

DESIGN OF SMART WEED REMOVAL ROBOT**Dr. Narmada Alaparathi¹****Jyoti Kushwaha², V Lakshmi Priya³**^{1,2,3} Department of Electronics and Communication Engineering

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Abstract—For crops to provide a high yield, weeds constitute a risk. Herbicides were uniformly sprayed throughout the entire field or manually pulled out of the way to remove weeds. As observed, herbicides application causes numerous health problems in addition to contaminating crops. To address these problems and keep farmers competitive, modern technologies must be used. The use of herbicides in the field is to be minimized, and a robot design that attempts to deliver cost, time, and fuel economies is presented. Autonomous robotic weeding systems for precision farming have shown to be entirely capable of eliminating the reliance on agrochemicals like pesticides and herbicides currently in use, hence reducing environmental pollution and boosting sustainability. The aim of this paper is to develop and use an AI-powered robot that can classify crops(desired plants) and weeds in real-time and pluck the undesired weed plant from the dry land soil. With a prediction accuracy of 50% approximately, the algorithm first performs a leaf, stem, color or weed flower detection scan of the targeted region before classifying it as crop or weed. If it is determined that the categorized image is a weed, the coordinates are discovered, and the robotic arm pulls it out using a electric gripper without damaging the environment or the useful crops. We have selected a plot of land measuring 100 square meters for this project as a proof-of-concept for the weed removal. The created autonomous robot is further employed to weed dry farmlands.

Keywords: Farmlands, Eradicate, Robotics, Autonomous, Agrochemicals, Sustainability.

I. INTRODUCTION

Agriculture is a crucial part of India's economy, with more than 70% of the country's economy depending on it. The yield obtained in the fields directly affects the income source for more than half of the population. Farmers face various challenges throughout the crop-generation process, with weeds being one of the biggest threats to the environment. They destroy natural habitats and the targeted crop, resulting in reduced crop productivity and increased economic difficulties. To increase crop output, farmers must effectively remove weeds from crop fields. Weed removal can be done through two conventional methods: manual plucking and plowing the land. In traditional weed control methods, herbicides are uniformly sprayed across the field. However, this method is highly inefficient as only 20% of the spray reaches the plant and less than 1% of the chemical actually helps control weeds. This results in waste, environmental pollution, and health issues for humans.

To overcome the limitations of the existing weed removal technique we have designed a commercial robot with the following objectives:

- 1) To eradicate the undesired plants from farmlands using robotics technology and deep learning powered approaches.



- 2) The designed robot is used for weed removal process especially in dry farmlands.
- 3) To increase the national economy to large extent by rapidly increasing the agricultural productivity of commercial crops (cotton, cashew nuts, etc.).

II. LITERATURE SURVEY

A. “Automated Computer Vision based Weed Removal Bot” 2021 [14]

The authors suggest a mobile system that can find and remove weeds in real-time using a robotic arm. The system first recognizes leaves in a specific area and classifies them as weeds or crops with 99.5% accuracy. If a weed is found, the system locates it and uses a high-speed blade to eliminate it without harming the crops or the environment. The robot has four modules: an image processing module, a weed detection and segmentation module, a servo control module, and a stepper control module. The image processing module processes images taken by a Raspberry Pi camera using the OpenCV 3.4.4 library.

B. “Development and evaluation of a low-cost delta robot system for weed control applications in organic farming” 2019 [4]

Stephan Hussmann, Florian J. Knoll to secure the food supply for future generations it is necessary to increase the automation level in agriculture significantly. One particular problem especially in organic farming is the weeding process. The weeding process is usually performed by human workers. However, this manual weeding is very costly and uneven. Therefore, an automated solution should replace the manual weeding. Generally, a weed control robot system consists of a weed identification and a weed removal unit.

C. “Plant Identification Using Leaf Images”, 2015 [12]

The propose of this paper is to create a system that can identify plants automatically using computer. They use leaf as the organ to get the plant features. They calculate five geometrical parameters using image processing techniques. They also extract six basic morphological features and one vein feature from the leaf. They scan the leaf images and use the features to classify them. They test the algorithm on 92 images of 12 plants. The method is effective, fast and independent of leaf maturity.

D. “Very Deep Convolutional Networks for Large-Scale Image Recognition”, 2014 [11]

In this paper we study how the depth of convolutional networks affects their performance in large-scale image recognition. Our main contribution is a comprehensive evaluation of deeper networks, which shows that we can achieve a significant improvement over the previous state-of-the-art by increasing the depth to 16-19 layers of weights. We used these results to submit our entry to the ImageNet Challenge 2014, where our team won the first and the second places in the localization and classification tasks respectively.

III. EXISTING SYSTEM

A good weed management method is needed to avoid these effects. The main goal of sustainable farming is to increase production while reducing the use of pesticides, herbicides, and weed spread. This problem requires the use of precision farming techniques, and many researchers are working on it to find a feasible solution. AgriBot has made it possible to communicate while doing different agricultural tasks using WiFi technology [2]. Some examples of automation for mechanical weed control are the field robot BoniRob [3] that uses high-speed vision to control weeds and the low-cost delta robot [4] that controls weeds in organic farms. Manual weeding is a difficult task to perform. Modern robots help to improve production. One example is the Oz Weeding Robot, which helps with weeding and hoeing tasks to enhance agricultural profitability and protect the environment [5]. Instead of spraying or cutting weeds, it would be better to



remove or uproot them. A mobile system that could use real-time data to locate the leaf position coordinates with computer vision and help to eliminate weeds with a robotic arm would be more effective and less damaging to the environment.

IV. PROPOSED SYSTEM

A. METHODOLOGY

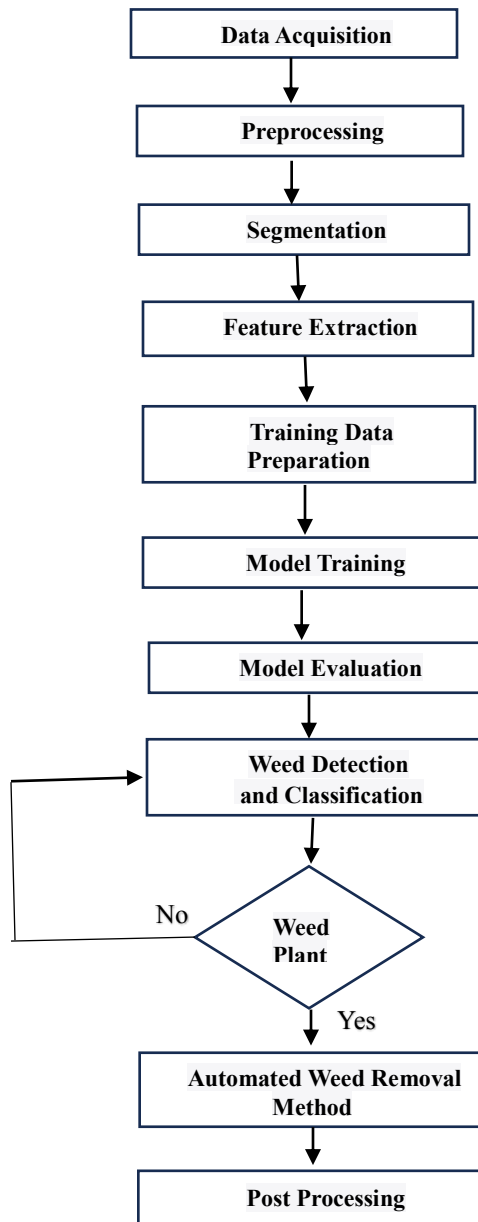


Fig. 1. Process Flow of Weed Removal Robot



Data Acquisition: Obtain images or sensor data of the agricultural field or area where weed detection is required. This can be done using various methods such as robotic platforms equipped with cameras.

Preprocessing: Clean and preprocess the acquired data to enhance the quality and remove any noise or artifacts. This may involve techniques like image enhancement, noise reduction, and calibration.

Segmentation: Segmentation is used for weed detection and removal. The model can detect and segment the weeds from the crop images with an accuracy of up to 85%. These coordinates are then used to control the robotic arm and the delta arm that can pluck out the weeds from the soil.

Feature Extraction: Extract relevant features from the preprocessed data that can differentiate weeds from other objects in the image. These features can include color, texture, shape, size, or spectral information.

Training Data Preparation: Prepare a labeled dataset for training the weed detection and classification model. This involves annotating the acquired data by manually identifying and labeling the weeds present in the images. The dataset should contain a sufficient number of examples to represent different weed species and variations in appearance.

Model Training: Use machine learning or deep learning techniques to train a model using the labeled dataset. Common approaches include convolutional neural networks. The model learns to recognize and classify weeds based on the extracted features from the training data.

Model Evaluation: Evaluate the trained model's performance using evaluation metrics such as accuracy, precision, recall, or F1-score. This step helps measure how well the model can identify and classify weeds correctly.

Weed Detection and Classification: Apply the trained model to new, unseen data to detect and classify weeds. The model processes the features of the input data and predicts the presence or absence of weeds and their respective classes.

Automated Weed Removal Method: The robot moves the robotic arm and the gripper to the position of the weed using a stepper motor and a servo motor. It grasps the weed with the gripper and pulls it out of the soil with its roots. It repeats the process until all weeds are removed or the battery is low.

Post-processing: Apply any necessary post-processing techniques to refine the results or remove false detections. This may involve filtering based on size, shape, or spatial constraints.

B. BLOCK DIAGRAM

Camera: The camera is used to capture images of the crop field and send them to the image processing module. The camera can be mounted on the robot or on a drone that flies over the field. The camera should have a high resolution and a wide angle of view to cover a large area of the field.

Image Processing: The image processing module is used to preprocess the images captured by the camera and prepare them for the weed detection and segmentation module. The image processing module can perform tasks such as noise reduction, contrast enhancement, color correction, edge detection, and feature extraction.

Weed Detection and Segmentation: The weed detection and segmentation module is used to identify and locate the weeds in the images using artificial intelligence techniques such as deep learning and computer vision. The weed detection and segmentation module can use a pre-trained neural network model such as Faster R-CNN to classify and localize the weeds in the images. The weed detection and segmentation module can also estimate the stem position of the weeds based on the bounding box coordinates of the weeds.

Servo Control: The servo control module is used to control the servo motors that drive the robotic arm. The servo control module receives the weed location and stem position information from the weed



detection and segmentation module and calculates the appropriate angles and speeds for the servo motors to move the robotic arm to the desired position.

Stepper Control: The stepper control module is used to control the stepper motors that drive the wheels. The stepper control module receives the navigation commands from the robot navigation module and calculates the appropriate steps and directions for the stepper motors to move the wheels to the desired direction.

Robotic Arm: The robotic arm is used to remove the weeds from the field using a mechanical tool such as a claw or a cutter. The robotic arm has seven degrees of freedom (DOF) and can move in three directions: up-down, left-right, and forward-backward. The robotic arm can also rotate around its base to reach different areas of the field.

Pick and Place Gripper: A pick and place gripper for weed removal is a tool that can help you remove weeds from your garden or lawn without bending over or using chemicals. It works by gripping the weed with metal claws and pulling it out of the ground with its roots. Gripper finger blanks are attachments that are mounted to robotic arm or a pneumatic gripper to create custom fingers for picking and placing weeds. They come in different shapes and sizes and can be machined to fit your specific needs.

Weed Removal: The weed removal module is used to perform the actual task of removing the weeds from the field using the robotic arm. The weed removal module can use different methods such as cutting, pulling, or burning to remove the weeds depending on the type and size of the weeds.

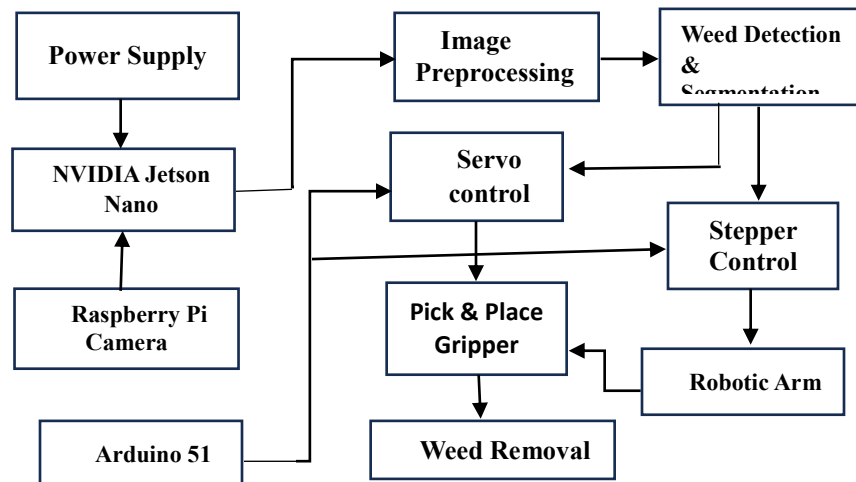


Fig. 2. Block Diagram

C. DESIGN APPROACH

i. Windows Subsystem for Linux (WSL)

Windows Subsystem for Linux (WSL) is a feature that lets you run a Linux distribution (such as Ubuntu, OpenSUSE, Kali, Debian, Arch Linux, etc) and use Linux applications, utilities, and Bash command-line tools directly on Windows. Ubuntu 20.04.6 LTS is one of the Linux distributions that you can install on WSL. It gives you access to a full Ubuntu terminal environment with efficient command line utilities including bash, ssh, git, apt, npm, pip and many more. Various cross-platform applications are developed, improves data science or web development workflows and manages IT infrastructure without leaving Windows.

ii. ROS Noetic

ROS is a software framework designed for building robot applications. It offers a collection of tools, libraries, and standards that make it easier to develop sophisticated and reliable robot behaviors on many different robot platforms.

ROS was first released in 2007 and has since become one of the most popular and widely used platforms for robotics research and development.

The use of ROS Noetic for weed detection and removal robot is to provide a framework for programming robots that can autonomously identify and eliminate weeds from crop fields using artificial intelligence and mechanical methods. ROS Noetic offers various advantages such as compatibility with Ubuntu 20.04, support for Python 3, and improvements in performance and stability.

This paper uses a robotics arm-based weed removal mechanism and a RPi camera with AI interface for weed detection. The whole robot modules are natively built on ROS, which is the generation of ROS that offers more features such as real-time capabilities, security, and modularity.

It uses a deep learning model based on Faster RCNN for weed detection and with a pick and place gripper for weed removal. The robot also uses a RPi camera for processing the images. The robot is controlled by ROS Noetic using the Robotics Operating System (ROS) framework, which allows for easy integration of different components and modules.

iii. 3D Model in RViz

3D modelling of seven dof arm in rviz is a process of creating and visualizing a 3D model of a seven degrees of freedom (dof) robotic arm in rviz, which is a 3D visualization tool for ROS (Robot Operating System).

RViz is a 3D visualization tool for robots, sensors, and algorithms that allows you to see the robot's view of its environment, whether real or simulated. Its main function is to help you visualize the robot's state.

RViz is a part of ROS (Robot Operating System), which is a framework for developing and running robotics applications. RViz can display the robot model, sensor data, and other information from ROS topics and services. RViz can also interact with the robot using interactive markers.

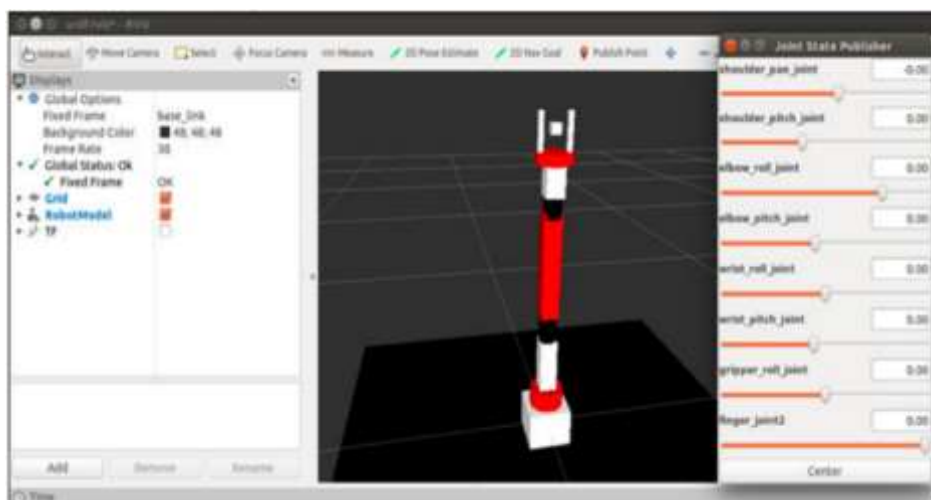


Fig. 3. Seven-DOF arm visualization in RViz

iv. Gazebo Simulation of Smart Robot

Gazebo simulator is a 3D dynamic simulator that can simulate populations of robots in complex indoor and outdoor environments with high accuracy and efficiency. The latest major release of Gazebo is version 11, which is a long-term support release with end-of-life planned for January 2025.

Gazebo simulation of pick and place weed removal robot is a process of using Gazebo to create a virtual environment where a robot can perform the task of picking up weeds from a field and placing them in a bin. This can be useful for testing and developing the robot's hardware and software before deploying it in the real world.



Fig. 4. Gazebo Simulation of seven DOF arm

v. Spyder For Deep Learning

Spyder can be used to develop and run deep learning models for various applications, such as weed detection from images.

Spyder has been used for deep learning training of crop and weed images for weed detection. Dataset of labeled images of crops and weeds, a deep learning framework like TensorFlow or PyTorch, and a suitable convolutional neural network (CNN) architecture are required to train the model.

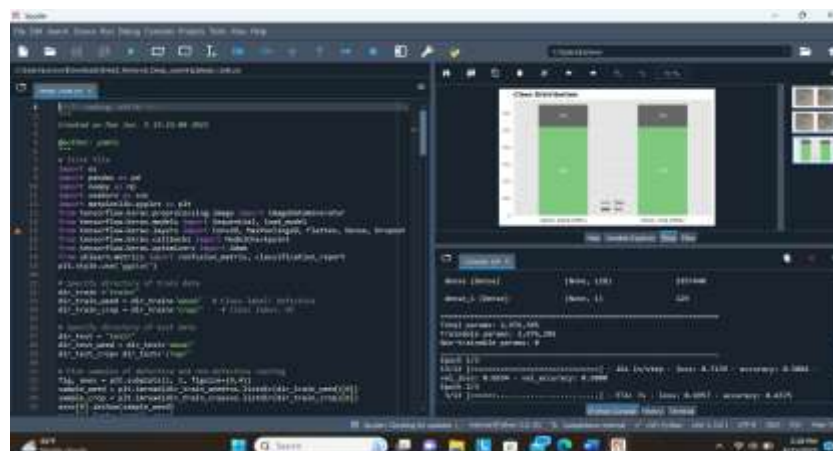


Fig. 5. Training crop and weed images for weed detection using Spyder



vi. TensorFlow & Keras

In robot, TensorFlow and Keras are used for developing the artificial intelligence model that can detect and segment the weeds from the crop images. The model is based on Faster R-CNN, which performs both object detection and instance segmentation. The model is trained on a custom dataset of crop and weed images using Keras API and TensorFlow backend. The model is then deployed on the Jetson Nano Dev Kit, which is a small and powerful device that can run TensorFlow and Keras applications. The model can process the images captured by the RPi camera and send the weed coordinates to the robotic arm for removal.

vii. OpenCV 3.4.4

OpenCV 3.4.4 is a library of programming functions that can be used for computer vision and machine learning applications. OpenCV 3.4.4 can run on the Jetson Nano Dev Kit and communicate with the Keras and TensorFlow framework for weed detection and segmentation using artificial intelligence.

This robot is an autonomous weed removal robot that uses a delta arm based mechanical tool to pluck and drop the weeds using a pneumatic cylinder. It uses OpenCV 3.4.4 to preprocess the images captured by a Raspberry Pi camera and perform tasks such as noise reduction, contrast enhancement, edge detection, and feature extraction.

viii. NVIDIA Jetson Nano

The NVIDIA Jetson Nano is a compact and low-power device capable of running multiple neural networks in parallel for applications such as weed removal robots. It has various interfaces and ports, such as USB, HDMI, Ethernet, GPIO, CSI, etc. NVIDIA Jetson Nano can be used for deployment of weed removal robot because it can perform fast and efficient deep learning inference on images captured by the robot's camera to detect and classify weeds from crops. It can also integrate with ROS (Robot Operating System) to control the robot's motion, navigation, and weed removal mechanism. NVIDIA Jetson Nano can be powered by a battery or a DC power supply, and it can operate in two modes: 5W and 10W. The 5W mode is suitable for battery-powered applications that require low power consumption, while the 10W mode is suitable for applications that require higher performance.



Fig. 6. NVIDIA Jetson Nano Development Kit



D. MECHANICAL DESIGN

i. Raspberry pi camera

A raspberry pi camera is a device that can capture images of the crop field and send them to the Jetson Nano for weed detection and segmentation. The raspberry pi camera is mounted on the robotic arm and connected to the raspberry pi board.

A raspberry pi camera is useful for providing visual feedback and information for the weed removal process. A raspberry pi camera can help the robot to locate and identify weeds from crops using machine vision and artificial intelligence. A raspberry pi camera can also help the robot to adjust the position and angle of the gripper according to the crop height and width. A raspberry pi camera can also enable remote monitoring and control of the robot using a web interface or a VNC viewer.



Fig. 7. RPi camera

ii. Stepper Motor

A stepper motor is a type of motor that can rotate in discrete steps or angles with high precision and accuracy. A stepper motor consists of a rotor, a stator, and a control circuit. The rotor has permanent magnets and the stator has electromagnets. The control circuit switches the current to the electromagnets in a specific sequence to make the rotor align with the magnetic field and rotate.

In robot, three stepper motors are used to control the movement of the delta arm that supports the robotic arm. The stepper motors are connected to stepper drivers that receive commands from the Jetson Nano Dev Kit via an Arduino 51 microcontroller. The commands specify the speed and direction of the stepper motors based on the position of the weeds detected by the AI model. The stepper motors then rotate the delta arm accordingly and move the robotic arm to the desired location.



Fig. 8. Stepper Motor

iii. Stepper Driver

A stepper driver in this robot is a device that can control the speed, direction and position of the stepper motors that are used to move the robotic arm and the gripper. A stepper driver can receive signals from the Arduino Mega board and send pulses to the stepper motors. A stepper driver can also regulate the current and voltage of the stepper motors to prevent overheating and damage. A stepper driver can be a separate module or integrated with the stepper motor.

A stepper driver is useful for providing precise and smooth motion control for the weed removal process. A stepper driver can help the robot to move the robotic arm and the gripper to the position of the weed using a stepper motor and a servo motor. A stepper driver can also help the robot to adjust the speed and torque of the stepper motors according to the load and resistance. A stepper driver can also enable remote monitoring and tuning of the stepper motors using ROS2 and Python.

iv. Servomotor

A servo motor is a motor that can rotate to a specific angle or position with high precision and accuracy. It is made up of a motor, a gearbox, a potentiometer, and a control circuit. The potentiometer measures the angle of the motor shaft and provides feedback to the control circuit, which compares the feedback signal with the desired angle or position and adjusts the power supply to the motor accordingly.

In this robot, a servo motor is used to control the robotic arm that can pluck out the weeds from the soil. The servo motor receives commands from the Jetson Nano Dev Kit via an Arduino 51 microcontroller. The commands specify the angle or position of the robotic arm based on the weed coordinates detected by the AI model. The servo motor then rotates the robotic arm accordingly and activates a solenoid valve to release compressed air for weed removal.

v. Pick and Place Gripper

A pick and place gripper for weed removal robot is a tool that can help the robot to grasp and pull-out weeds from the crop fields using pneumatic or hydraulic power. A pick and place gripper for weed removal robot can have different designs and shapes, such as two-finger, three-finger, four-finger, claw-like, etc. A pick and place gripper for weed removal robot can be mounted on a robotic arm that can move and rotate in different directions and angles. A pick and place gripper for weed removal robot can work in conjunction with a camera or a sensor that can detect and locate weeds in the field. It can improve the efficiency and accuracy of weed removal, reduce the use of herbicides and labor, and increase the crop yield and quality. A pick and place 3 finger gripper is useful for gripping a wide range of objects with different sizes, shapes and orientations. A pick and place 3 finger gripper can provide a strong, stable and precise grip for both form fit (inside the object) or friction fit (external) gripping. A pick and place 3 finger gripper can also adapt to the object geometry by adjusting the finger position and angle



Fig. 9. Three finger Pick and Place Gripper

vi. Arduino 51

Arduino 51 is a microcontroller board based on the ATmega51 chip. It is used for various projects that require digital and analog inputs and outputs, such as sensors, motors, LEDs, etc. Arduino 51 is programmed using the Arduino IDE or other compatible software.

Arduino 51 is used in this weed removal robot as a microcontroller for controlling the servo motors and stepper motors that drive the robot arm and base. This AI-based weed removal robot that uses ROS 2, it also uses an Arduino51 as a microcontroller for this purpose. Arduino Mega could be used as an alternative or a replacement for Arduino 51, as it has similar features and specifications



Fig. 10. Arduino 51

V. PROJECT MODEL



Fig. 11. Project Model

VI. RESULT

This paper uses Faster R-CNN to detect and segment weeds from crops. The robot has a robotic arm with a gripper that can pull out weeds from the soil. The robot is built on ROS Noetic and can run for up to 10 hours on battery. The image's background was removed, and the plant leaves and stems were categorized. The robot used a fast pick and place electric gripper to remove the categorized leaf along with

stem from the soil if it belonged to the weed family. It can also work for long hours and in various weather conditions. The results of the training of weed and crop images are displayed in the figures below.

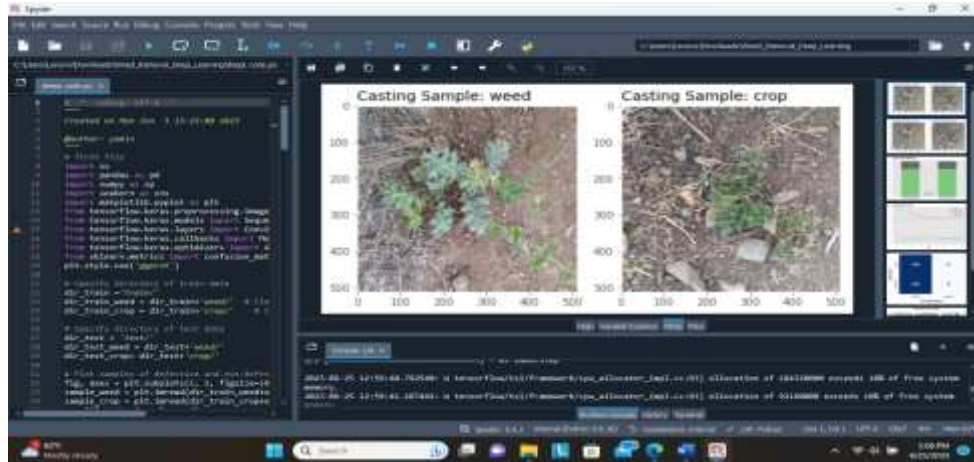


Fig. 12. Casting Samples of Crop and Weed

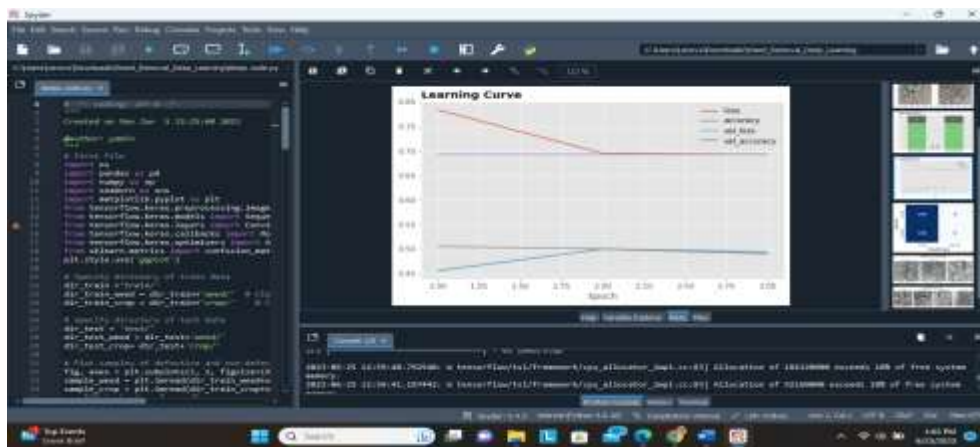


Fig. 13. Deep Learning Training Learning Curve

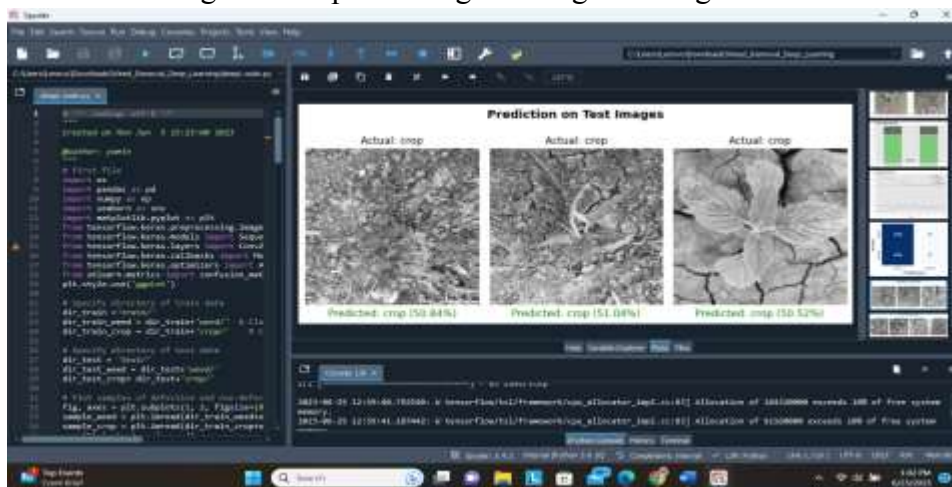


Fig. 14. Prediction of Test Images

VII. COMPARISON TABLE

Parameter	“Automated Computer Vision based Weed Removal Bot” Values	“Design of Weed Removal Robot” Values
Weed Detection Accuracy	89%	50 %
Weed Removal Speed	Not Specified	1 weed per second
Runtime	Not Specified	8-10 hours
Power Consumption	Not Specified	48V 30ah
Weed Removal Efficiency	72%	80%

Table. 1. Comparison of Automated and Weed Removal Robots

VIII. CONCLUSION

Smart Weed Removal robot is a prototype of an AI-driven, mechanically weed removal robot that can autonomously detect and segment weeds from crops using Faster R-CNN. It is designed to reduce the use of herbicides and labor in agriculture, and to improve the yield and profit of farmers. This robot is built on ROS Noetic and consists of a robotic arm with a gripper, a camera, stepper motor and a servo motors. It can operate for up to 10 hours on battery and has a weed detection accuracy of up to 50%. The method employed to determine the right leaf species produced a weed removal efficiency of 80%, which is superior to the outcomes of the majority of the earlier investigations. The segmentation results have greatly improved thanks to Transfer Learning (TensorFlow) neural network, which has also immediately enhanced classification and regression accuracy. Our method for getting rid of weeds eliminates the need for pesticides, which wasn't guaranteed in any of the preceding systems, by using a high-speed GPU (NVIDIA Jetson Nano) and electric grippers.



IX. FUTURE SCOPE

The Smart Weed Removal robot has the potential to become a part of the swarm farming paradigm, where multiple robots work together to perform different tasks in agriculture, such as spraying, seeding, harvesting and hauling. This can increase the efficiency and sustainability of farming practices and reduce the dependence on human labor and chemical inputs. The robot can also be improved by enhancing its gripper design, arm reach, GPS navigation and wheel steering. These improvements can make the robot more versatile, accurate and autonomous in weed removal. It can also be adapted to different crops and environments by training its AI model on more diverse data sets and using different sensors and cameras. This Smart Weed Removal Robot is an innovative and promising solution for the future of weed management in farming.

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