspension system to be a rocker-bogie mechanism to fit the rough agricultural land.
- Due to the proposed solution, suitable electrical components were chosen to achieve the criteria we aimed for in our robot. Such as motors that help both robots (delta and mobile) to move smoothly, in addition to solar panels to make it sustainable and reduce the consumed power, and raspberry pi so we can upload our codes and algorithms through it.
- Our software is divided into two main parts the mobile robot and the delta robot. To control the mobile robot' s motion we used the algorithms with computer vision and image processing, and motor drivers. For delta robot control algorithms for weeds detection, inverse kinematics of delta, and motor drivers are used.
- During the testing process, we faced a major issue which was that whenever we tried making the robot rotate around itself or take a circular path, a twist occurred in the links connecting the rocker bogie mechanism. We solved this issue by using a bearing on the front wheels, in addition to doubling them by using four front wheels.
- As for the delta robot, it was working properly with no major issues; however, the resulting torque was higher than what the robot could handle; hence we decided to add a gearbox with a ratio of 1:3 to make sure that we were in the safe side. This slightly affected the speed of the robot; however, speed is not among the most important aspects of the robot's main function.
- We tested the delta robot by itself. We used green-colored shapes, representing the crops, and red-colored shapes, representing the weeds. The detection process turned out to be successful.
- After that, we tested the delta robot and the mobile robot together. The robot was able to move in the

correct lines, and whenever it detected the weeds with the help of the camera, it would stop momentarily to spray them, then it would continue taking its correct path.

- We estimated the accuracy of the robot to be around 85%

ACKNOWLEDGMENT

First and foremost, we always feel indebted to ALLAH, the most kind and most merciful who enabled us to accomplish this work.

Second, we wish to express our sincerest gratitude and ultimate thanks to our supervisor, Dr. Ghada Hamissa for her enthusiasm, patience, insightful comments, practical advice, and unceasing ideas that have helped us tremendously in our research, planning, and implementation of this project.

REFERENCES

[1] Jayaraj, R., Megha, P., & Sreedev, P. (2016). Organochlorine pesticides, their toxic effects on living organisms and their fate in the environment. Interdisciplinary toxicology, 9(3-4), 90-100.
[2] Nicholls, P., & Green, R.. (2016). Detecting Tramways in Crops for Robot Navigation, University of Canterbury, New Zealand.
[3] Correa Farias, C., Valero Ubierna, C., & Barreiro Elorza, P. (2011). Row Crop's Identication Through Hough Transform using Images Segmented by Robust Fuzzy Possibilistic C-Means.
[4] Robot, A. F. D. The Delta Parallel Robot: Kinematics Solutions Robert L. Williams II, Ph. D., williar4@ ohio. edu Mechanical Engineering, Ohio University, October 2016.