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Design of Agricultural Robot for Fruit Picking and Tuning

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Abstract: ***There are mainly five steps in agriculture that are plowing, seeding, watering, tuning, harvesting. In this project, we are going to mainly focus on Boring, where a robot with the help of the drilling tool attached at its rear side will be used to remove the soil for the plantation. Secondly comes plantation, here the person will carry out plantation at desired places. Then comes the maintenance of the crop in which the amount of watering, sunlight, pesticide, fertilizer required for the healthy growth of the plant is controlled by the robot with help of electronic circuits present inside a robot. Then we focus on tuning operation, this module will be taken care of by cutters attached to the robot. Finally, fruit picking operation is done by a three-hand jaw attached to a robot which will be used to pick the fruits. Another additional module is a sample of soil that will be taken and processed with different chemicals and give us output as deficient nutrients in the soil and fertilizers to be added to make soil fertile land and suitable atmospheric conditions for the crop***

Keywords ***:Agricultural robot, modelling.***

I. INTRODUCTION

India's inorganic and organic resources, food, GDP and economic stability is highly dependent on agricultural sector. Even now about 68% of population of rural areas still depend on agricultural for their livelihood. Augmented productivity in agricultural sector contributes to financial elevation, employment generation and accomplishment of upper rates of economic process. Hence it has become more important for development of agricultural sector after independence. Agriculture, that accounted for quite thirty per cent of total gross domestic product within the starting of reforms didn't maintain its pre-reform growth or keep up with growth within the non-agricultural sector.

We can have good productivity in agricultural sector by adopting SMART or PRECISON agriculture. Here farmer is able to have higher yield with minimum usage of resources like seeds, water and fertilizers.

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Farmers will adopt crop of smaller size and more in number for a particular area thereby saving land and environment. Once farmers are prepared to map their crop areas correctly, planting, maintenance, weed treatments and harvesting are tracked and controlled with the help of sensors and end effector module attached to the robot. In this project we are mainly focusing on Rowbots i.e. agricultural robots for small scale farming and small crops. These Rowbots can check the crop growing capacity of land, boring operation, plant the seed, check plant condition, tuning of crops and fruit picking operation. The Rowbot can fit in between crop rows, without compacting soil. General function of robots in agriculture are replacing labor and jobs and getting rid of heavy, dangerous, or monotonous operations, to raise the product's market value by producing homogeneous products and to make conditions of hygienic / aseptic growth.

II. LITERATURE SURVEY

'Weed removing machine for agriculture' by Albert[1], Aravindh R, Ajith M. This paper mainly focuses on the compact layout of the weed removal system, which reduces the time needed to remove the weeds between the plants. The height of secondary spinning wave and rotating blades will be increased and decreased by the vertical change. It is mainly aimed at increasing plant growth. **'Survey Paper on Fruit Picking Robots**' by Ashwini K[2]. A study on a moving strawberry harvester robot (third and fourth prototyping) is carried out, which can be formed by a traveling frame, designed and basically operated in a greenhouse to boost robotic harvesting and reduce production costs. This paper also shows the power and energy consumption of mechanism. **'Introduction to Robotics Agriculture in Pest Control: A Review'** by Hassan[3], Abdul Shukor. This paper therefore aims to raise awareness in agriculture of robotic technologies. Five basic components, sensors, effectors, actuators, controllers and arms most often constitute them. Weeding automation is the most important development in sustainable agriculture and food security, such as weeding, weed mapping, micro scrambling, seeding, irrigation and harvesting. **'Automatic Weed Removal System using Machine vision'** by D Puspavali.[4] The paper consists of guidance system used to track the rows accurately and to control in real time a row grower and an independent farm robot. Two specific models are used to automatically remove weeds from the seed line: a mechanical knife removes weeds from the inter-row rows, and rotating hoe removes weeds from the intra-roll lines using machine vision. **'A systems approach to pest control research'** by Robert P. Jenkins[5].

A framework for study of the pesticide research system can be built at least five different levels. The following designations are given: (1) Enterprise System (2) chemical control system (3) Production System and (4) Ecological System. The Enterprise System has been labelled the lowest level. **‘Leaf Disease Detection using Image Processing’** by Suja Radha[6]. Plant disease detection in the field of agriculture is very difficult. We can therefore use the image processing in MATLAB to identify the leaf disease. Disease detection involves steps such as image processing, contrast improvement, RGB to HSI conversion, function extraction and SVM. **‘Pest detection and control techniques using wireless sensor network: A review’ by** Saeed Azfar[7], Adnan Nadeem, Abdul Basit. This paper analyzes and classifies the process of pest control into technical, non-technological, and integrated solutions. We then compare the mechanisms for pest control based on their effectiveness, expense, and other performance parameters. **‘A Review on Fruit Maturity Detection Techniques’** by M. Surya Kiran[8], G. Niranjana. This paper is all about techniques for detecting fruit maturity, in which pre-processing, sensor detection and image processing are major stages involved. Spectroscopy was an important advance in the processing of images. The findings will be categorized or grouped in later stages according to requirement. **‘Appearance-Based Obstacle Detection with Monocular Colour Vision’ by** Ulrich Iwan[9]**.** This paper presents a new method for Mobile Robots to detect obstacles based on vision. Each individual pixel of the image is identified as belonging to either an obstacle or the ground based on its presence in colour. **‘Study of object detection implementation using MATLAB’** by Professor of Walchand Institute of Technology[10]. This paper consist of video analytics, I which object detection is a critical step. The output in this phase is essential to evaluate, fit and monitor artefacts, identify the operation.

III. AGRICULTURAL ROBOT

In this chapter, different views of agricultural robot CAD model are focused. Fig.1 represents the robot with drill bit at its rear end used for drilling holes for plantation after ploughing operation. Whereas Fig. 3 and Fig. 4 shows variable track width of robot, while Fig. 5 and Fig. 6 shows variable height of the robot. The electronic circuit inside the robot is used to determine the amount of irrigation, sunlight, pesticide and fertilizer required for healthy plant maintenance and growth. Then comes fruit harvesting and tuning, which is carried out training the robot with required fruits for harvesting and size of crops respectively and dumping the code obtained from MATLAB to processing unit, thereby the processor will send signals to actuators of variable end effectors (i.e. 3 Hand jaw and cutter) as per the obtained information to carry out respective operation.

1. Agricultural robot with different views

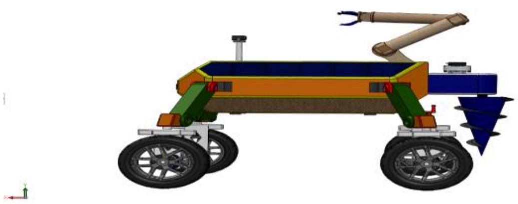


Fig. 1 Agricultural Robot with drill bit

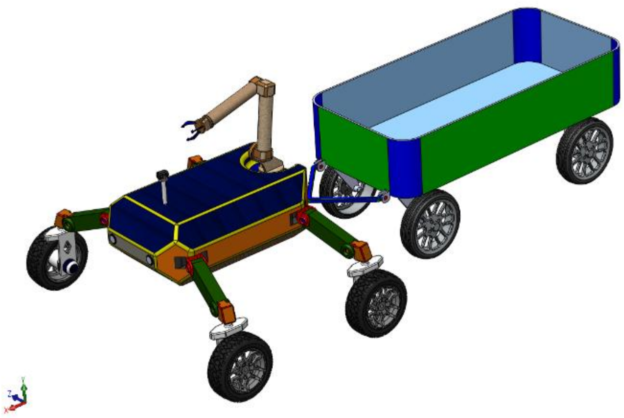


Fig. 2 Agricultural robot with fruit placing carriage

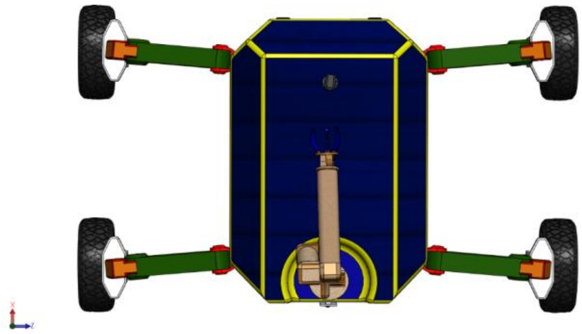


Fig. 3 Agricultural robot with maximum track width

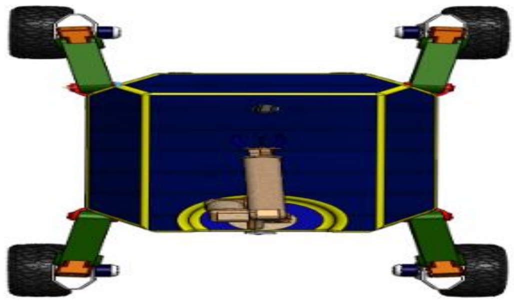


Fig. 4 Agricultural robot with minimum track width

Rear right & front left motors are actuated along the Y-axis (Yaw axis) in clockwise rotation and Rear left & front right motors are actuated along the Y-axis (Yaw axis) in anticlockwise rotation to get the minimum track width of the vehicle and reverse the rotation of motors of the vehicles will get the maximum track width of the vehicle.

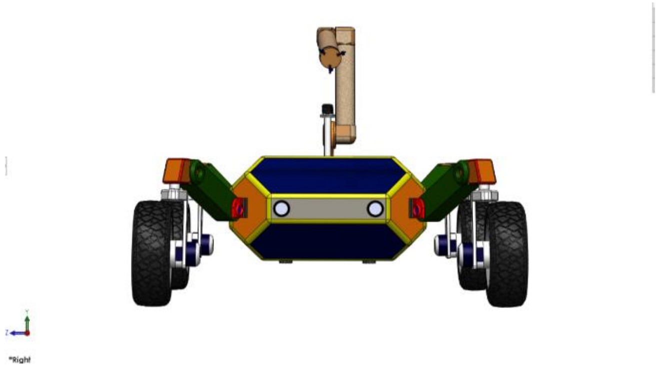


Fig. 5 Agricultural Robot with minimum height

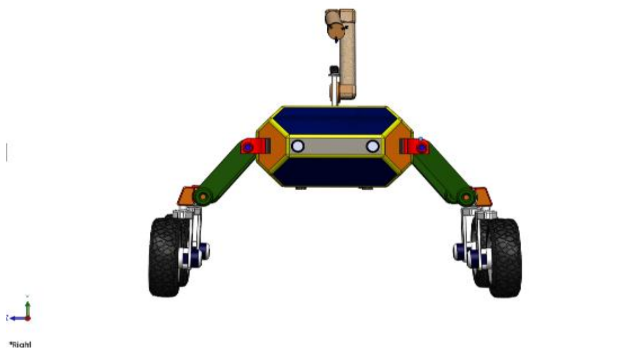


Fig. 6 Agricultural robot with maximum height

Rear right & left motor are actuated along the X-axis (rolling axis) in anticlockwise rotation and front left & right motors are actuated along the X-axis (rolling axis) in clockwise rotation to get the maximum height of the vehicle and reverse the rotation of motors of the vehicles will get the minimum height of the vehicle.

Table- I: Agricultural Robot specifications

Title	Dimension
Track width range	730 mm – 1470mm
Wheelbase range	685mm – 1435mm
Ground clearance range	0mm – 475mm
Robot body length	900mm
Total arm length	770mm
Total area of solar panels	4,83,340mm^2
Total weight of the robot	100kg
Motors required	24

2. Power Calculation

Energy : 70 KWh
Total area of solar panel (A) : 0.5m^2
Solar panel yield : 15%
Annual average irradiation on tilted panels (r) :1250KWh/m^2
Performance ratio (Pr) : 0.5 to 0.9 (standard range)
Total power of the system : A*r*H*Pr
: 0.1KWh

IV. METHODOLOGY OF AGRICULTURAL ROBOT

1. Ploughing

Initially the barren land will be levelled with the help of ploughing techniques such as mold board plough, Disc type plough, Rotary plough, chisel plough or sub soiler plough then the agricultural robot will be made to move throughout the land in defined way for training purpose and also to collect different information through sensors and refined data will be displayed directly to farmer, which will be helpful for the agricultural purposes. Here we set the parameters to robot initially so that it could define the path itself by differentiating the objects as shown in the Fig. 7. In this project, we have designed a layout of driving scenario using a software named MATLAB. In this driving scenario we have given appropriate dimensions of the field to work and the arrangements of trees accordingly so that we can trace the path to each tree in the field and to perform various operations like fruit picking, tuning of leaves etc. Firstly, on opening the MATLAB software we can find the driving scenario tab in the above menu bar, Selecting the tab we can find the driving scenario in apps shown in that bar, by selecting that we are able to decide the dimensions of field and vehicle class required.

Now place the vehicle at the place where we must start. Place the radar sensor by clicking add sensor icon and place at appropriate location on the robot to cover the maximum distance. In order to identify whether it is a tree or anything else, we are going to add camera and then train it, so that it can identify the crop easily without considering other objects in the path. Place it at the front of the vehicle so it can visualize the travelling path easily.

After installing all the required sensors go to the previous location of the road. Add way points to the road using way point command so that it will travel by the way points which are predetermined, now by clicking on the run icon it will travel around the points which are given, If any obstacle is found in the path it will eradicate that way and continues to travel in another way in which it is clear in travelling. It will identify the path by using radar sensor which is placed on both sides of the vehicle or robot. The Fig. 7 represents driving scenario of agricultural robot and visualization of robot to identify the objects in its path.

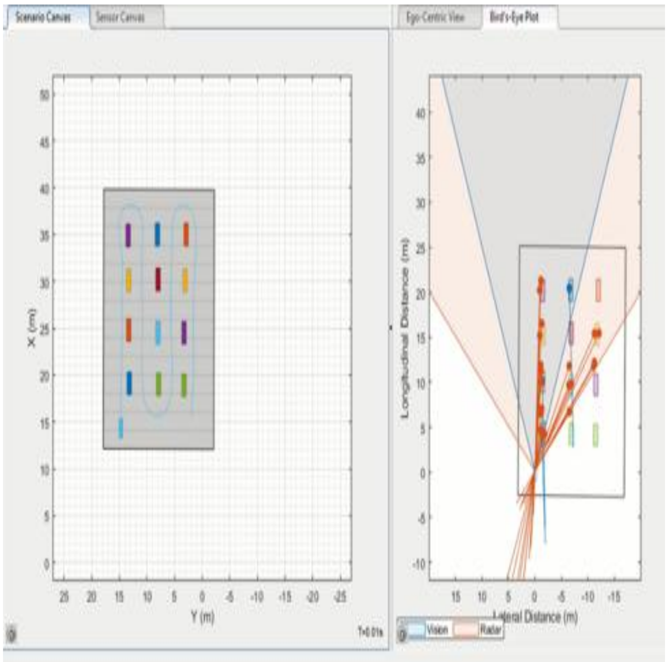


Fig. 7 Driving scenario of agricultural robot.

A) Drilling operation

After land is completely levelled the drilling operation is carried out at specific points in different rows as per defined route and available land by the agricultural robot.

Here specialty of the robot is it can change its track width and wheel base as per requirement because of turning pairs near the wheels, using this facility the robot will reduce it ground clearance and then will carry out drilling operation and again robot will move up and go forward to drill new hole.

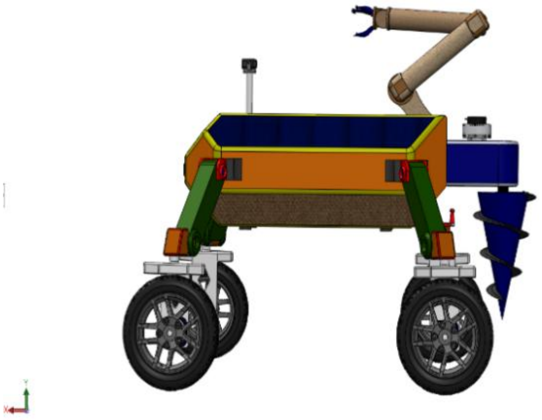


Fig. 8 Agricultural robot with drill bit (500*200mm) upside

Fig. 9 Agricultural robot with drill bit downside

Sensors for computer vision, acceleratorometer and gyroscope for robot, RPM mesasuring device for drill bit, torque transmitting capacity of drill bit, LIDAR for obstacle detection, and soil compaction and resistance measuring device may be required for this opeartion. Here seeding or planting operation of required plant is done manually with hands or with help of other mechanical instruments as per farmers requirement.

2. Maintenance of crops

Initially as agricultural land is levelled using anyone of the ploughing techniques and then the drilling is carried throughout the land at desired locations using the drill bit at rear side of the robot and then plantation is done at drilled locations.

Watering is carried out by drip irrigation methods. Then with supply of sunlight, fertilizers and pesticides as per the crop's requirement, growth of the crops takes place. During the movement of robot in the farm, the radar and camera mounted on the robot will detect the individual crops and their fruits based upon the training given to the robot via MATLAB and will move towards it. The robot will scan the crop and check whether it is in the given dimensions or not, if not the cutter attached to robot will carry out tuning operation and ensure that crop is growing in the required dimensions and area of the land.

Agricultural robot also scans the crop completely and based on preinstalled data of fruits/vegetable properties (such as dimensions, colors) and ethylene content for the ripen fruit/vegetable in the robot, by sending the electromagnetic waves it will decide whether to pluck the fruit/vegetable with the 3-hand jaw and place it in the carriage or not.

Another additional feature of robot is that it will take the soil sample and will notify the farmer the deficient nutrients for that specific crop, so that farmer could take necessary action. Sensors for determining the moisture content, water holding capacity, organic matter, pH value, productivity of soil may be required for this operation.

A) Digital image processing for plants and fruits

Image is a 2D function, f(x, y), where x and y spatial coordinates and f is called the intensity or gray level of the image at that point in any pair of coordinates (x, y). There are two types of image i.e. Analog image and Digital image

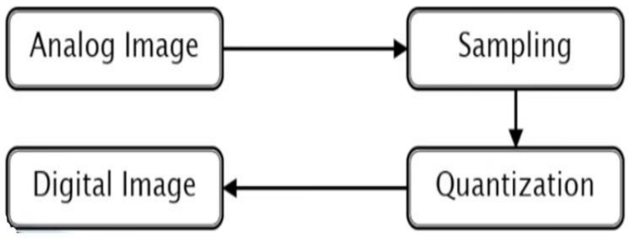
Analog Image: The Analog image processing is applied to analog signals, and only two-dimensional signals are processed. Electrical signals manipulate the images. In analog image processing the mathematical representation of the image has a continuous range of values representing the position and the intensity.

Examples of Analog images are television images, photographs, paintings, and medical images etc.

Digital Image: Digital image processing (a matrix of small pixels and elements) is applied to digital images; There are a variety of applications and algorithms which are implemented to adjust modify the images. If x, y, f are all finite discrete quantities in the mathematical representation, the image is a digital image. Digital image processing is one of the fastest growing industry which affects everyone's life.

Examples of digital images are colour processing, image recognition, video processing, etc.

Digital image processing: The analysis and manipulation of digitalised image, especially in order to improve its quality



General steps in digital image processing are image acquisition i.e. to obtain image from external source such as camera, pendrive, software's, etc. then image filtering is carried out where different filters are applied such as high and low pass filters are applied to smoothen and sharpen image respectively for edge and color detection of the image. After that image restoration is carried out to remove noise and degradation factor added to it during the transmission of the image. Here image obtained from any source can be interpreted in the form of grey scale, RGB, CYM, CYMK, HSI image models, as per the users processing unit. Then the image is compressed using lossy or lossless compression techniques to ease the storage and transfer of image file.

Then wavelets and multiresolution processing is carried out to improve its resolution.

Then comes the major part of image processing i.e. segmentation, where the image is divided into different understandable segments for the representation, recognition or description of particular portion of image or a complete image in this process the image is converted into grey scale or red or green or blue pixeled image as per convenience for further processing and then a threshold pixel value is given to the image, then every pixel in the image is compared to the threshold pixel value, if above that value that particular pixel is converted into white pixel otherwise black pixel.

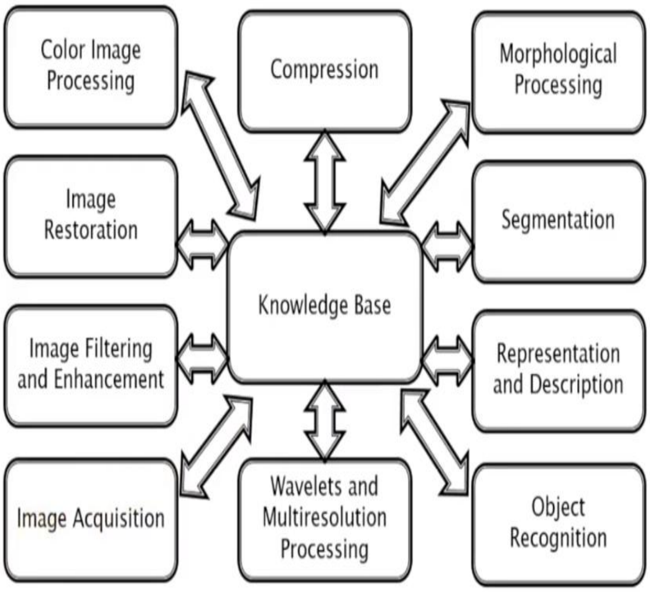


Fig. 10 Steps in Digital image processing

In this project, the agricultural robot is trained with the photos of required fruits and plant and then the video, which is captured by the camera of robot moving in the farm is interpreted frame by frame as single image by the processor. Here we are mainly focusing on image segmentation of that captured image using 'semantic segmentation processing' so that the required details from that image can be extracted and then based on the obtained information by the processor, it will send the output signals to the actuators to perform the specific motion.

Semantic segmentation process using MATLAB involves converting an image into a collection of regions of pixels that are represented by a mask or a labelled image. By dividing an image into segments, you can process only the important segments of the image instead of processing the entire image. Then by using the Video Labeller apps which enables us to label ground truth data in a video, in an image sequence, or from a custom data source reader to interactively label pixels in form of rectangular regions of interest (ROI) labels, polyline ROI labels, pixel ROI labels, and scene labels and then use built-in detection or tracking algorithms or customize your own algorithm to label ground truth data.

Finally export the labelled ground truth as a ground Truth object and use the obtained MATLAB code for 'object verification in system' or 'for training an object detector or semantic segmentation network. The below graphs show the time that the labelled object in the image will appear throughout video runtime vs count of labelled object in the image.

Fig. 11 Agricultural robot detecting different objects in the video

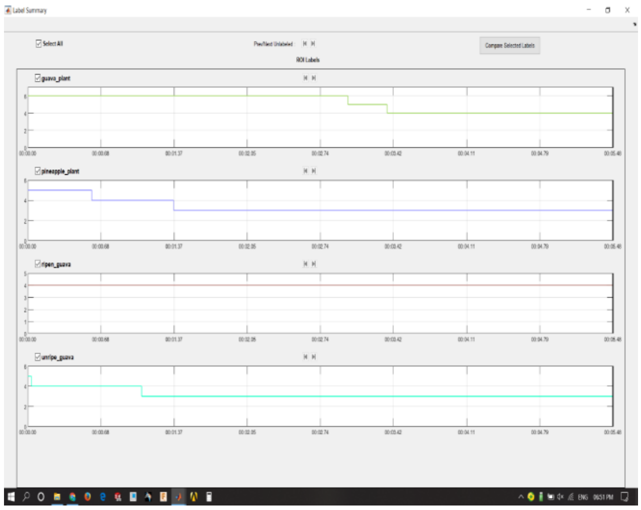


Fig. 12 Time vs Count of object graph for Fig. 11

Fig. 13 Agricultural robot detecting different objects in the video

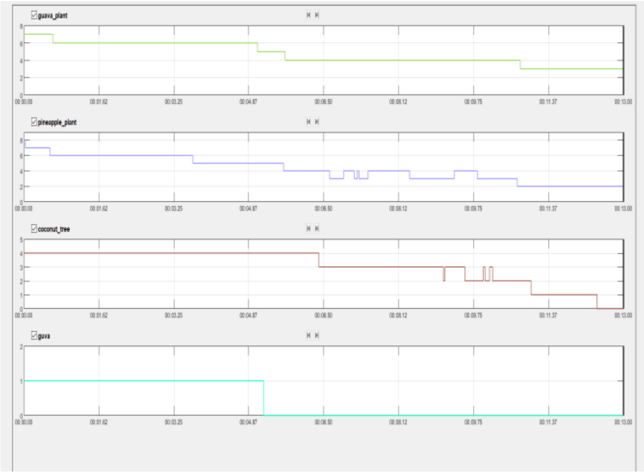


Fig. 14 Time vs Count of object graph for Fig. 13

3. Tuning operation

Here data obtained from the camera is sent into processing unit after undergoing digital image processing. Then based on the obtained information the processor will send the electronic signals to the actuators attached to end effector for carrying out the cutting operation

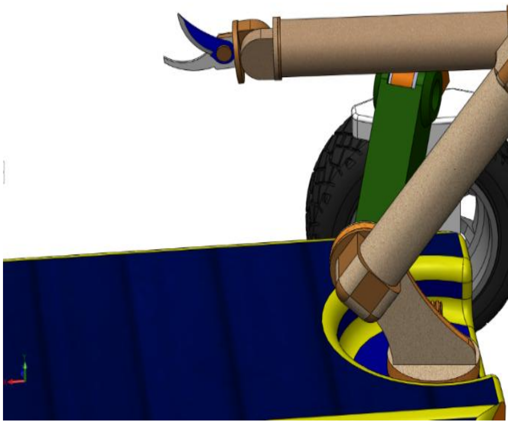


Fig. 15 Agricultural robot with cutter(150mm) as end effector

4. Crop harvesting

Based on the obtained data from the sensor and processing it, we can carry out the crop harvesting process with help of 3-jaw arm as a end effector and place fruits in the basket.

Table -II: End effector specification

Arm geometry	Articulated arm
DOF	6
Actuators	Electromechanical motor
End effector	3-jaw arm and cutter
Motion	point to point interpolation
Control strategy	PID controller
Controllers	Microcontroller

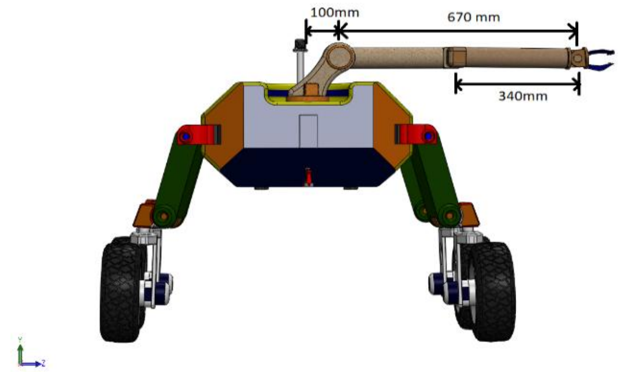


Fig. 16 Agricultural robot with 3-Hand jaw dimensions

Sensors for computer vision, GPS module, determining the ethylene content of fruits, obstacle avoider, object holding pressure may be required for this operation.

V. RESULTS

It can be clearly concluded from the above chapters that a robot has been modelled which can carry out basic agricultural operations such as drilling with help of drill bit attached at its rear end, while the maintenance of crop is carried out by observing the crops with help of camera and based upon the obtained data the actuators will perform required operation such as tuning and harvesting (i.e. all the required algorithms will be initially dumped in the processor of the robot)

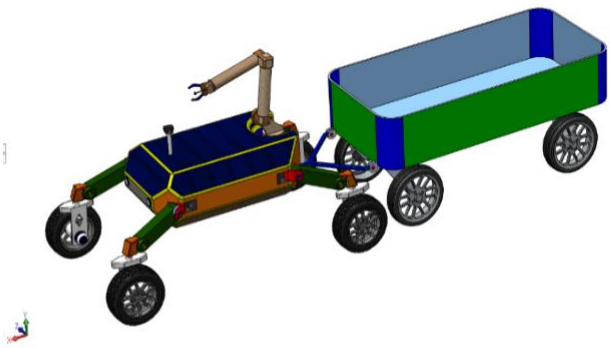


Fig. 17 Agricultural robot with 3-Hand jaw & fruit carriage (1.4*0.7m)

The below fig. 18 shows the momentary visualization of the robot by camera where we can clearly observe that the robot is able to identify each induvial element such as ripen guava, unripen guava, guava trees, pineapple plants based on the training given to the robot.

The below fig. 19 is graph representing that considering a particular time interval the total number of each induvial element such as ripen guava, unripen guava, guava trees, pineapple plants appearing vs that particular time (second). For example, in the fig. 19 for a time interval of 5 seconds particularly at 3.42 seconds robot is able to determine that there are 6 ripen guava, 7 unripen guava, 4 guava trees, 8 pineapple plants up till its visual approach.

Fig. 18 Agricultural robot detecting different objects in the video

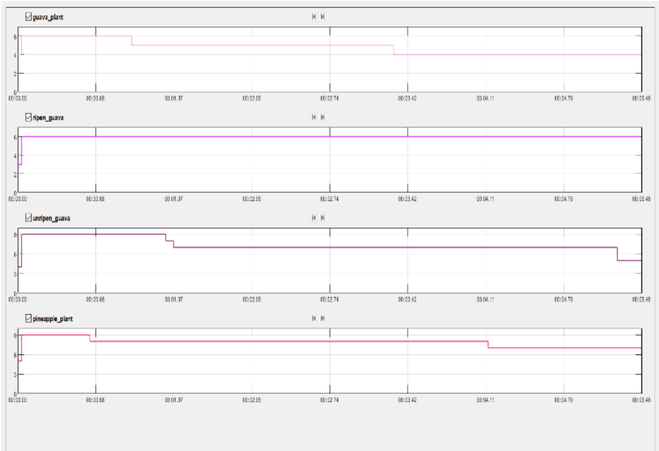


Fig. 19 Time vs Count of object graph for Fig. 18

The obtained data of individual elements is sent to the processor of the robot, where controller will send the signals to actuators to pluck the ripen guava with help of 3-hand jaw and place it in the carriage or it can also send signals to trim the crop, if it is exceeding its dimension with help of cutter attached at end of articulated arm. The fig. 20 represents the movement of articulated arm done in ADAMS simulation, while the fig. 21, fig. 22, fig. 23, fig. 24 represents the value of angular velocity, angular acceleration, velocity, acceleration, of each individual link of the articulated arm at that particular time obtained from ADAMS software.

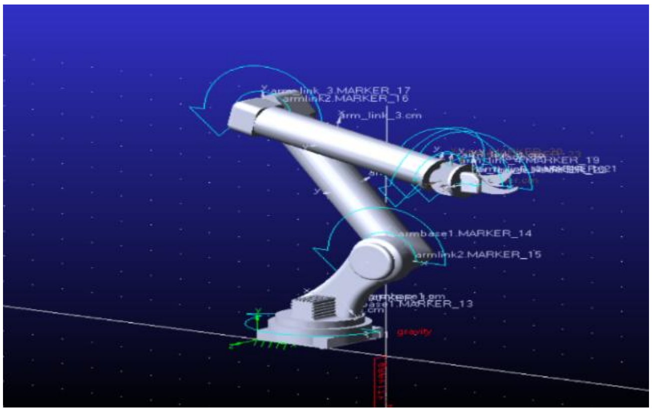


Fig. 20 Agricultural robot end effector ADAMS simulation

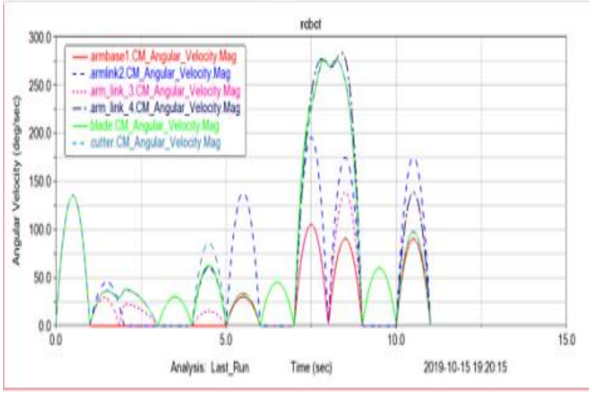


Fig. 21 Angular Velocity Vs Time graph

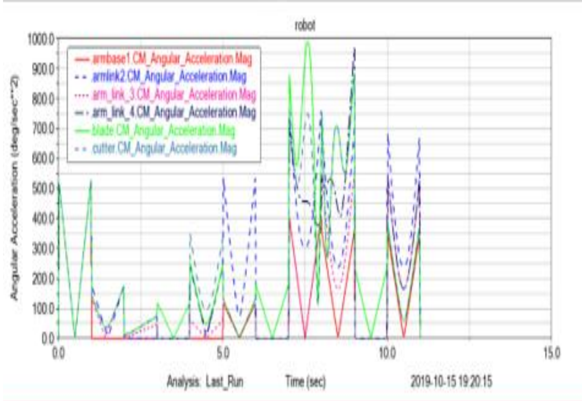


Fig. 22 Angular acceleration Vs Time graph

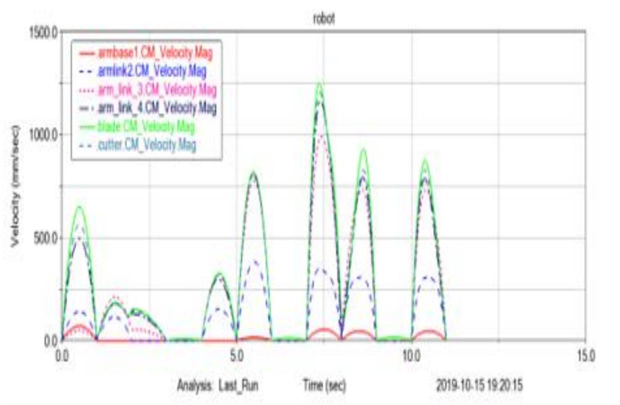


Fig. 23 Velocity Vs Time graphs

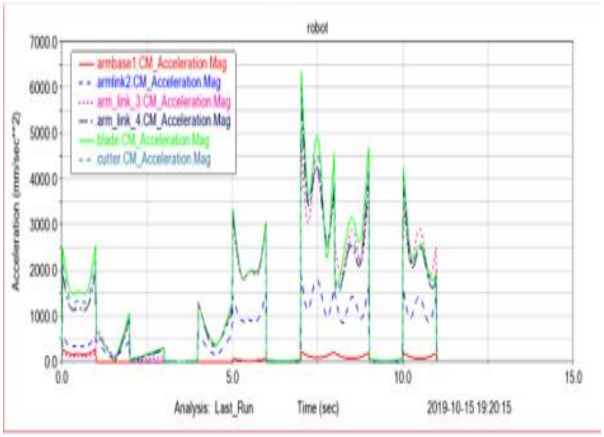


Fig. 24 Acceleration Vs Time graphs

VI. CONCLUSION

More than 80% of the food consumed is created by about 500 million local farmers in the developing world. Given that UN projects are expected to improve growing global demand by 50% by 2050, precise farms of all sizes will be in demand with comparison to current farming technologies.

Precision farming seems to have become increasingly effective in meeting the worldwide demand for food, using technology that makes data collection and application easier and cheaper, adapted to changing the environment and allows the most efficient system. While large farms are the first to occupy these technologies, small farms are now also able to benefit from smartphone tools, relevant applications or smaller machinery. However, these technologies lead to environmental benefits such as reducing global warming emissions and increasing sustainability. In addition to the enhanced wireless data transmission and acquisition for the smart, smaller Unmanned Aerial and Unmanned Ground Vehicles (UAVs and UMVs), future development in precision cultivation is probably going to include increased use of aerial farm vehicles. Such smaller vehicles can also monitor the situation of farming and their equipment’s also.

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