# AGRICULTURAL ROBOT USING MACHINE LEARNING AND COMPUTER VISION

**Dr. N Saravanan[1], Shrivarshan R[2], Pugalenthi C[3], Tamil Arasan S[4], Sivanesh S[5]**

[1] *Professor, Department of Mechatronics Engineering, K S Rangasamy College of Technology, Tamil Nadu, India.*
[2,3,4,5] *Student, Department of Mechatronics Engineering, K S Rangasamy College of Technology, Tamil Nadu, India.*

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**Abstract -** *Agriculture is the primary source of survival for about 60 percent of India's population. Over 18 percent of India's GDP is contributed by agriculture. But yearly there was about 7-8 percent of farmers quit agriculture. The reason behind this is a low profit, weather, manpower, and many more. No technology has evolved to help farmers. To overcome some of the problems, a robot was designed that is capable of seeding, planting, spraying weedicides & insecticides, and cultivation. The planting operation has a moisture sensor in it to check whether the soil is suitable for planting. The robot is built with an efficient sprayer that can spray as tall as the plant is and another nozzle for spraying insecticides. The weeds and insects are monitored with the help of computer vision and Machine Learning algorithms. The robot also has a robotic arm for picking the products from plants. The robotic arm is controlled with machine learning and computer vision. This robot is equipped with a Magnetometer and Global Positioning System (GPS) module that is capable of receiving GPS coordinates at higher accuracy so that it can maintain its path according to the path provided by the farmer. The robot will be smart in that it monitors the growth of weed and controls it with the help of a cutter at its bottom. Also, the robot is built with IoT capable of sharing the process going on with the farmer. Here the robot has a battery as a power source. It can be both electrically and solar charged. The robot that is designed are suitable for limited vegetable farming. The future work is to build a robot that can work in all crop fields. In the future, the robot will get updates on the mechanisms in the robot based on the performance.*

***Key Words:*** Agricultural Robot, Machine Learning, Computer Vision, GPS, Magnetometer, Planting / Seeding, Weeding, Spraying, Harvesting

## 1.INTRODUCTION

Agriculture can be a field as favourable as an industry for the application of automation. The challenges for robots in the field of agriculture are diverse. On the one hand, agricultural environments, in contrast to industrial facilities, are not structured and cannot be controlled easily. On the other hand, industrial processes can be designed into small modules to apply robotics for specific works, whereas the complex tasks of agricultural activities cannot be split into simpler actions. For the above reasons, agricultural tasks require more versatile and robust robots. In the last years, many researchers around the world have applied different automation solutions (e.g., Sensor networks, manipulators, ground vehicles, and aerial robots) to diverse agricultural tasks (e.g., Planting and harvesting, environmental monitoring, the supply of water and nutrients, and detection and treatment of plagues and diseases. But there were no robots on fields for the applications of seeding, spraying, weeding, and harvesting This paper will discuss the work of designing a robust, multitasking agricultural robot.

## 2. LITERATURE REVIEW

Over history, agriculture is evolving with the modern type of machinery and technology. The use of these technologies and machinery improves the quality of farming, reduces the need for labours, and fulfills the need for skilled agricultural workers. The introduction of new machineries helps farming into a new phase production of agricultural products.

The idea of bringing robotics into agriculture begins in the late '90s, in 1993, the robots that developed are for harvesting melons. Initially, the robots are designed with various configurations and simulated in the laboratory conditions and also with various configurations i.e., Degrees of freedom of the arm, manipulators, etc. [1] In Japan (1996), a harvesting robot was developed for harvesting grapes, cucumber, and tomatoes. This robot has a crawler-type motion capable of cutting and dropping in the basket. It requires human assistance for path guidance and harvesting.[2] In the year 1999, the idea of bringing in geomagnetic and image sensors for vehicle guidance and raw detection.[3]

At the beginning of the 21st century (2000), the use of laser finder, visual sensor, and object detections algorithms are used for recognition fruits /vegetable that needs to be harvested. The output of the vision sensor is in 3d and gives the 3d position of an object.[4] Later in 2009, the robots became brilliant with machine learning algorithms and computer vision techniques. Paths for the robot to more become easier by using GPS and obstacle detection sensors. A robot was designed (2009) for harvesting was developed using the above technique, the results look good. [5],[6],[7],[8]

In 2014, identification techniques have neutral naturals along with computer vision for image segmentation. After segmentation, the fruit target was preserved while most positions are rejected. The experimental results using this technique have a successful percentage of 76%. Apart from harvesting, there were agricultural robots designed for planting, phenotyping, and weed detection using computer vision.[9] In 2010, the robot uses GPS, a 3D MEMS LIDAR sensor, an inertial sensor, WLAN for the detection of rows and controlling the movement of the robot.[10],[11] In 2015, robots are designed is cad software that is capable of planting, spraying, and IoT for controlling the robot. After 2016, IoT plays a crucial role in farming and make farmers smarter, robots were designed with IoT for temperature, humidity monitoring, irrigation management, birds, and animal monitoring, from a remote place. This also suggests the farmer the with its predication to do.[12],[13],[14],[15] From all the experiments and simulations of previous works, the growth for the use of robots in agriculture has steadily increased. But the robots designed till now have an only specific tasks to do for example., only harvesting. There are no robots designed capable of doing all the farming tasks that are not done by tractors. At the same time, these robots have not replaced the requirement of workers on the field.

## 3. System Overview and Architecture

The robot is powered by Raspberry Pi it uses a machine-learning algorithm to harvest fruits and vegetables and it is programmed to do tasks like seeding, weed removal, and pesticide spraying. The robot has an arm and a camera assembled to it, which helps in the picking of fruits/vegetables. The arm has 5 degrees of freedom and a gripper at the end. The robot has a tank, pump, and nozzles for spraying those nutrients, insecticides, and weedicides. It has seed storage and a mechanism to split seeds one by one and seeds at a required distance. To control the growth of weeds on fields it has a set of blades arranged circularly to cut down and maintain its growth on the field. The path is pre-programmed in the robot by using GPS and a magnetometer is used to guide the robot to navigate in the path specified. The robot's activity can be monitored using IoT.

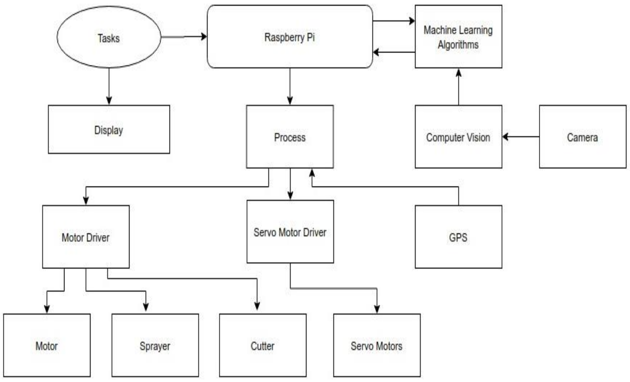


**Fig – 1:** Block diagram of system architecture

### 3.1 Hardware Units

The hardware units consist of the following:

### Raspberry Pi Model 4B

The brain of the robot is going to control all the mechanisms, movements of the robot and make interactions with the farmer. It is a 1.5 GHz 64-bit quad-core ARM Cortex-A72 processor, on-board 802.11ac Wi-Fi, Bluetooth 5, two USB 2.0 ports, and USB 3.0 ports. The Pi 4 is also powered via a USB-C port, enabling additional power to be provided to downstream peripherals.

### Pi Camera

It is a 5 Megapixel camera to record and process live information from the field and control mechanism accordingly.

### Servo motor

The servo motors are the motors that move at great precision. This has a potentiometer as feedback for knowing the exact position of where it is. The servo motors are used for controlling arm and other applications.

### Global Positioning System (GPS) NEO- 6M

The GPS is used to detect the exact location using the values of latitude and longitude values from the satellite. This GPS helps in guiding the robot through its pre-programmed paths.

### Motor driver

The motor driver used here is IC L293D for controlling motors. Since the microcontroller cannot current that is needed for running motors.

### Servo Driver

Similarly, for servo’s a 12-bit, 16-channel servo driver is used. It communicates serially with a microcontroller capable of controlling sixteen servo motors.

### 16x2 LCD and Matrix keyboard

These LCD and Matrix keyboard are used for communicating with the farmer. And the farmer can also give some instructions to the robot.

### 12 V Lead Acid Battery

A 12V lead-acid battery is the primary source of electrical energy for the robot. A 12V, 7Ah battery has been used.

### Solar Panel

Solar radiation is high in the fields so the use of solar panels helps in charging the battery and running the robot in the day time. A 12V, 10W solar panel has been used.

## 3.2 Software Units and Libraries

The software units and libraries consist of the following:

### Operating System

Ubuntu Linux is an operating system that runs on Raspberry Pi for programming and controlling processes.

### Machine learning

In machine learning, the neural network is trained using various images of the object. The training set consists of a 70% dataset and the test consists of a 30% dataset.

### YOLO

YOLO (You only look once) is used for object detection and localization at good frame rates.

### OpenCV

It is an open-source computer vision library used for object detection.

### LabelImg

It is used to draw a bounding box over the objects in the image for localization.

## 4. EXPERIMENTATION

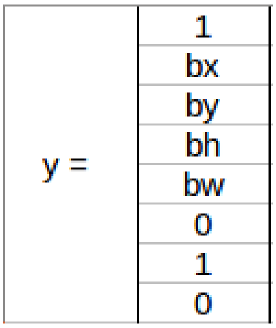
The experimental setup of this has three parts. The first and important part of this project is to train the machine (Machine Learning) with a set of various images to get an acceptable range of accuracy and precision. Also programming GPIO for controlling the robot. The second most important step is to create the Computer Aided Drawing (CAD) model of the robot and to print the models with additive manufacturing technique. The additive manufacturing technique used here is Fused Deposition Modelling (FDM). Then the last step is to assemble printed components with hardware units and calibrate the machine for final use.

## 4.1 TRAINING THE MACHINE

Machine learning is a subset of AI techniques that uses a static method to enable machines to improve with experience. IN this project the machine learning is used to detect fruits and vegetables.

For object detection and localization using a machine learning algorithm Initially multiple images of the particular object to be detected are collected then a bounding box is drawn at that image. After collecting all images, the images are split in the ratio of 70% for train and 30% for test. for training images, the Yolo algorithm is used.

YOLO first takes an input image. then the framework divides the input image into grids (say 3 X 3 grid). Image classifications and localization are applied on each grid. YOLO then predicts the bounding boxes and their corresponding class probabilities for objects that need to pass the labeled data to the model to train it. The image is divided into a grid of size 3 X 3 and there is a total of 1 class which the objects to be classified and localized into. Let's say the class is tomato. So, for each grid cell, the label y will be an eight-dimensional vector.



| | |
|---|---|
| y = | 1 |
| | bx |
| | by |
| | bh |
| | bw |
| | 0 |
| | 1 |
| | 0 |

**Fig – 2:** Final layer of neural network for a single class

Here,

- (pc)- defines whether an object is present in the grid or not.
- (bx, by, bh, be)- specify the bounding box if there is an object
- (c1, c2, c3)- represent the classes. So, if the object is a tomato, c2 will be 1 and c1 & c3 will be 0, and so on

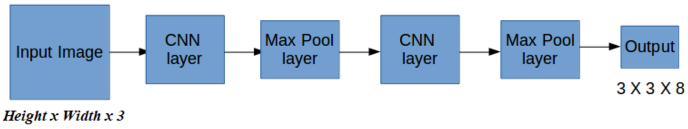


**Fig – 3:** figure showing convolutional neural networks

In a single convolutional neural network, it predicts multiple bounding boxes and class probabilities simultaneously for those boxes. The YOLO algorithm trains on full images and directly optimizes detection performance. This unified model has several benefits over the traditional method of object detection. First, YOLO is extremely fast.

The training of the image may take more time depending upon the compute capabilities. If the compute capability is more than the training time will be less. If the compute capability is less then it will take more time. For the training purpose, Nvidia's Cuda library is used. Which will boost up the speed of training as compared to the CPU (central processing unit).

It is ensured that the training should not be overfitting or underfitting. After training, image weights generated for the prediction of the object is collected.

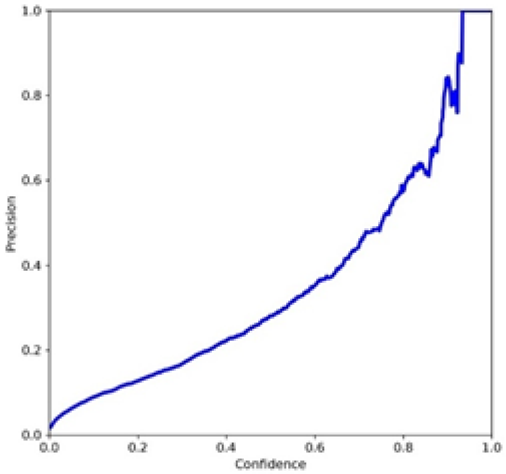


**Chart – 1:** Chart showing precision by confidence ratio.

The above image is the graph of precision to the confidence. The greater the value of precision and confidence better the image predicted and the Accuracy is high. and the predicted image Has a higher probability towards that class.

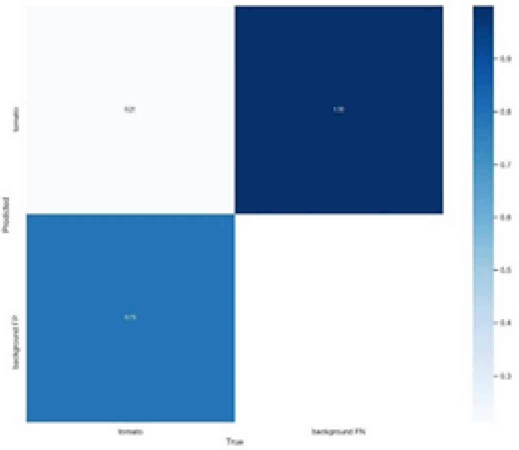


**Fig – 4:** Confusion Matrix of the model

A confusion matrix is a table that is often used to describe the performance of a classification model (or "classifier") on a set of test data for which the true values are known. The confusion matrix itself is relatively simple to understand, but its related terminology can be bit confusing.

**Fig – 5:** Figure showing Training Results

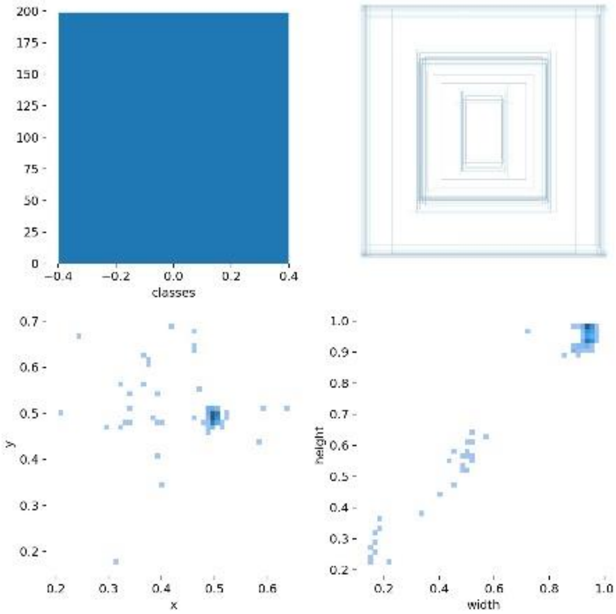


**Fig – 6:** Bounding box prediction

The above image is the overall bounding box prediction for all the images trained. The region of interest for the object is calculated in the captured image, which is used in the rotation of the robot in the direction towards the object the region of interest concerning the image is calculated in a ratio that will determine the robotic arm movement towards the object.

## 4.2 Preparing of CAD model

- Prototypic dimensions of the robot were planned and dimensions of other components that are used in this project were measured.
- From the dimensions, CAD models were prepared, assembled and their motions are simulated using Creo Parametric 5.
- Then the designed components are tested with various load parameters using ANSYS Workbench.

- Then the CAD files are saved and converted to .stl format for getting better support with FDM (Fused Deposition Modelling) software.

## 4.3 FDM and Assembling of Components

- Parts designed with Creo are converted to .stl format.
- The software that is used here for slicing and FDM is Ultimaker's Cura 4.8.
- The parts are finely sliced and supports are generated for overhanging parts using software Cura.
- The parts are successfully printed by transferring G and M-codes to the FDM machine.
- Once the parts are ready the robot is assembled.

## 4.4 Experimentation

Once assembly is done, the robot is installed with a computing device, camera, servomotors, and other remaining components the code programmed is run to check for the working of the robot. This robot works on the pre-programmed field, GPS and Magnetometer is using to go through the path. Seeding and spraying tasks follow these same paths for doing it. For weeding whenever the robot goes through the path it tracks the growth of the weed and once the weed grows over the limit, the cutters will be turned ON. The harvesting operation is completely depending on the camera. The camera is used for surveillance of field and harvesting using ML algorithms. Once the image of the plant is captured, the computing module will look for selective product and through ROI the arm with the help of servos reaches the object, picks it, and drops it in the object. If the farmer wants the robot to do surveillance activity then the robot with the help camera, surveillance the field also sends the live video of the field.

## 5. Results

The results of the robot were discussed, based on the machine trained i.e., results of doing machine learning for the specific work and complete work as a robot on the laboratory and field conditions.

In the machine learning section, the images of the object were trained for more than 8 days using Nvidia's 940 MX GPU (Graphical Process Unit), YOLO algorithms, PyTorch, OpenCV, labelImg, and python3. Initially the image processing, image cleaning took more time than the training part. during training the machine learning model was overfitting, to solve this some of the images were removed, and new images were added. And while training 1000 iterations. The weights of the training model are saved After every 100th of iteration. The training should be carried out until the precision and confidence level of the training model increases The Precision and confidence level should be greater than 70%. After training for more than 4000 iterations the accuracy was 76% this can be increased by adding more images from different scenarios the images used here is in the range of 600. if the images are given where more than 10,000 then the accuracy will increase by More than 76%. For testing purposes ripen tomato is placed in front of the camera to test its accuracy It predicted a maximum of 94.65% And wrong predictions were less. Finally, the data are saved for future validation purposes.

Considering the results of robot assembly and Fieldwork, the assembly robot looks robust and aesthetic looking as it was developed through the FDM process since it is a prototype and the scale factor was not the same as planned. The results of doing mentioned tasks in the field like laboratory conditions were good than expected. The robot follows the path pretty well with help of GPS and magnetometer but still has some small deviations in the path. The robot was instructed to plant seeds in the programmed path with seed – seed distance of 1.5m. The seeding mechanism places the seed at specified intervals as programmed. The pump was powerful enough to convert given liquid content to spray on plants and the weeding mechanism does well. In the test area, 10 pseudo-plants with tomatoes hanging around them. Total of 30 tomatoes placed the robot manages to get around 21 tomatoes. Though the computing power of Raspberry pi was not great as processors used in PCs, the Raspberry pi powered robot takes some time (few more seconds than PC) in detecting the object. Once the object gets detected, the arm moves towards the object, picks, and drops in the specified area.

## 6. Conclusions

Automation and autonomous features are very essential in today's agricultural activities. As one can't always concentrate on one job and need for more labours, for them this kind of technology is very useful. In this paper, machine learning algorithms and different technologies are used to automate the work. The works are split into tasks. The tasks are performed according to the choice.

The computation power of the Raspberry Pi is very low as compared to the modern Personal Computers. So, the Frame rate at which its processes are very low. It took more than 70 seconds for a single raw image to process. For this reason, PC can be used as a server for processing the algorithms and balance the workload.

The robot is tested under several laboratory conditions, there was a minor deviation in the results but these can be resolved by training with huge datasets and increasing the computation power.

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