A
Project Phase II Report
on

COMPUTER VISION BASED COTTON HARVESTING ROVER

SUBMITTED TO THE SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE

IN THE PARTIAL FULFILMENT OF PROJECT PART-II OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE
OF
BACHELOR OF ELECTRONICS & TELECOMMUNICATION ENGINEERING
BY

Abhimanyu Rajesh Kanase Seat No. B191223027
Anshu Biju Varghese Seat No. B191223062
Aditya Prasad Deshmukh Seat No. B191223017
Under the guidance of

Prof.Dr.Rahul.G.Mapari

Department of Electronics and Telecommunication Engineering
Pimpri Chinchwad College of Engineering and Research,Ravet, Pune-412101

ACADEMIC YEAR:2023-24

PIMPRI CHINCHWAD EDUCATION TRUST'S
Pimpri Chinchwad College of Engineering and Research,
Pune-412101

CERTIFICATE

This is to certify that the Project Phase-II report entitled

"COMPUTER VISION BASED COTTON HARVESTING ROVER",

Submitted by

Abhimanyu Rajesh Kanase	**(Exam Seat No. B191223027)**
Anshu Biju Varghese	**(Exam Seat No. B191223062)**
Aditya Prasad Deshmukh	**(Exam Seat No. B191223017)**

is a bona fide work carried out by them under the supervision of **Prof.Dr.Rahul.G.Mapari** and it is approved for the partial fulfillment of the Project Phase II of the requirement of Savitribai Phule Pune University, Pune for the award of the degree of Bachelor of Engineering (Electronics & Telecommunication). The Dissertation work has not been submitted to any other institute or university for the award of a degree.

Prof.Kishor Bhangale
Project Guide

Prof.Dr.Rahul G.Mapari
Prof.Guide Name

Prof.Dr.Rahul G.Mapari
Head of Department

Prof.Dr.H.U.Tiwari
Principal

Acknowledgement

We are greatly indebted to Head of Electronics & Telecommunication Engineering and Project Guide **Prof.Dr.Rahul.G.Mapari** for his able guidance throughout the course of this work.It has been anal together different experience to work with him and we would like to thank him for his help,suggestions and numerous discussions.

We are heartily thankful to **Prof.Dr.Harish U.Tiwari** (Principal, Pimpri Chinchwad College of Engineering & Research,Ravet)for providing research environment;also for his kind inspiration.

We are gladly taking this opportunity to thank the Head of Electronics & Telecommunication Engineering **Prof. Dr.Rahul Mapari** and project Coordinator **Mr. Kishor Bhangale** for their valuable guidance and providing facility during the progress of the seminar.

Last but not least we are also thankful to all those who help directly or indirectly to develop this Project work and complete it successfully. With Deep Reverence,

Abhimanyu Rajesh Kanase
Anshu Biju Varghese
Aditya Prasad Deshmukh

Date:
Place:

Contents

1 Introduction **1**
1.1 Introduction 1
1.2 Research background 2
1.3 Problem Statement 3
1.4 Objectives of the Study 3
1.5 Scope of the Study 3
1.6 Overview of Proposed System 4
1.7 Organization of the Report 4

2 Literature Review **6**
2.1 Literature Survey 6
2.2 Findings from Literature Survey 9
2.2.1 Gap Identification 9
2.2.2 **From the literature survey following gaps are identified :** 10

3 Proposed Methodology **11**
3.1 System Implementation/Block Diagram and Explanation 11
3.2 Data preprocessing 12
3.3 Detection using Yolov5 14
3.4 Yolov5 architecture 17
3.5 Design and Formulation 19
3.6 Objectives completed till date 20
3.7 Flow Chart and algorithm 21

4 Results and Discussions **23**
4.1 Hardware Setup 23
4.1.1 Hardware Components and Specifications 23
4.2 Software Setup 30
4.3 Results 33
4.4 Summary 38

5 Advantage and Applications **39**
5.1 Advantages 39
5.2 Applications 39

6 Conclusion and Future Scope **40**
6.1 Conclusion 40
6.2 Future Scope 42

A Project Outcomes **46**
A.1 Plagiarism Report 47
A.2 Project Competition Participation Certificates 52
A.3 Publication Documents 55
A.3.1 Publication Work 55
A.3.2 Publication Copyright 62
A.3.3 Publication Certificate 65
A.4 Patent Documents 67
A.4.1 Patent Draft 67
A.4.2 Patent 75
A.5 Copyright Certificate and Work Uploaded 76
A.5.1 Copyright Certificate 76
A.5.2 Synopsis 78
A.5.3 Form 14 83

List of Figures

1.1 Block Diagram 4

3.1 Block Diagram 11
3.2 Detection of cotton bud 12
3.3 Detection of matured cotton boll 13
3.4 Generalized flow of YOLOv5 cotton detection model 15
3.5 YOLOv5 architecture 17
3.6 Schematic Diagram 19
3.7 Working of prototype 20
3.8 Flow Chart 21

4.1 Arduino Mega 23
4.2 16-channel 12-bit PWM servo driver 25
4.3 Servo 995 26
4.4 Servo MG90s 27
4.5 Servo SG90 28
4.6 SMPS 12v,5A 29
4.7 Jumper cable 29
4.8 Anaconda Dashboard 30
4.9 Jupyter Dashboard 31
4.10 Google Colab 31
4.11 Arduino IDE 32
4.12 Confusion Matrix 33
4.13 F1 confidence curve 34
4.14 Precision confidence curve 34
4.15 Recall confidence curve 35
4.16 Evaluation metrics 35
4.17 Performance metrics 36
4.18 Simulation results for the position of the robotic arm 36
4.19 Results of working of the robotic arm 37

6.1 Real time testing of model using Images 41

List of Tables

3.1 Comparison of YOLO versions 14
3.2 Configuration details of Yolo 16

4.1 Specifications of Arduino Mega 24
4.2 Specifications of Servo Driver 25
4.3 Specifications of Servo 995 26
4.4 Specifications of Servo MG90s 27
4.5 Specifications of Servo SG90 28
4.6 Performance metrics 36

Abstract

Cotton harvesting has historically required a lot of labor, taken a long time, and presented many difficulties. Yield and quality were inconsistent when harvested by hand. In traditional systems, the cotton blooms could not be detected accurately due to obstruction due to leaves, or detecting the sky instead of the cotton based on features like color, etc. In traditional harvesting, there were major concerns which included the preparation for plantation, determining the harvest season, manual labor, unavailability of skilled workers, and transport capability.

To deal with this matter the robotic technology used by Cotton Harvesting Rover is capable of identifying cotton blossoms precisely with the aid of computer vision technology. The cotton is automatically identified by the system as it selects flowers from the fields using a robotic arm after analyzing specific attributes.

The novelty of this project is that it identifies the cotton blooms from all perspectives so that inaccuracy can be avoided. With the help of the rover, it becomes convenient to keep plucking the mature cotton blooms and detecting them simultaneously. This solution helps reduce the labor work, increasing yield and quality and reducing of usage of harmful chemicals.

The expected outcome of this idea is that the model should identify the mature cotton blooms accurately and the robotic arm should pick the cotton without much delay thus ensuring improved cotton harvesting.By increasing the effectiveness and sustainability of cotton harvesting, this ground-breaking approach has the potential to completely change the cotton business. The successful completion of this project is expected to produce a considerable improvement in cotton harvesting techniques by accurately identifying mature cotton blooms and enabling the robotic arm to function flawlessly.

Chapter 1

Introduction

This chapter emphasizes the critical need for improving cotton harvesting methods and introduces an engineering project focused on developing a cotton-picking rover equipped with computer vision technology. It provides a detailed research background, defines the problem statement, outlines the project objectives, delineates the scope, and presents an overview of the proposed rover system.

1.1 Introduction

Traditionally cotton picking was done by using methodologies such as hand picking, chemical defoliation, mechanical stripping, manual picking machines, etc. The idea of the project is to develop an advanced cotton-picking robot that incorporates computer vision to enhance and upgrade the efficiency and accuracy of cotton harvesting.

Computer vision is a field that allows computers to extract information from images and other visual inputs. Based on this information it takes necessary actions. It trains the machines to perform according to the functionality that is indicated to be done. Computer vision can be used in various applications such as the detection of faces, video capturing, and tracking moving objects. Using image processing and computer vision the cotton bolls can be detected based on their features and the robotic arm aims to pick them and store them in a container. A deep learning object detection model called YOLOv5 (You Only Look Once version 5) is employed for cotton blossom detection in real-time. The process for successful cotton boll detection includes data collection, labeling the data, selecting the version of the model, training the model by providing the annotated dataset, fine-tuning, and then evaluating the results based on test datasets. Finally, the model is integrated into the robotic system for real-time cotton boll collection.

The rover's functionality will be to move autonomously through the cotton fields. The system will be equipped with cameras and image processing capabilities to analyze each cotton bloom particularly and identify the ripe ones.

1.2 Research background

Prior to starting a project that entails using robotics and computer vision to build a cotton-picking rover, extensive research covering several crucial topics was done:

1. **Cotton Plant Biology :** [1][2]Acquired knowledge of the characteristics, stages, and growth cycles of cotton plants. To find cotton, research was done to understand its visual characteristics at various growth stages.

2. **Optimal Picking Techniques:** Explored the most efficient methods for cotton harvesting that won't damage the plants or lower output.

Automation and Robotics:

1. **Robotic Arm Capabilities:** [3] Analyzed the accuracy of current robotic arm designs and their applicability to precise tasks like cotton picking.

2. **Mobile Robotics:** Investigated rover designs, propulsion systems, and techniques for traversing diverse terrains.

Computer vision and image processing:

1. **Algorithms:** [4][5]Used OpenCV to research various methods of object recognition and detection, including CNNs, Haar cascades, and contour detection for plant recognition.

2. **Image processing techniques:** [6]Inquired about color thresholding, feature extraction, and other image processing techniques to distinguish cotton plants from the background.

1.3 Problem Statement

To develop a cotton harvesting rover using computer vision which identifies and selectively picks up mature cotton blooms from the plants, hence reducing labor dependencies and improves crop yield.

1.4 Objectives of the Study

The objectives of the proposed works are mentioned as follows

1. To develop an image processing model that accurately identifies cotton bolls among other plants.
2. To ensure that plucked cotton bolls are not damaged.
3. To minimize the total initial cost for the system
4. To ensure that hardware setup and software model are well integrated.
5. To distinguish mature cotton blooms from pre-matured ones
6. To make certain that the system is portable, robust, and has increased mobility.
7. To make sure that repair and maintenance are easy and cost-efficient.

1.5 Scope of the Study

A project that builds a cotton-picking rover with computer vision and robotics has a wide scope and touches on a number of different fields:

Technical Features: Creating and assembling the rover's robotic arm, cameras, sensors, and motors while ensuring proper hardware integration is known as hardware integration.

Software Engineering: Write code for object detection, image processing, and identification using computer vision. Creating algorithms to control the robotic arm and identify cotton plants against a backdrop is required for this.

Developing the navigation and control systems that will enable the rover to go through fields, avoid obstructions, and reach the designated cotton plants.

1.6 Overview of Proposed System

Description of the proposed system and overall block diagram are as follows:

The proposed system uses cameras in cotton fields to record color, shape, and size images. In order to distinguish between mature and premature cotton blossoms, computer vision analyzes these photos using a Convolutional Neural Network (CNN). When ripe cotton bolls are identified, a robotic arm is triggered to gather and store them in a container. The CNN is trained using labeled datasets. The rover's ability to navigate the field with efficiency is its main goal.

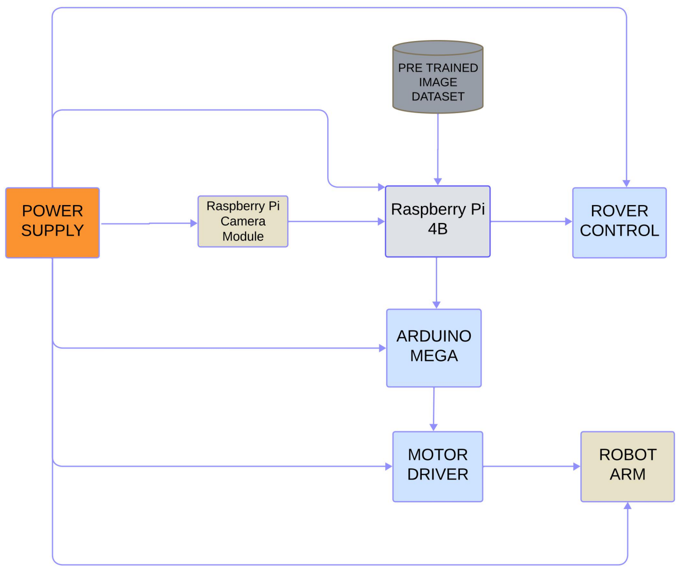


Figure 1.1: Block Diagram

1.7 Organization of the Report

The project report is organized as follows:

Chapter 1 Introduction: Provides the information regarding the introduction of ..area, need, relevance, problem statement, objectives, and scope of the study. Further, it provides a short overview of the proposed system.

Chapter 2 Literature Review: Gives a survey of various articles on the used technology and provides the major gaps that pave the way for the development of the proposed system.

Chapter 3 Proposed Methodology: Provides the system implementation, data pre-processing, information about YOLOv5, designn , objectives completed till date and flowchart.

Chapter 4 Results and Discussions: Gives an overview of hardware setup, software setup, and results.

Chapter 5 Advantages and Applications: Provides the advantages and applications of the project.

Chapter 6: Conclusion and Future Scope: Consists of the conclusion and future scope of the project.

Chapter 7: Consists of the references used.

Chapter 2

Literature Review

2.1 Literature Survey

A promising method for harvesting cotton in India and other developing nations is Cotton Harvesters. Even though there have been significant advancements in recent years, there are still difficulties with its implementation in India. All cotton picking in developed nations is done by machines. The Indian agriculture sector has become more mechanized due to rising labor costs and a shortage of labor [7]. According to Haolu Li, remote sensing imageries were used for accurate identification of cotton crop. The deep-learning model used was DenseNet, which is a multidimensional densely connected convolutional network. Remote sensing techniques benefit viewpoints like growth monitoring, disease identification, area estimation and multiple parameters. SVM can do agricultural classification in which the support vectors are limited and the training dataset can be reduced without altering the accuracy of classification. Remote sensing images are obtained from satellites, unmanned air vehicles (UAVs) and unmanned ground vehicles (UGV) [8]. Xu et al detail the procedure for gathering aerial photos of cotton fields, analyzing the photos to determine possible bloom locations, and employing a convolutional neural network to categorize the possible blooms as either non-blooming objects or cotton flowers.[4]Deep Learning based models like RCNN perform better than ML algorithms like multi-layer perceptron and K-nearest neighbour to achieve a high detection rate. ResNet-18 was more accurate than Random Forest (70.16 %) and Support Vector Machine (60.6 %) [6].

K. Fue describes, the utilization of OpenCV (version 3.3.0) mission vision to detect cotton and Robot Operating System (ROS) for rover and robot arm control. Z. Xu et al have explained cotton detection using fuzzy reasoning-based approach combined with RGB and HSV color spaces to manipulate image color pixel values and set upper/lower limits for white cotton bolls. Amanda Issac et al [9]. This paper concludes that they were able to achieve a joint reduction in dimensionality and file size by combining the bitwise-masking and PCA processes on sliced images. This technique produced a significant percentage of smaller files while preserving high-quality reconstructions, outperforming the default JPEG compression [10]. Adalberto I. S. Oliveira developed a robot whose purpose is to monitor the cotton crop and move between rows of crops. The control system of the robot consists of an image-based visual servoing method and a fuzzy logic-based controller [11]. The potential to enhance cotton farming techniques through automation and robotics, from pre-planting to harvesting and ginning. The authors contend that utilizing technology to enhance cotton farming methods has a wide range of possible advantages. Utilizing programs such as OpenCV, ROS, PBI Logger Utility, a John Deere program, and the plastic-inspection-detection-ejection system (PIDES) [4]. According to Zhang, Yan and Yang etc an Improved YOLOv5 network was presented that integrated DenseNet, attention mechanism, and bi-frequency frequency prediction to correctly and economically identify unopened cotton bolls in the field. According to the experiment results, the suggested approach outperforms the original YOLOv5 model as well as alternative approaches like YOLOv3, SSD, and FasterRCNN when taking into account the simultaneous considerations of detection accuracy, computational cost, model size, and speed [5].

Yong Wang and the research team present a novel approach to cotton recognition based on color subtraction information of various cotton components. Besides, dynamic Freeman chain coding is used to reduce noise and improve recognition accuracy in order to raise the accuracy rate of cotton recognition [12]. Nimkar Amey Sanjay concludes that to create sustainable and successful agriculture, the goal of the project is to identify, harvest, and store cotton using a cotton harvester that makes use of strong digital analytics, robotics, and image processing. The machine would pluck several crops by using multiple robotic arms built in the harvest zone [13]. This machine is ideal for women because it is remote-controlled and electrically operated, eliminating the need for a driver. This work by W. M. Porter explores and validates the optical detection of cotton rows. The row depth is detected using a stereo camera, and the upper and lower portions of the cotton row canopy are then calculated using a pixel-based method that assumes a normal distribution for the high and low pixels. Pixel-based sliding window algorithms and perspective transform are used to detect left and right rows. For the cotton-picking robot to navigate smoothly, the center of the rows is calculated along with the Bayesian score of the detection [3]. According to Kadeghe Fue SMACH, a ROS-independent library for finite state machines, is utilized by the system. Using a 2D manipulator that travels linearly in both the horizontal and vertical directions, the robot harvests the bolls. The finite state machine's decision directs the manipulator and the rover to the destination, and the stereo camera parameters are used to calculate the boll 3-D location. To regulate the rover's journey to the boll, PID control is used [14]. This work by Spyros Fountas is an overview of the existing research on scientific agricultural robotic systems and their uses in weeding, crop monitoring, phenotyping, disease detection, spraying, navigation, and harvesting is covered in this work. The review also covers the many kinds of AI algorithms and sensors that are employed in these systems [15].

This paper focuses on the development of an improved YOLOv5 algorithm for the detection of appearance-based damage in cotton seeds [16]. The creation of a computer vision algorithm that uses YOLOv5m to identify volunteer cotton plants in cornfields is covered in the document[17]. This paper used Point annotation and multi-scale fusion-based cotton boll localization approach [18]. It details the construction and deviation analysis of an image processing-based 5-axis robotic arm. The study offers an affordable technique for doing laboratory tests on a robotic arm [19]. The report provides a comprehensive overview of the latest advancements in LiDAR technology and its potential applications in ground crop analysis [20].The X, Y, and Z axes deviations are provided in the paper. Image processing carried out in MATLAB was used to calculate them. The deviation is detected to be roughly 0.3 mm in the X, 0.1 to 0.2 mm in the Y, and 0.1 mm in the Z axes [21]. The creation of an instructional robotic arm with color detection and object handling capabilities is suggested in this research using a vision-based control system. There are possible uses for the system in education, employment, and training [22] . An overview of sensors and systems in navigation systems, recognition and detection algorithm classification, and crop row techniques are given in this work [23].

2.2 Findings from Literature Survey

From the widespread survey of various techniques of Cotton Picking using deep learning we found the following gaps that needed to be concentrated.

2.2.1 Gap Identification

According to the existing literature and the state of knowledge in object detection, there are some limitations that may arise in the methodology, observed findings and some questions which may be unanswered. The below table contains all the gaps/limitations which were identified during the analysis of the papers. This paper describes the existing methodology, the design and formulation, methods for data collection and their drawbacks. Based on this analysis it is possible to address issues that had been faced in the previous research papers. Around 26 papers were studied, out of which 25 gaps were identified. The gap identification from the following papers are as follows: The cost and availability of labor are two major issues that Indian cotton farmers must deal with [7]. Machine learning techniques do not use automatic feature extraction and need careful tuning of hyperparameters [2]. In real field obstruction caused by branches and other leaves can result in longer picking time. Implementation cost due to hardware, software, and maintenance is high [1]. Detects only white cotton bolls therefore may not be directly applicable to other types of crops or monitoring scenarios. Requires specialized equipment [9]. Specifies the outlines the application case for identifying flowering patterns in cotton blooms, and does not specify other use cases. Does not specify the computational requirement and time complexity [10]. Potential challenges faced can be field obstacles, theft, cost, etc. Due to the system being autonomous, they must require minimal management time [4]. Techniques like YOLOv3, SSD, and Faster-RCNN showed less performance in terms of detection, computational costing, model size, and speed [5]. Requires specific lighting conditions, does not work well with certain types of cotton [12]. This paper focuses on the development of a cotton harvester using ML and IP techniques and not on the practical use [13]. New automated machines will have to match the reliability, self-sufficiency, and economic competitiveness of the existing harvesters used in the U.S [3]. The system was struggling to get a boll if it is located behind the stem or branch. Some-times it causes the system to leave behind some bolls [14]. Need for specialized sensors and algorithm calibration, difficulty in comparing AI algorithm performances among papers using different data sets [15]. It is deficient in thorough assessment, comparative analysis, and specific details on a few key areas, including the computational efficiency and the algorithm's performance with coated cotton seeds [16]. ACO algorithm used for generating the optimal path and spot-spray is stochastic in nature and may not provide a globally optimal solution [17]. Not all of the computational resources needed for MCBLNet training and implementation, particularly in real-time applications may have been taken into consideration [18]. Testing equipment for robotic arms is costly [19]. Challenges involved in complexity in robotic arm programming [21]. Possible drawbacks could be limited to only color and shape recognition, environmental conditions could impact the reliability of computer vision [22]. The challenges of differentiating between crop species, the requirement for extreme precision and accuracy in data collection, and the possibility of interference from meteorological elements like wind and rain [20]. Accurate direction-finding and self-governing agricultural equipment are challenged by the unstructured and complicated character of the agricultural environment [23].

2.2.2 From the literature survey following gaps are identified :

1. Obstruction caused due to leaves, branches or other materials can slow the picking time.

2. Implementation cost due to hardware, software, and maintenance.

3. Autonomous systems must have less maintenance time.

4. Only identifies specific cotton blooming patterns and does not specify other use cases.

5. Could not identify cotton bolls which were hidden behind some branches leaving behind some bolls.

Chapter 3

Proposed Methodology

3.1 System Implementation/Block Diagram and Explanation

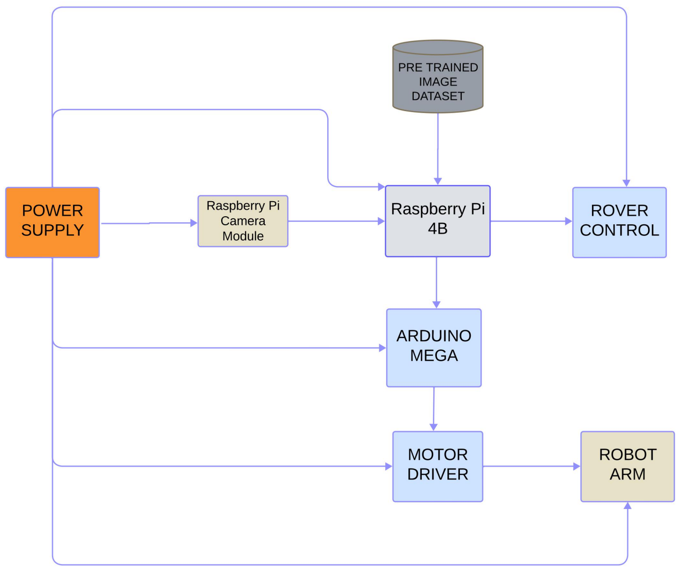


Figure 3.1: Block Diagram

A trained model called YOLO v5 for cotton detection is shown in the above block diagram. It is capable of recognizing cotton bolls from their surroundings. 1421 distinct annotated images using Roboflow were used to train the model on Google Collab plus platform. The trained model could be deployed on Raspberry Pi to carry out the cotton detection using the robotic arm. This model in future will be integrated with the robotic arm. The Raspberry Pi initiates the model's operation by receiving a video feed from the Raspberry Cam. The trained model then processes the video and sends the user the detected cotton boll. The cotton is then harvested from the plant by feeding the robot arm having 6 DOF with the coordinates that the system has determined for the cotton boll's location.

3.2 Data preprocessing

The Dataset was collected from two different websites, Roboflow. We utilized every bit of data from the over 1421 photos in the Roboflow dataset.In order to precisely represent the many stages and components of the cotton plant, the dataset is divided into five classes: split cotton boll, matured cotton boll, early boll, cotton blossom, and cotton bud. The process of creating the model was facilitated by the pre-labeled and annotated internet dataset that we gathered.

Figure 3.2: Detection of cotton bud

The images were preprocessed, followed by data augmentation, resizing. Before preprocessing, the dataset's image resolution was 640x640 pixels. 85% of the data set is used for training, 10% is used for validation, and 5% is used for testing [24]. The dataset contains images of individual cotton bolls on the plant to help the model recognize cotton

Figure 3.3: Detection of matured cotton boll

bolls up close, and images of multiple cotton bolls on a single plant to help the model detect cotton bolls at a distance.

Data preprocessing converts raw data into a format that computers and machine learning can comprehend and analyze as part of the data analysis process. In this process auto-orientation and resizing of the images is done. Auto-orientation adjusts the and corrects the orientation to make sure image are aligned properly. The images are then resized to 640x640 , which means that the original aspect ratio of images is changed. We annotated the photographs by putting an anchor box around the area of interest that has to be detected to obtain raw data for our investigation. The cotton boll in this case is growing in several stages, including split, maturity, early, and flower. By first specifying all classes for each growth stage and then selecting a particular class each time a bounding box is created during the annotation process, this can be split into five categories. The next stage is data augmentation after each image has been annotated. In augmentation for an original image , 3 augmented versions have been generated. During this procedure, the photographs are rotated 90 degrees in both clockwise and counterclockwise directions, flipped vertically and horizontally, and their exposure is adjusted between -12% and +12% to increase the size of the data. The Roboflow platform was used for data augmentation and annotation, and the dataset was exported in a format compatible with PyTorch version 5 [24].

3.3 Detection using Yolov5

This paper describes how YOLOv5, a deep learning-based pre-trained model, can be explicitly trained for a cotton dataset and, once installed, be able to recognize cotton in any surroundings. The specific goals at hand and the availability of data for the model's training are the determining factors when choosing YOLOv5 or any other machine-learning model. To achieve high-performance object identification, YOLO models are used. YOLO divides an image into grid systems, and each grid system is aware of its contents.

Table 3.1: Comparison of YOLO versions

Parameter	**YOLOv4**	**YOLOv5**	**YOLOv7**
Speed	Varies based on the model selected	Has good balance	Fastest
Accuracy	Varies according to the selected mode	Offers good balance	Highest
Open- source	No	Yes	No
Training data	COCO dataset	Diverse D5 dataset	COCO dataset
Computation power	Higher generally	Low than v4	Lowest

In the above table, various YOLO versions are compared. Since v5 is open source, lighter than v7, and more accurate than v4, it is the most appropriate of them for our application in cotton detection. Version 5 uses a variety of D5 datasets for data training, whereas versions 4 and 7 only use the COCO dataset, as shown in the table below. The cotton detection research uses this model:

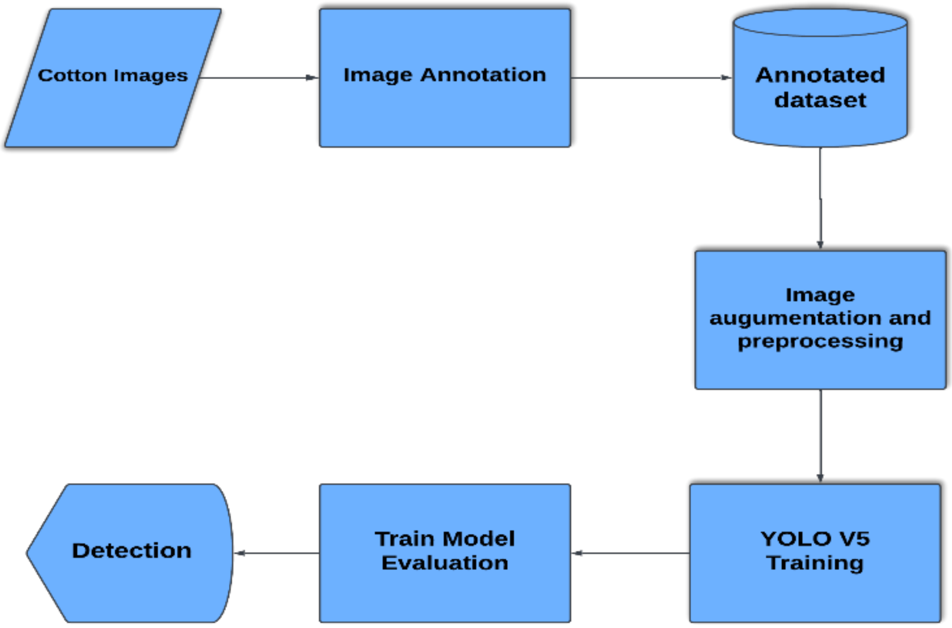


Figure 3.4: Generalized flow of YOLOv5 cotton detection model

The explanation of the YOLO cotton detecting model is provided in above figure:

Cotton Image: The initial stage of model training is data collection. This information was obtained from several sources, including cotton grown in a greenhouse or a laboratory, among others. The Roboflow dataset is used for training.

Image Annotation: Machine learning and artificial intelligence techniques are used to annotate images. Often, image annotation is carried out by human annotators who use an image annotation tool to label photos or tag pertinent information, such as assigning the proper classifications to different objects in an image. We created two classes for our model, as mentioned in the section on picture datasets. For simple tasks like classification and segmentation, pre-trained models are usually available. These models can be tailored to specific use cases with the help of Transfer Learning and little data. The comprehensive description of the Roboflow platform, where the annotation was finished, may be found in the data preprocessing section.

Annotated Dataset: The data is sent to the Colab for model training after going through the platform's annotation process. It is separated into three sections: test, validation, and training.

Image augmentation and preprocessing: Before exporting the dataset to Colab, it is first made larger using the augmentation technique, which is covered in detail in the data pretreatment section.

YOLOv5 training: To train our v5 model on our custom dataset, we first export our previously processed data from the Roboflow platform in a format that is compatible with Python. After everything is finished, a repository code is produced. We set the parameters to start training after importing the dataset into Colab using the code. Initially, we adjusted the image size to match the export size. The epochs for this model are then set. To train our model, we tried training it with epochs ranging from 50 to 200; however, the best results were obtained with a batch size of 32 and 150 epochs. We obtained an accuracy of 0.83 by using this input value.

Train Model Evaluation: We use the trained model to perform object detection in test set photos after testing it on unseen data. After an object has been detected, the performance is evaluated, and metrics including precision, mAP, and the accuracy and effectiveness of the model in object detection are examined.

Detection: After cotton is detected, a box enclosing the cotton emerges, which appears to represent the degree of confidence. This level only expresses the degree of confidence that the object being recognized is cotton or not (for instance, a level of 0.8 would indicate an 80% confidence level on cotton detection).

Table 3.2: Configuration details of Yolo

Parameter	**Details**
Batch Size	32
Model	YOLOv5s
Loss function	Returns class loss, box loss, object loss
Convolutional network	Backbone-Darknet Neck-PANet
Epochs	150
Resolution	640 x 640
Activation function	SiLU and Sigmoid activation function

3.4 Yolov5 architecture

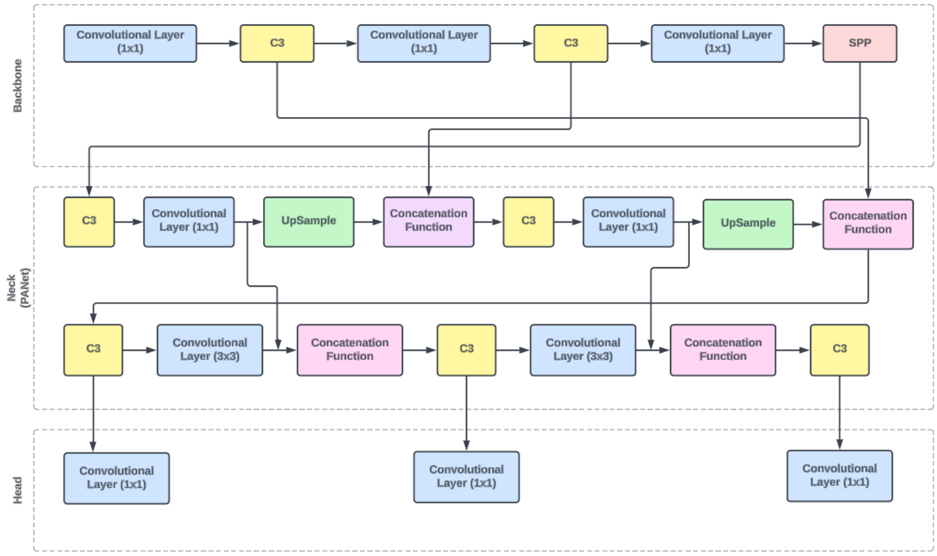


Figure 3.5: YOLOv5 architecture

The Yolov5 architecture consists of three parts:

1. **Backbone:** The task of extracting features from the input image falls to the backbone network. The backbone of YOLOv5 usually consists of a sequence of convolutional layers that increase the number of channels to record hierarchical information while gradually downsampling the input image's spatial dimensions.

   (a) **Convolutional layer**: This layer is responsible for extracting features from the input image by convolving with the kernels.

   (b) **C3**: Convolutional 3x3 is a specific type of convolutional layer in which 3x3 filters are applied to the input image.

   After a set of Convolution layer and C3 the output goes through SPP.

   (c) **SPP**: Spatial Pyramid Pooling is done which divides the feature maps into sub-regions of various sizes and the pooling operation is done without the need for resizing the image.

2. **Neck**: The YOLOv5 architecture's neck functions as a transitional element between the head and the backbone. It is in charge of performing further processing

on the characteristics that the backbone has retrieved to improve its representational ability. To enhance the network's capacity to identify objects of different sizes, YOLOv5's neck usually consists of extra convolutional layers, feature pyramid networks (FPNs), or other architectural components that merge features from several scales.

In this layer Convolution and C3 are done along with Upsampling and application of concatenation function.

(a) **Concatenation function**: The resultant feature maps from various sub-regions are concatenated together along the depth dimension after applying SPP. Concatenation retains spatial information across many scales by combining the data from these sub-regions into a single feature vector.

(b) **Upsample**: Feature maps can have their spatial resolution increased through the technique of upsampling. It means increasing the size of feature maps through the use of interpolation methods like bilinear or nearest-neighbor interpolation, or by adding empty rows and columns (zero-padding). Spatial features lost during downsampling processes, such as max pooling or convolution with stride, can be recovered with the aid of upsampling.

3. **Head**: The YOLOv5 architecture's head is in charge of producing object detection predictions using the features of the neck and backbone supply. The final output layer, which predicts boundaries, objectness scores, and probabilities of classes for the objects in the input image, usually comes after a series of convolutional layers. Depending on which version of YOLOv5 is being used, the head of the algorithm may incorporate methods like anchor box clustering, sigmoid activation, or softmax for classifying object classes, and prediction of objectness scores.

3.5 Design and Formulation

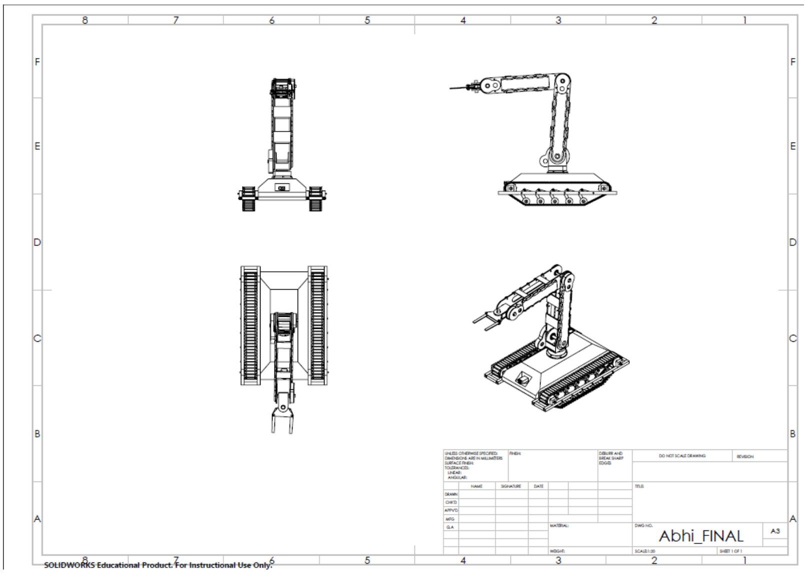


Figure 3.6: Schematic Diagram

Above figure illustrates the design for the robot arm and the rover. The self-navigating cotton-picking rover is made up of a wheeled platform for moving through cotton fields. The rover has a hand extension installed that can reach mature cotton bolls on plants and delicately harvest them. The rover's sensors and cameras enable it to capture in-depth images of the cotton plants. These photos are processed in real-time using computer vision algorithms, which allow mature cotton bolls to be distinguished from other plant components including leaves and stems. The computer vision system uses a variety of visual signals, including size, texture, and color, to accurately identify mature cotton bolls. Once a mature cotton boll is discovered, the rover's control system decides the optimal route and position for the hand attachment to reach and pick it. The hand extension's actuators allow for the exact and cautious removal. It is set up with defined pathways and obstacle elimination algorithms for efficient field coverage while avoiding collisions with impediments.

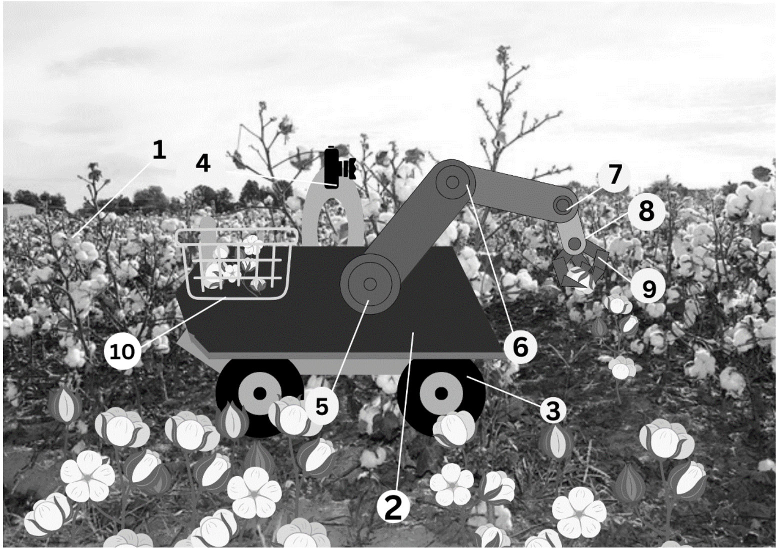


Figure 3.7: Working of prototype

Above figure shows rows of fully grown cotton plants extending into the distance on a cotton field. An automatic cotton picking rover is situated among the cotton plants in the image's foreground. The rover is a small, three-wheeled vehicle with a robust structure made for challenging outdoor conditions.

3.6 Objectives completed till date

1. To select an image processing model for the cotton detection in actual condition, which is easy to deploy on any processing device with less specification.

2. To train the YOLO v5 model to identify and detect cotton boll from the plant when provided with a real-life video feed through a camera module.

3. To design a robot arm to pluck cotton from a plant and store it in a container.

4. To create a robotic arm that, when manually operated, can accomplish particular, coordinated tasks in three dimensions.

3.7 Flow Chart and algorithm

The flow chart is as follows:

Take pictures of the cotton field with cameras or other video recording equipment. Make sure there is enough quality in the video to process the images accurately.

Picture Division:

Divide the photos into segments so that the cotton plants are separated from the surrounding area and other objects. Convolutional neural networks (CNNs) trained on annotated datasets are a common technique for learning the characteristics of cotton plants.

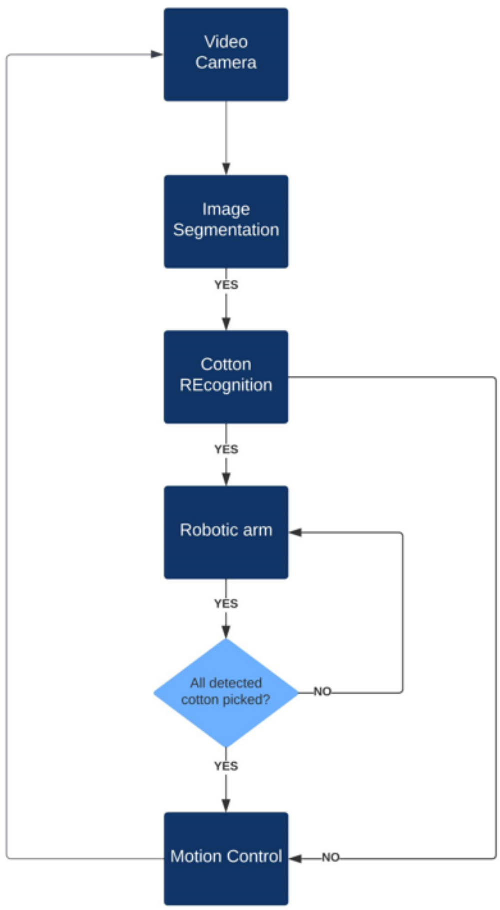


Figure 3.8: Flow Chart

Recognition of Cotton:

For cotton recognition, use a deep learning model. Train the model to discriminate between various cotton plant components, particularly the cotton bolls. Individual cotton bolls within the segmented images can be recognized and located using characteristics like color, texture, and shape.

Arm Control via Robots:

Apply control algorithms to convert the locations of cotton bolls that have been identified into accurate robotic arm movements. To account for changes in the positions of the plant and cotton, take into consideration feedback mechanisms like sensors on the robotic arm.

Picking Cotton:

Create a mechanism for the robotic arm's end effector—the portion that interacts with the surroundings—to delicately pick up and remove the cotton bolls. Use a grasping device that can adjust to the various sizes and positions of cotton bolls.

Iterative Method:

Repeat the entire procedure for every frame in the movie or every plant in the field. Use real-time processing to adjust to conditions that change, such as shifts in plant growth and lighting.

Chapter 4

Results and Discussions

4.1 Hardware Setup

The Cotton Picking Robot has extensive hardware in the Robotic body where three different types of motors are used, these motors are controlled using a motor driver whose current rating is more than 5 Amperes.

4.1.1 Hardware Components and Specifications

- **Arduino Mega**

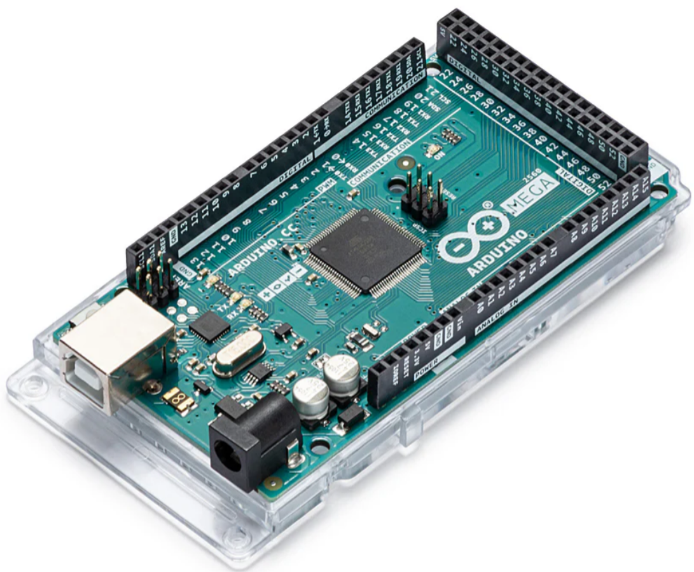


Figure 4.1: Arduino Mega

The Arduino Mega is a microcontroller board that is built around the ATmega2560. This board is perfect for more complicated projects because it has a lot more power than many other Arduino boards. With its huge memory capacity, it can accommodate more variables and larger programs. Temperature, potentiometer, and light sensors are just a few examples of the sensors that may be connected to the Arduino Mega's 16 analog inputs. It also has 54 digital pins for input and output (I/O), 15 of which can be utilized as outputs for pulse width modulation, or PWM. It can manage numerous components at once, including LEDs, relays, buttons, and screens, because to its huge number of I/O pins.

Table 4.1: Specifications of Arduino Mega

Parameter	**Value**
Operating voltage	5V
Analog input pins	16
Digital I/O pins	54
Clock speed	16 MHz
Flash memory	256 KB

- **Servo Driver**

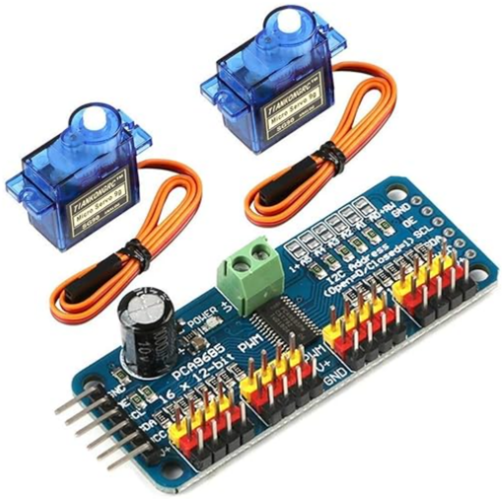


Figure 4.2: 16-channel 12-bit PWM servo driver

A compact module, the 16-channel 12-bit PWM servo driver, has the ability to precisely control several servo motors. Using pulse-width modulation (PWM) signals, it precisely places servos, offering 12-bit resolution for more fluid motions. For robotics and automation applications, precise motion control—which can manage up to 16 servos independently—is essential.

Table 4.2: Specifications of Servo Driver

Parameter	**Value**
Chip	PCA9685
Number of channels	16
Resolution	12-bit
PWM frequency range	40 Hz to 1000 Hz

- **Servo Motor**

Figure 4.3: Servo 995

The Servo 995 is a standard-sized servo motor that is well-known for its dependability and adaptability. It operates at 4.8V to 6V and has a torque range suitable for many robotic and hobbyist applications. Its widely compatible standard servo interface is used by both animatronics and model airplanes.

Table 4.3: Specifications of Servo 995

Parameter	**Value**
Operating voltage	4.8V - 7.2V
Rotation range	180°
Motor type	DC Motor
Connector type	3-pin (Power, Ground, Signal)

Figure 4.4: Servo MG90s

The MG90s and other small servo motors are renowned for their small size and light weight. Because it can run on 4.8 to 6 volts and has respectable torque and speed performance, it is appropriate for small-scale robotics and radio control projects.

Table 4.4: Specifications of Servo MG90s

Parameter	**Value**
Operating voltage	4.8V - 6V
Dead bandwidth	5 µs
Rotation range	180°
Operating temp. range	-30°C to +60°C

Figure 4.5: Servo SG90

The SG90 micro servo's lightweight and compact design makes it an affordable choice. Operating at 4.8V to 6V, its modest torque and speed make it perfect for little mechanical jobs, remote control vehicles, and lightweight robotics applications.

Table 4.5: Specifications of Servo SG90

Parameter	**Value**
Operating voltage	4.8V - 6V
Weight	9 grams
Dead bandwidth	10 µs
Gear Type	Plastic

- **Power Supply**

Figure 4.6: SMPS 12v,5A

SMPS 12V, 5A, often known as switched mode power supply, is a compact and efficient power source. Its maximum current capacity of 5 amps and its consistent 12 volt output make it suitable for a wide range of DIY projects and electronics. Its switching technique ensures minimal heat generation and optimal energy efficiency.

- **Connecting Wires**

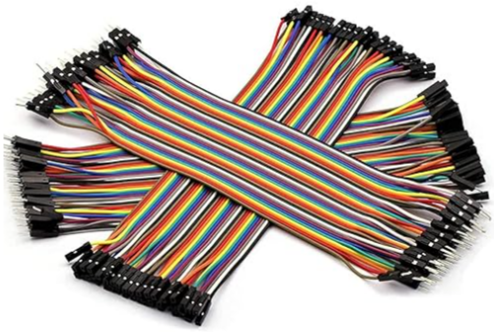


Figure 4.7: Jumper cable

4.2 Software Setup

- **Initial Setup**

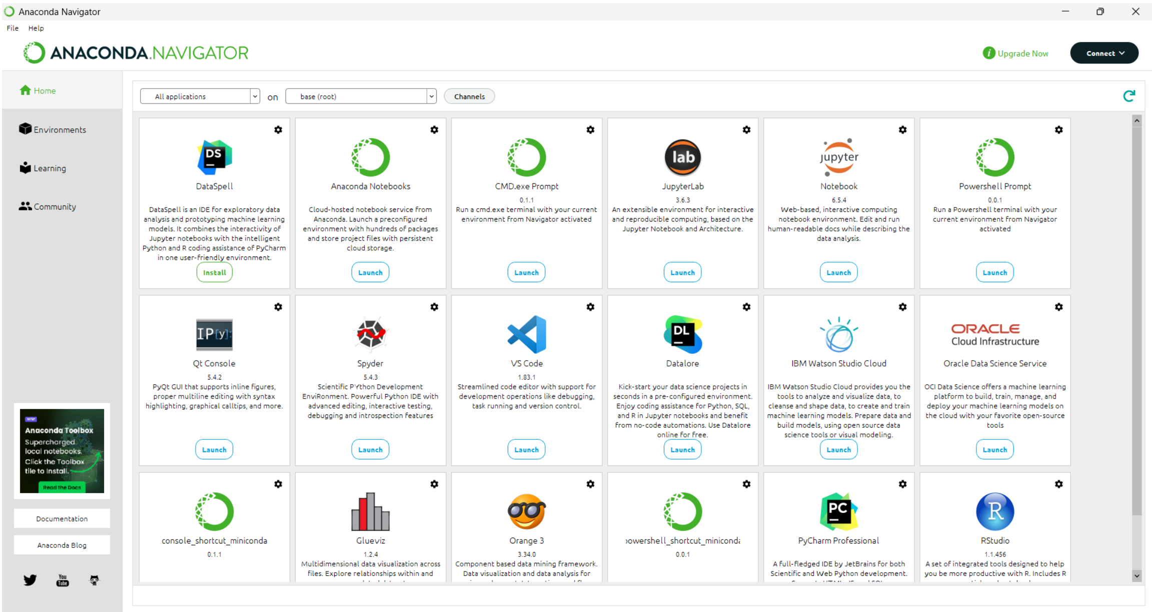


Figure 4.8: Anaconda Dashboard

Install Anaconda on your laptop first, then set up an environment within it. Running on Linux, macOS, and Windows, Conda is an open-source package and environment management system. Conda installs, runs, and updates dependencies and packages quickly. On your own computer, it also makes it simple to build, save, load, and move between environments. Although it may package and deliver software for any language, it was designed for Python projects.

- **Jupyter Notebook**

You may create and share documents with live code, equations, graphics, and narrative text using the well-known open-source web program Jupyter Notebook. For interactive computing and prototyping, it is extensively utilized in data science and machine learning. There are many different frameworks and packages available for Jupyter Notebook object identification, but TensorFlow or PyTorch for Python is one of the most popular options.

To ensure that all of the processing is done on the GPU, install Jupyter Notebook in the environment that has been built and add the file locations for Yolov5, Cuda, and

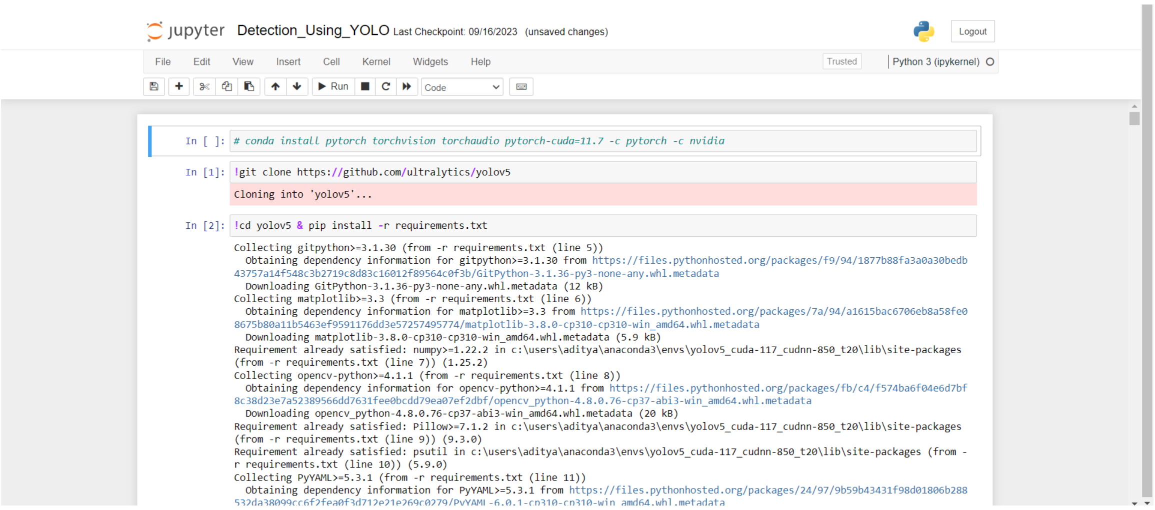


Figure 4.9: Jupyter Dashboard

Cudnn. Data scientists can create and share documents with live code, equations, and other multimedia elements using Jupyter Notebook, an open-source web tool.

- **PyTorch**

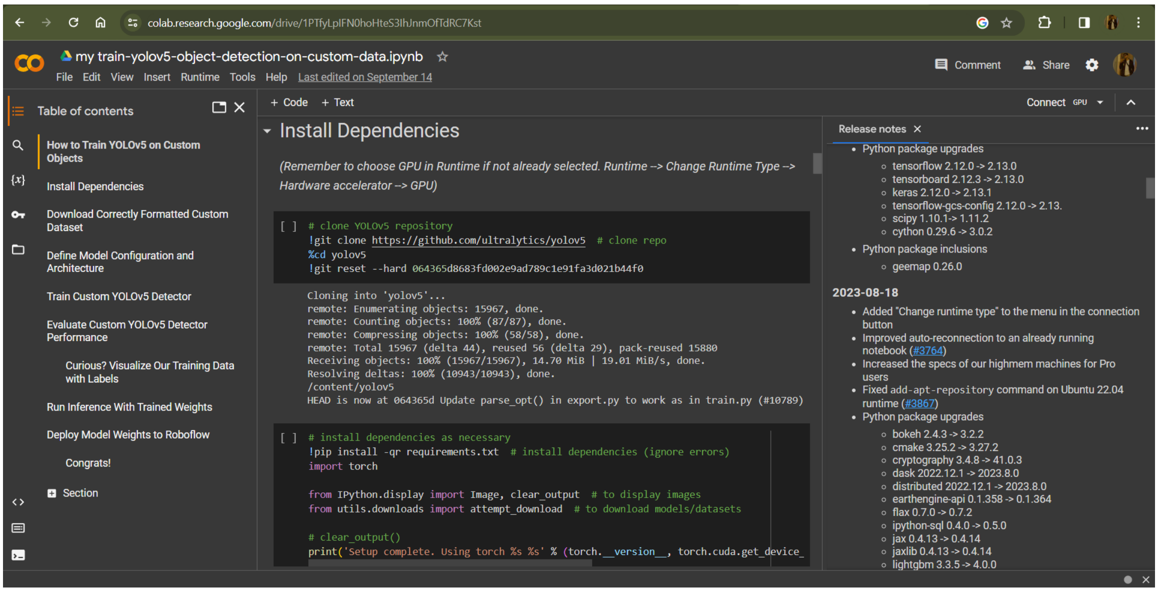


Figure 4.10: Google Colab

Install the relevant Pytorch version on the machine. PyTorch is a feature-rich framework for creating deep learning models, a kind of machine learning that's frequently applied to tasks like language processing and picture identification. Most machine learning developers find it reasonably easy to understand and use because it is written in Python.

- **Arduino IDE**

Writing, editing, and uploading code to Arduino boards is done with the software program known as the Arduino Integrated Development Environment (IDE). It has a code editor with syntax highlighting for creating sketches, or programs that are developed with functions like setup() and loop(). Users can choose the right board and communication port for their projects by using the IDE's support for numerous built-in and external libraries. Verifying, assembling, and uploading code to the Arduino hardware are important tasks. The IDE also offers a serial monitor to facilitate communication between the board and the computer, as well as a ton of tutorials and example sketches to help with learning. With compatibility for Windows, macOS, and Linux, the Arduino IDE's open-source design makes it a popular and adaptable option.

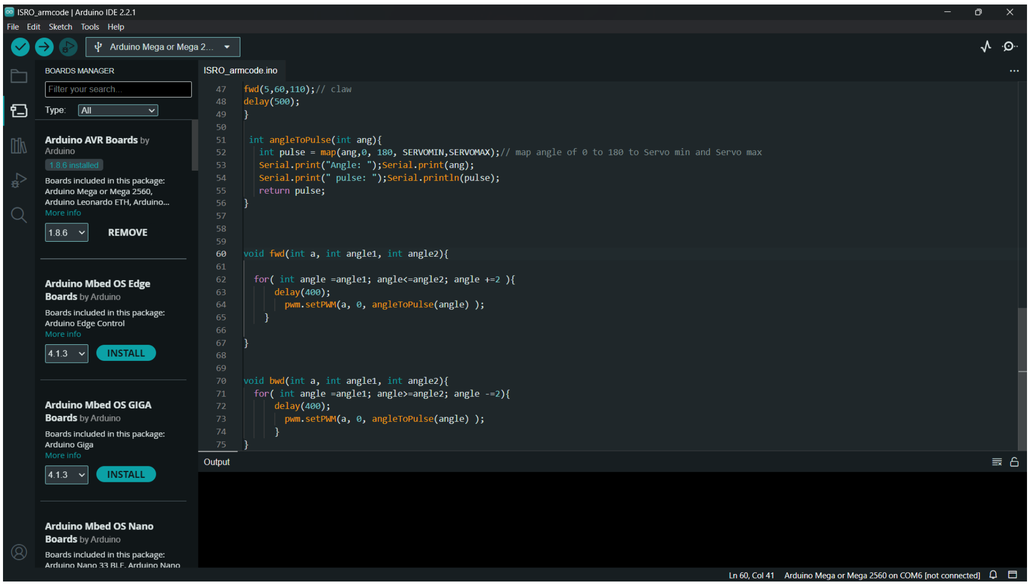


Figure 4.11: Arduino IDE

4.3 Results

1. **Software Results**

   The confusion matrix of our model is specified in Figure. A confusion matrix, also called an error matrix, is a specific table arrangement used in the field of machine learning, specifically for statistical classification problems. It makes the performance of an algorithm easier to visualize. Typically, this algorithm is supervised learning; in unsupervised learning, it is commonly referred to as a matching matrix

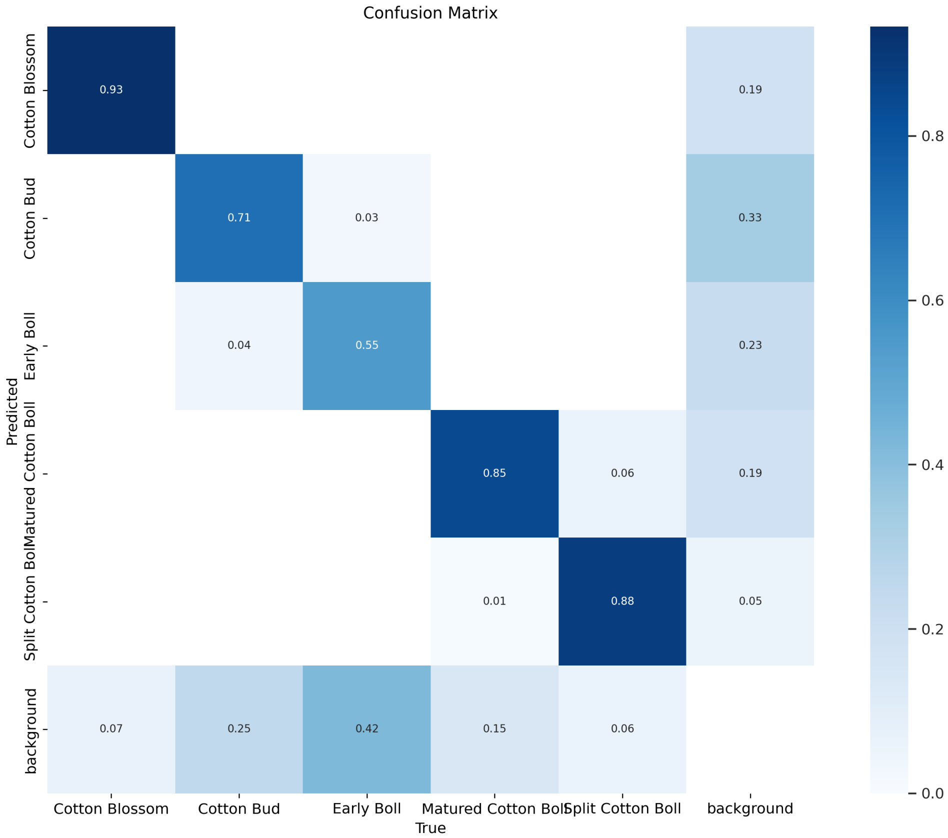


Figure 4.12: Confusion Matrix

From Figure 4.12 we can see from the confusion matrix that the true value for the cotton blossom matches the projected values by 0.93 times, the true value for the bud matches by 0.71 times, and the true value for the early boll matches by 0.55 times. Both the split cotton forecast and the matured boll prediction match the true value by 0.88 times and 0.85, respectively. The background influences the values of the cotton buds and the early boll.

In Figure 4.13, the F1 curve as a reference for all classes, the confidence value of

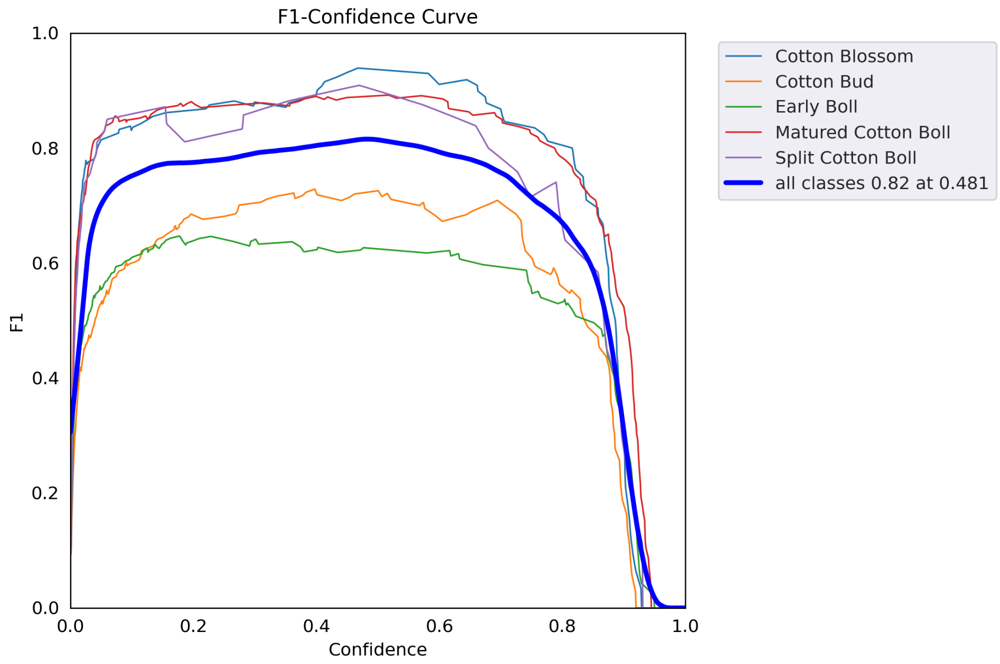


Figure 4.13: F1 confidence curve

0.481 maximizes both precision and recall. A greater confidence value is preferred in many situations. This model's confidence value must be 0.8, which isn't far from its highest confidence of 0.82.

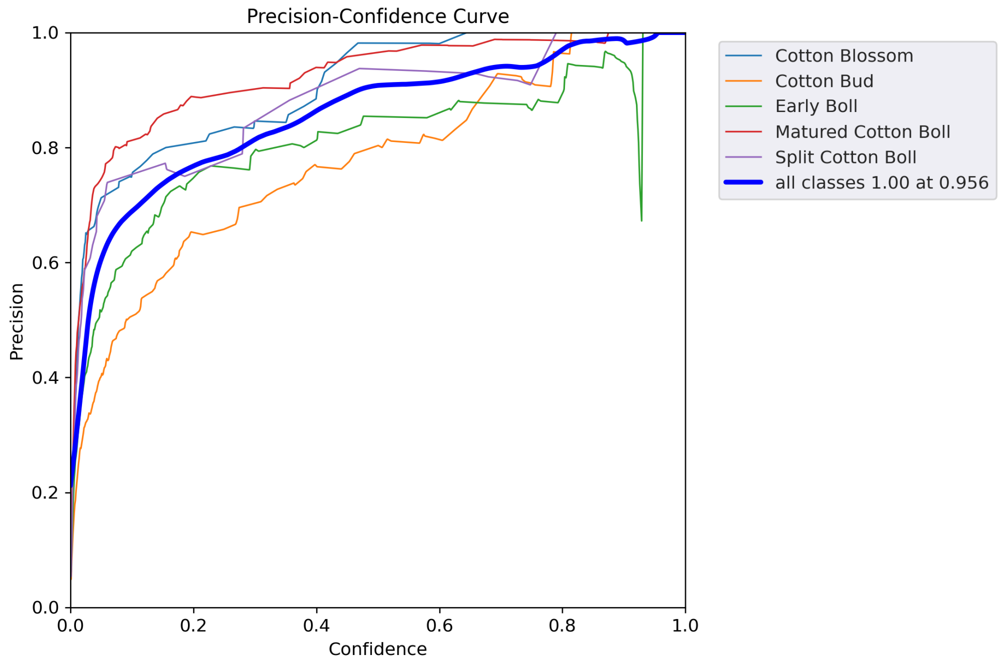


Figure 4.14: Precision confidence curve

Above figure illustrates the relationship between the model's confidence and precision.

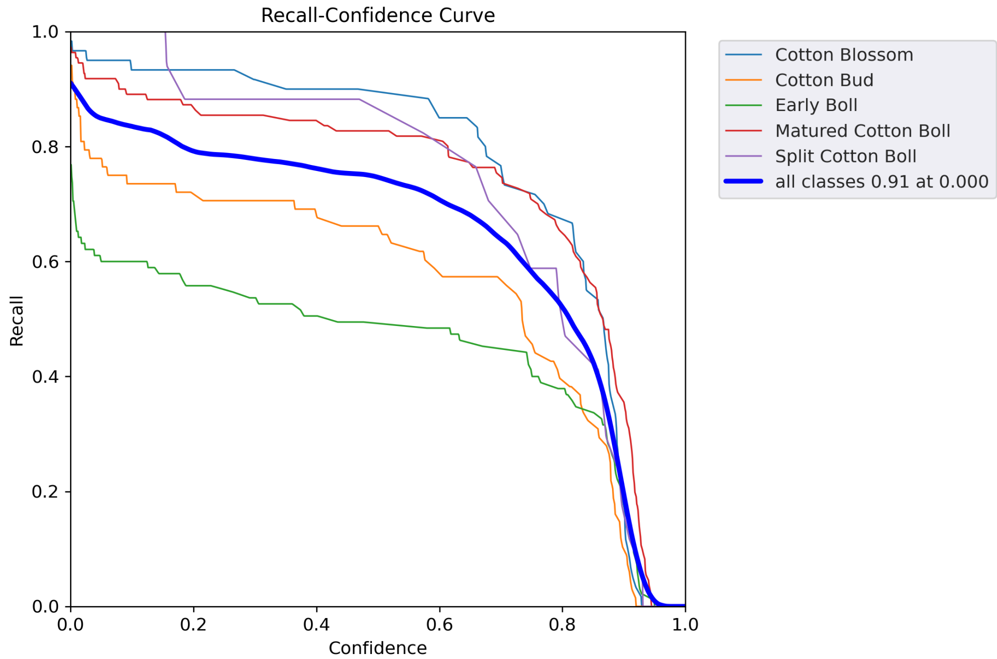


Figure 4.15: Recall confidence curve

Above figure shows the relationship between the trained model's recall and confidence.

$$\text{F1} = 2 * \left(\frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}}\right) \qquad (1)$$

$$\text{Precision} = \frac{\text{TP}}{\text{TP}+\text{FP}} \qquad (2)$$

$$\text{Recall} = \frac{\text{TP}}{\text{TP}+\text{FN}} \qquad (3)$$

$$\text{Accuracy} = \frac{\text{TP}+\text{TN}}{\text{TP}+\text{FP}+\text{TN}+\text{FN}} \qquad (4)$$

Figure 4.16: Evaluation metrics

The summary of performance metrics is given in the following table which gives information of precision, recall and F1 score of multiple classes.

Table 4.6: Performance metrics

lasses	Precision	Recall	F-! score
cotton Blossom	0.8	0.93	0.87
Cotton Bud	0.66	0.71	0.68
Early Boll	0.67	0.55	0.60
Mature Cotton	0.77	0.84	0.80
Split Cotton	0.91	0.87	0.88

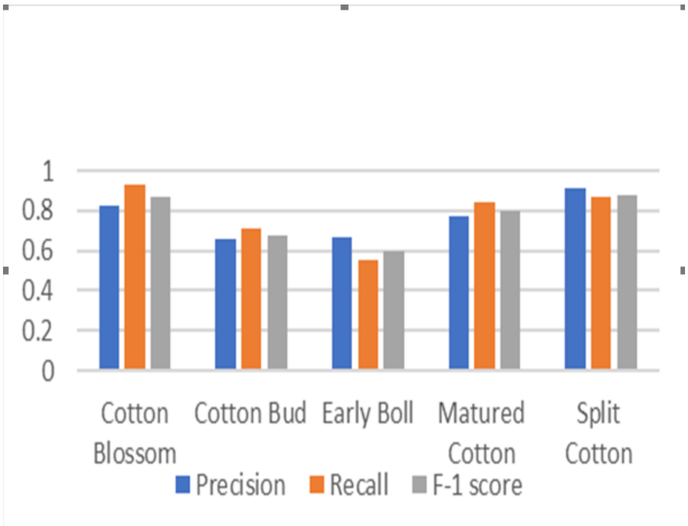


Figure 4.17: Performance metrics

2. **Hardware Results**

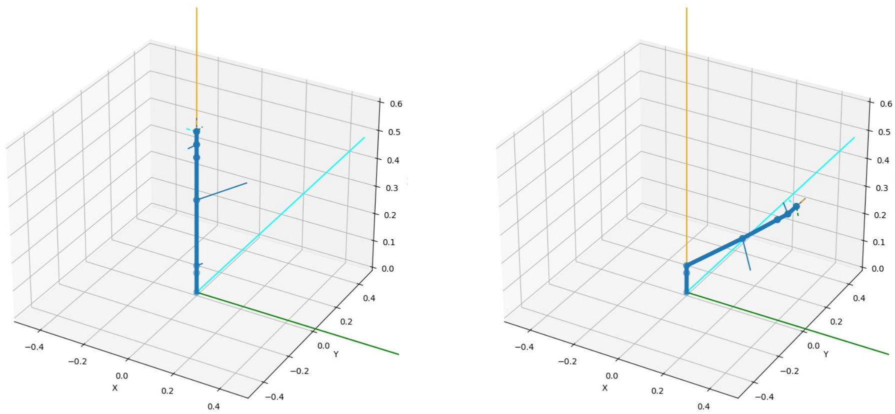


Figure 4.18: Simulation results for the position of the robotic arm

Concerning with the above figure, the simulation results were obtained by running a Python program on Jupyter Notebook which depicted the position of the robotic arm. To get the position and the required angles required for the movement of the arm, the 3d coordinates were provided to the program which then calculates the angles for each joint resulting in the positioning of the end effect-or at the mentioned 3d coordinates to the program.

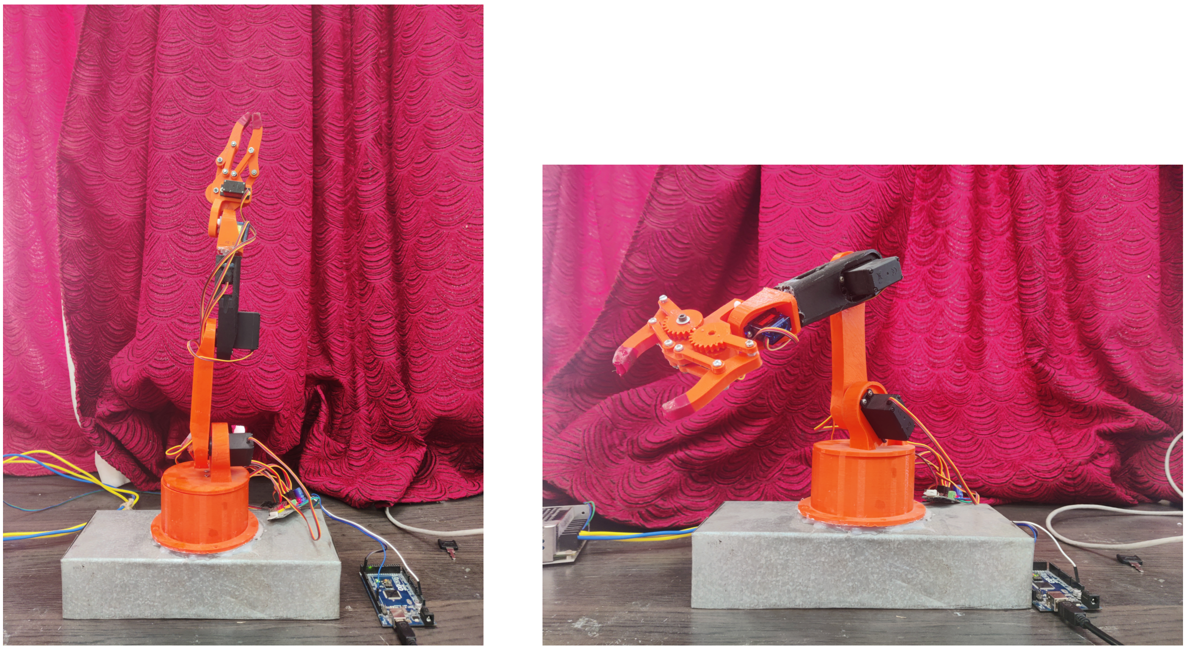


Figure 4.19: Results of working of the robotic arm

The Python code that developed the simulation results was modified into Embedded C for real-time servos control and uploaded on Arduino Mega. The micro controller was able to actuate the servos according to the coordinates provided, based on the calculation of the angles for each joint the simulation results and the real-time working of the arm had similar results. The model is shown in above figure.

4.4 Summary

The summary of the report is to create a reliable system that can recognize, handle, harvest, and transport cotton blooms.

A rover equipped with a robot arm and a storage area for processed cotton blooms would be the ideal setup for that.

The system's overall practical application is to decrease the amount of labor and resources needed for cotton harvesting while increasing its profitability and efficiency.

Chapter 5

Advantage and Applications

5.1 Advantages

The advantages of the proposed system can be summarized as follow:

1. There is no need for human intervention as the robot can work autonomously.
2. Real-time image processing improves crop yield and making the process more efficient.
3. Improved accuracy of cotton detection and chances of missing or damaging the cotton is less.
4. Using computer vision the probability of unripe cotton being harvested is less, thereby ensuring minimal wastage.
5. Reducing need for chemical defoliation, machine learning based detection contributes to environment friendly practices.

5.2 Applications

the proposed system can be employed at variety of applications such as :

1. Crop yield estimation
2. Textile industry
3. Disease and pest detection

Chapter 6

Conclusion and Future Scope

6.1 Conclusion

In this paper, an object detection technique called YOLOv5 (You Only Look Once version 5) was used to construct a model for cotton detection. With the help of YOLOv5 and a PyTorch-compatible dataset, we successfully developed and trained a cotton recognition model using the Google Colab platform. In order to teach the model to recognize and correctly anticipate the existence of cotton bolls in new, unseen photos, annotated photographs of cotton bolls at different stages of growth were fed to it. The cotton bloom, cotton bud, early boll, matured boll, and split cotton boll are the five different categories into which the cotton detection model was intended to identify and categorize cotton bolls. Following the training phase, the model showed a high degree of accuracy in identifying and categorizing these various cotton boll phases.

Figure 6.1: Real time testing of model using Images

Regarding the robotic arm, while it was intended to reach specific locations and execute picking operations using determined angles, it was not feasible to incorporate the cotton detecting model within the parameters of this project. Nonetheless, simulation of the robotic arm's functionality was done, and the results demonstrated that the arm could precisely locate given coordinates and carry out picking tasks as predicted. The simulation results matched the theoretical requirements closely and showed promise. In order to establish a seamless and autonomous cotton-picking system, future work will concentrate on fully integrating the robotic arm with the YOLOv5-based cotton detecting algorithm. By lowering labor costs and raising productivity in the cotton sector, this integration hopes to open the door for more sophisticated agricultural robots solutions.

6.2 Future Scope

1. **Combining Various Sensor Systems:** Use a range of sensors, including LiDAR and infrared sensors, to provide the robot with a thorough grasp of the surroundings in the cotton field.

2. **Personalized Path Planning and Self-governing Navigation:** To improve the robot's agility in the field, create complex algorithms for autonomous navigation and dynamic path planning.

3. **Technological Developments in Image Processing:** Investigate and apply state-of-the-art image processing techniques to improve cotton bloom detection accuracy and speed.

4. **Diverse Methods of Harvesting:** Consider various cotton plant varieties and field variations while researching and implementing solutions that adapt to changing harvesting conditions.

5. **Human-Robot Synchronization:** This can entail building interfaces for remote observation and management or allowing the robot to work in control of humans on more complex jobs.

Bibliography

[1] K. Fue, W. Porter, E. Barnes, C. Li, and G. Rains, "Center-articulated hydrostatic cotton harvesting rover using visual-servoing control and a finite state machine," *Electronics*, vol. 9, no. 8, p. 1226, 2020.

[2] M. H. Saleem, J. Potgieter, and K. M. Arif, "Automation in agriculture by machine and deep learning techniques: A review of recent developments," *Precision Agriculture*, vol. 22, pp. 2053–2091, 2021.

[3] K. Fue, T. Georgia, W. Porter, E. Barnes, and G. Rains, "Visual row detection using pixel-based algorithm and stereo camera for cotton-picking robot," 2019 ASABE Annual International Meeting, Boston, Massachusetts, 2019.

[4] E. Barnes, G. Morgan, K. Hake, J. Devine, R. Kurtz, G. Ibendahl, A. Sharda, G. Rains, J. Snider, J. M. Maja, *et al.*, "Opportunities for robotic systems and automation in cotton production," *AgriEngineering*, vol. 3, no. 2, pp. 339–362, 2021.

[5] Y. Zhang, G. Yang, Y. Liu, C. Wang, and Y. Yin, "An improved yolo network for unopened cotton boll detection in the field," *Journal of Intelligent & Fuzzy Systems*, vol. 42, no. 3, pp. 2193–2206, 2022.

[6] R. Xu, C. Li, A. H. Paterson, Y. Jiang, S. Sun, and J. S. Robertson, "Aerial images and convolutional neural network for cotton bloom detection," *Frontiers in plant science*, vol. 8, p. 2235, 2018.

[7] A. S. Deshmukh and A. Mohanty, "Cotton mechanisation in india and across globe: a review," *International Journal of Advance Research in Engineering, Science & Technology*, vol. 3, no. 1, pp. 2393–9877, 2016.

[8] H. Li, G. Wang, Z. Dong, X. Wei, M. Wu, H. Song, and S. O. Y. Amankwah, "Identifying cotton fields from remote sensing images using multiple deep learning networks," *Agronomy*, vol. 11, no. 1, p. 174, 2021.

[9] Z. Xu, M. A. Latif, S. S. Madni, A. Rafiq, I. Alam, and M. A. Habib, "Detecting white cotton bolls using high-resolution aerial imagery acquired through unmanned aerial system," *IEEE Access*, vol. 9, pp. 169068–169081, 2021.

[10] A. Issac, H. Yadav, G. Rains, and J. M. Velni, "Dimensionality reduction of high-throughput phenotyping data in cotton fields," *IFAC-PapersOnLine*, vol. 55, no. 32, pp. 153–158, 2022.

[11] A. I. Oliveira, T. M. Carvalho, F. F. Martins, A. C. Leite, K. T. Figueiredo, M. M. Vellasco, and W. Caarls, "On the intelligent control design of an agricultural mobile robot for cotton crop monitoring," in *2019 12th International Conference on Developments in eSystems Engineering (DeSE)*, pp. 563–568, IEEE, 2019.

[12] Y. Wang, X. Zhu, and C. Ji, "Machine vision based cotton recognition for cotton harvesting robot," in *Computer And Computing Technologies In Agriculture, Volume II: First IFIP TC 12 International Conference on Computer and Computing Technologies in Agriculture (CCTA 2007), Wuyishan, China, August 18-20, 2007 1*, pp. 1421–1425, Springer, 2008.

[13] N. A. Sanjay, N. Venkatramani, V. Harinee, and V. Dinesh, "Cotton harvester through the application of machine learning and image processing techniques," *Materials Today: Proceedings*, vol. 47, pp. 2200–2205, 2021.

[14] K. G. Fue, E. M. Barnes, W. M. Porter, and G. C. Rains, "Visual control of cotton-picking rover and manipulator using a ros-independent finite state machine," in *2019 ASABE Annual International Meeting*, p. 1, American Society of Agricultural and Biological Engineers, 2019.

[15] S. Fountas, I. Malounas, L. Athanasakos, I. Avgoustakis, and B. Espejo-Garcia, "Ai-assisted vision for agricultural robots," *AgriEngineering*, vol. 4, no. 3, pp. 674–694, 2022.

[16] Z. Liu, L. Wang, Z. Liu, X. Wang, C. Hu, and J. Xing, "Detection of cotton seed damage based on improved yolov5," *Processes*, vol. 11, no. 9, p. 2682, 2023.

[17] P. K. Yadav, J. A. Thomasson, S. W. Searcy, R. G. Hardin, U. Braga-Neto, S. C. Popescu, D. E. Martin, R. Rodriguez, K. Meza, J. Enciso, *et al.*, "Computer vision for volunteer cotton detection in a corn field with uas remote sensing imagery and spot spray applications," *arXiv preprint arXiv:2207.07334*, 2022.

[18] M. Sun, Y. Li, Y. Qi, H. Zhou, and L. Tian, "Cotton boll localization method based on point annotation and multi-scale fusion," *Frontiers in Plant Science*, vol. 13, p. 960592, 2022.

[19] S. K. Shah, R. Mishra, D. Prasanna, and G. Mohapatro, "Fabrication and deviation analysis of a 5-axis robotic arm using image processing technique," *Materials Today: Proceedings*, vol. 18, pp. 4622–4629, 2019.

[20] M. J. Micheletto, C. I. Chesñevar, and R. Santos, "Methods and applications of 3d ground crop analysis using lidar technology: A survey," *Sensors*, vol. 23, no. 16, p. 7212, 2023.

[21] R. Reddy and S. Nagaraja, "Integration of robotic arm with vision system," in *2014 IEEE International Conference on Computational Intelligence and Computing Research*, pp. 1–5, IEEE, 2014.

[22] N. Rai, B. Rai, and P. Rai, "Computer vision approach for controlling educational robotic arm based on object properties," in *2014 2nd International Conference on Emerging Technology Trends in Electronics, Communication and Networking*, pp. 1–9, IEEE, 2014.

[23] J. Shi, Y. Bai, Z. Diao, J. Zhou, X. Yao, and B. Zhang, "Row detection based navigation and guidance for agricultural robots and autonomous vehicles in row-crop fields: methods and applications," *Agronomy*, vol. 13, no. 7, p. 1780, 2023.

[24] proj1, "cotton$_d$*atadataset.*″, feb 2024. visited on 2024-02-15.

Appendix A

Project Outcomes

A.1 Plagiarism Report

Cotton_Picking_Rover_1-1-50[1].pdf

ORIGINALITY REPORT

10%	6%	3%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Bayard Rustin High School Student Paper	3%
2	Submitted to University of Macau Student Paper	1%
3	Submitted to Central University of Rajasthan Student Paper	<1%
4	Submitted to Madanapalle Institute of Technology and Science Student Paper	<1%
5	Prajakta Shinde, Kautubhi Shukla, Shraddha Zagade, V. S. Kumbhar. "E-Rationing Management System", International Journal of Research in Advent Technology, 2019 Publication	<1%
6	ir.uitm.edu.my Internet Source	<1%
7	Pramod Kumar Mishra, Ankit Sharma, Apoorv Prakash. "Current research and development in cotton harvesters: A review with	<1%

application to Indian cotton production systems", Heliyon, 2023
Publication

8	dokumen.pub Internet Source	<1 %
9	Zhongjian Xu, Muhammad Ahsan Latif, Syed Shaham Madni, Ammar Rafiq, Iqbal Alam, Muhammad Asif Habib. "Detecting White Cotton Bolls Using High-Resolution Aerial Imagery Acquired Through Unmanned Aerial System", IEEE Access, 2021 Publication	<1 %
10	Submitted to Liverpool John Moores University Student Paper	<1 %
11	Yong Wang. "Machine Vision Based Cotton Recognition for Cotton Harvesting Robot", The International Federation for Information Processing, 2008 Publication	<1 %
12	Submitted to Middlesex University Student Paper	<1 %
13	neuroquantology.com Internet Source	<1 %
14	Submitted to Asia Pacific University College of Technology and Innovation (UCTI) Student Paper	<1 %

15	Dipali Dhake, Kunal Gaikwad, Shreyas Gunjal, Sanket Walunj. "LSTM Algorithm for the Detection of Mental Stress in EEG", 2023 3rd International Conference on Intelligent Technologies (CONIT), 2023 Publication	<1 %
16	erepository.uonbi.ac.ke Internet Source	<1 %
17	Submitted to University of Northumbria at Newcastle Student Paper	<1 %
18	Submitted to Curtin University of Technology Student Paper	<1 %
19	Submitted to Mansoura University Student Paper	<1 %
20	megaeshop.pk Internet Source	<1 %
21	Submitted to Universiti Teknologi MARA Student Paper	<1 %
22	Submitted to University of Hull Student Paper	<1 %
23	financedocbox.com Internet Source	<1 %
24	Submitted to iGroup Student Paper	<1 %

25	Submitted to University of Sheffield Student Paper	<1 %
26	www.mdpi.com Internet Source	<1 %
27	"Computer Vision and Image Processing", Springer Science and Business Media LLC, 2022 Publication	<1 %
28	www.slideshare.net Internet Source	<1 %
29	aerodefenseinternational.com Internet Source	<1 %
30	www.ijraset.com Internet Source	<1 %
31	www.radioshack.com Internet Source	<1 %
32	www.tnsroindia.org.in Internet Source	<1 %
33	Ming Sun, Yanan Li, Yang Qi, Huabing Zhou, LongXing Tian. "Cotton boll localization method based on point annotation and multi-scale fusion", Frontiers in Plant Science, 2022 Publication	<1 %
34	Spyros Fountas, Ioannis Malounas, Loukas Athanasakos, Ioannis Avgoustakis, Borja	<1 %

Espejo-Garcia. "AI-Assisted Vision for Agricultural Robots", AgriEngineering, 2022
Publication

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		

A.2 Project Competition Participation Certificates

Shree Chanakya Education Society's
INDIRA COLLEGE OF ENGINEERING & MANAGEMENT
"Empowering Minds to Elevate Lives"

TECHFEST 2K24
INFOSPARK

CERTIFICATE
OF APPRECIATION

This is to certify that, Mr/Ms. Abhimanyu Kanase of PCCOER has participated in the Project Competition organized by Computer Department on 4th & 5th March 2024 at Indira College of Engineering and Management, Pune.

Staff Co-ordinator | Dr.Vikas Nandgaonkar, HOD | Dr.Soumitra Das, Principal

DEPARTMENT OF E&TC ENGINEERING
PIMPRI CHINCHWAD EDUCATION TRUST'S
PIMPRI CHINCHWAD COLLEGE OF ENGINEERING AND RESEARCH, RAVET

AgroTech Fest-2K24

CERTIFICATE OF APPRECIATION

This is to certify that Abhimanyu Kanse of PCCOER have successfully participated & secured First/Second/Third prize at National Level AgroTech Fest-2k24 Organized by Department of Electronics & Telecommunication Pimpri Chinchwad College of Engineering & Research, Ravet, Pune on 19th April, 2024.

Mr. Kishor Bhangale, Coordinator | Dr. Rahul Mapari, Head of Department | Dr. Harish U. Tiwari, Principal

Shree Chanakya Education Society's
INDIRA COLLEGE OF ENGINEERING & MANAGEMENT
"Empowering Minds to Elevate Lives"

INDIRA

After 30 Years, Moving To INDIRA@40 EMBRACING Excellence with Empathy

iCONS

TECHFEST 2K24
INFOSPARK

CERTIFICATE
OF APPRECIATION

This is to certify that, Mr/Ms. Anshu Varghese of PCCOER has participated in the Project Competition organized by Computer Department on 4th & 5th March 2024 at Indira College of Engineering and Management, Pune.

	Dr.Vikas Nandgaonkar	Dr.Soumitra Das
Staff Co-ordinator	HOD	Principal

DEPARTMENT OF E&TC ENGINEERING
PIMPRI CHINCHWAD EDUCATION TRUST'S
PIMPRI CHINCHWAD COLLEGE OF ENGINEERING AND RESEARCH, RAVET

AgroTech Fest-2K24

CERTIFICATE OF APPRECIATION

This is to certify that Anshu Vergese of PCCOER have successfully participated & secured First/Second/Third prize at National Level AgroTech Fest-2k24 Organized by Department of Electronics & Telecommunication Pimpri Chinchwad College of Engineering & Research, Ravet, Pune on 19th April, 2024.

Mr. Kishor Bhangale	Dr. Rahul Mapari	Dr. Harish U. Tiwari
Coordinator	Head of Department	Principal


INDIRA
30 YEARS
After 30 Years, Moving To
INDIRA@40
EMBRACING
"Excellence with Empathy"
Shree Chanakya Education Society's
INDIRA COLLEGE OF
ENGINEERING & MANAGEMENT
"Empowering Minds to Elevate Lives"
ICONS
TECHFEST 2K24
INFOSPARK
CERTIFICATE
OF APPRECIATION
This is to certify that, Mr/Ms. Aditya Deshmukh
of PCCOER has participated in the Project Competition
organized by Computer Department on 4th & 5th March 2024 at Indira College of Engineering and
Management, Pune.
Staff Co-ordinator
Dr.Vikas Nandgaonkar
HOD
Dr.Soumitra Das
Principal


DEPARTMENT OF E&TC ENGINEERING
PIMPRI CHINCHWAD EDUCATION TRUST'S
PIMPRI CHINCHWAD COLLEGE OF ENGINEERING AND
RESEARCH, RAVET
AgroTech Fest-2K24
CERTIFICATE OF APPRECIATION
This is to certify that Aditya Deshmukh of
PCCOER have successfully participated & secured
First/Second/Third prize at National Level AgroTech Fest-2k24 Organized by
Department of Electronics & Telecommunication Pimpri Chinchwad College
of Engineering & Research, Ravet, Pune on 19th April, 2024.
Mr. Kishor Bhangale
Coordinator
Dr. Rahul Mapari
Head of Department
Dr. Harish U. Tiwari
Principal

A.3 Publication Documents

A.3.1 Publication Work

Cotton Detection Using YOLOv5

Rahul Mapari
Department of E&TC, Pimpri Chinchwad College of Engineering and Research, Ravet,
Pune, India
rahul.mapari@pccoer.in

Anshu Varghese
Department of E&TC, Pimpri Chinchwad College of Engineering and Research, Ravet,
Pune, India
anshu.varghese_etc2020@pccoer.in

Aditya Deshmukh
Department of E&TC, Pimpri Chinchwad College of Engineering and Research, Ravet,
Pune, India
aditya.deshmukh1_etc2020@pccoer.in

Abhimanyu Kanase
Department of E&TC, Pimpri Chinchwad College of Engineering and Research, Ravet,
Pune, India
abhimanyu.kanase_etc2020@pccoer.in

Atharva Junonikar
Department of E&TC, Pimpri Chinchwad College of Engineering and Research, Ravet,
Pune, India
atharva.junonikar_etc2020@pccoer.in

Ayushi Singh
Department of E&TC, Pimpri Chinchwad College of Engineering and Research, Ravet,
Pune, India
ayushi.singh_etc2020@pccoer.in

Prajit Nair
Department of E&TC, Pimpri Chinchwad College of Engineering and Research, Ravet,
Pune, India
prajit.nair_etc2020@pccoer.in

Abstract— Cotton Harvesting has always been a labor-intensive and time-consuming task which involved significant challenges. Manual harvesting resulted in inconsistencies in yield and quality. In traditional systems the cotton blooms could not be detected accurately due to obstruction due to leaves, or detecting the sky instead of the cotton based on features like color, etc. To address this issue Cotton Harvesting Rover implements a robotic system which can detect cotton blooms accurately using computer vision technology. The system autonomously identifies the cotton blooms amongst the fields based on particular features and then picks them using a robotic arm. This study reviews the state-of-the-art deep learning methods for object detection. This review paper will provide a comprehensive study of various deep learning methods which can be useful for automatic detection and various image processing methodologies. Additionally, it offers performance indicators for every technique used, including F-1 score, accuracy, and precision. The climatic condition for cotton productivity in various regions has been discussed. This paper gives a review about the alternative to traditional methods which needed prior knowledge, processing of large data, and reducing difficulties caused due to computer hardware.

Keywords—Cotton Picking, Computer vision, Deep learning, Object detection, YOLOv5.

I. INTRODUCTION

Traditionally cotton picking was done by using methodologies such as hand picking, chemical defoliation, mechanical stripping, manual picking machines, etc. The idea of the project is to develop an advanced cotton-picking robot that incorporates computer vision to enhance and upgrade the efficiency and accuracy of cotton harvesting.

Computer vision is a field that allows computers to extract information from images and other visual inputs. Based on this information it takes necessary actions. It trains the machines to perform according to the functionality that is indicated to be done. Computer vision can be used in various applications such as the detection of faces, video capturing, and tracking moving objects. Using image processing and computer vision the cotton bolls can be detected based on their features and the robotic arm aims to pick them and store them in a container. A deep learning object detection model called YOLOv5 (You Only Look Once version 5) is employed for cotton blossom detection in real-time. The process for successful cotton boll detection includes data collection, labeling the data, selecting the version of the model, training the model by providing the annotated dataset, fine-tuning, and then evaluating the results based on test datasets.

In India and other emerging nations, farmers have an efficient method for harvesting cotton. Despite recent substantial developments, there are still challenges with its adoption in India. In affluent nations, machinery handles all aspects of cotton picking. The Indian agriculture sector has become more mechanized due to rising labor costs and a shortage of labor [1]. According to Haolu Li, remote sensing imageries were used for accurate identification of cotton crop. The deep-learning model used was DenseNet, which is a multidimensional densely connected convolutional network. Remote sensing techniques benefit viewpoints like growth monitoring, disease identification, area estimation and multiple parameters. SVM can do agricultural classification in which the support vectors are limited and the training dataset can be reduced without altering the accuracy of classification. Remote sensing images are obtained from satellites, unmanned air vehicles and unmanned ground vehicles [2]. Xu et al detail the procedure for gathering aerial photos of cotton fields, analyzing the photos to determine possible bloom locations, and employing a convolutional neural network to categorize the possible blooms as either non-blooming objects or cotton flowers [3].

[6] Has described how to adjust picture color pixel values and create upper/lower boundaries for white cotton bolls utilizing a fuzzy reasoning-based approach in conjunction with RGB and HSV color channels for cotton detection. Amanda Isaac et al. conclude that by combining the bitwise-masking and PCA methods on diced images, they were successful in reducing both the size of the file and its dimensions. This method outperformed the normal JPEG compression and generated a notable proportion of smaller files while maintaining high-quality reconstructions [7]. Adalberto I. S. Oliveira developed a robot whose purpose is to monitor the cotton crop and move between rows of crops. The control system of the robot consists of an image-based visual servoing method and a fuzzy logic-based controller [8]. According to Zhang, Yan and Yang etc an Improved version of YOLOv5 was presented which integrated DenseNet, attention mechanism, and bi-frequency frequency prediction to correctly and economically identify closed cotton bolls in the field. According to the experiment results, the suggested approach outperforms the original YOLOv5 model as well as alternative approaches like YOLOv3, SSD, and When weighing the simultaneous factors of precision of detection, computational price, model size, and speed, FasterRCNN [10].

Yong Wang and the research team present a novel approach to cotton recognition based on information from color subtraction of different cotton components. Dynamic Freeman chain coding is operated to reduce noise and improve recognition accuracy in order to raise the accuracy rate of cotton detection [11]. Nimkar Amey Sanjay concludes that to create sustainable and successful agriculture, the goal of the project is to identify, harvest, and store cotton using a cotton harvester that makes use of strong image processing, robotics, and digital analytics. The device would use several robotic arms constructed in the harvest zone to pick numerous crops. This machine is ideal for women because it is remote-controlled and electrically operated, eliminating the need for a driver [12]. This work by W. M. Porter explores and validates the optical detection of cotton rows. The row depth is detected using a stereo camera, and the top and bottom portions of cotton row canopy are then calculated using a pixel-based method that assumes a distribution for the high and low pixels. Pixel-based sliding window algorithms and perspective transform are used to detect left and right rows. For the cotton-picking robot to navigate smoothly, the center of the rows is calculated along with the Bayesian score of the detection [13]. The review also covers the many kinds of AI algorithm and sensors that are employed in these systems. The creation of an enhanced YOLOv5 for the identification of damage based solely on appearance in cotton seeds is the main objective of this work. [16]. The creation of a computer vision algorithm that uses YOLOv5m to identify volunteer cotton plants in cornfields is covered in the document [17]. This paper used Point annotation and large-scale fusion-based cotton boll localization approach [19]. An overview of sensors and systems in navigation systems, recognition and detection algorithm classification, and crop row techniques are given in this work [24].

II. Findings from Literature Survey

The following holes that needed to be focused on were discovered from our extensive deep learning assessment of various cotton-picking approaches.
From the literature survey following gaps are identified:
1. Obstruction caused due to leaves, branches or other materials can slow the picking time.
2. Implementation cost due to hardware, software and maintenance.
3. Autonomous systems must have less maintenance time.
4. Only identifies specific cotton blooming patterns and does not specify other use cases.
5. Could not identify cotton bolls which were hidden behind some branches leaving behind some bolls.

III. Gap Identification

According to the existing literature and the state ofknowledge in object detection, there are some limitations thatmay arise in the methodology, observed findings and some questions which may be unanswered. The below table contains all the gaps/limitations which were identified duringthe analysis of the papers. This paper describes the existing methodology, the design and formulation, methods for data collection and their drawbacks. Based on this analysis it is possible to address issues that had been faced in the previousresearch papers. Around 26 papers were studied, out of which25 gaps were identified as mentioned in below:

The cost and availability of labor are two major issues that Indian cotton farmers must deal with [1]. The use of supervised classification, which necessitates a large quantity of training data is a challenge [2]. The lower surface resolution at higher flight altitudes may prevent the pipeline from precisely detecting cotton flowers [3]. Machine learning techniques do not use automatic feature extraction and need careful tuning of hyperparameters [4]. In real field obstruction caused by branches and other leaves can result in longer picking time. Implementation cost due to hardware, software, and maintenance is high [5]. Detects only white cotton bolls therefore may not be directly applicable to other types of crops or monitoring scenarios. Requires specialized equipment [6]. Specifies the outlines the application case for identifying flowering patterns in cotton blooms, and does not specify other use cases. Does not specify the computational requirement and time complexity [7]. This paper specifies only crop monitoring and using a mobile robot whose accuracy is 8/10 use cases [8]. Potential challenges faced can be field obstacles, theft, cost, etc. Due to the system being autonomous, they must require minimal management time

[9]. Techniques like YOLOv3, SSD, and Faster-RCNN showed less performance in terms of detection, computational costing, model size, and speed [10]. Requires specific lighting conditions, does not work well with certain types of cotton [11]. This paper focuses on the development of a cotton harvester using ML and IP techniques and not on the practical use [12]. New automated machines will have to match the reliability, self-sufficiency, and economic competitiveness of the existing harvesters used in the U.S [13]. The system was struggling to get a boll if it is located behind the stem or branch. Some-times it causes the system to leave behind some bolls [14]. Need for specialized sensors and algorithm calibration, difficulty in comparing AI algorithm performances among papers using different data sets [15]. It is deficient in thorough assessment, comparative analysis, and specific details on a few key areas, including the computational efficiency and the algorithm's performance with coated cotton seeds [16]. ACO algorithm used for generating the optimal path and spot-spray is stochastic in nature and may not provide a globally optimal solution [17]. It's possible that not all of the computational resources needed for MCBLNet training and implementation particularly in real-time applications have been taken into consideration [19]. Testing equipment for robotic arms are costly [20]. Challenges involved in complexity in robotic arm programming [21]. Possible drawbacks could be limited to only color and shape recognition, environmental conditions could impact on the reliability of computer vision [22]. The challenges of differentiating between crop species, the requirement for extreme precision and accuracy in data collection, and the possibility of interference from meteorological elements like wind and rain [23]. Accurate direction finding and self-governing agricultural equipment are challenged by the unstructured and complicated character of the agricultural environment [24].

IV. Image Dataset

The image dataset was produced in June and July of 2023 utilizing images taken from local farmers' farms in Marathwada and information gathered from the internet. The internet-based dataset was gathered from two distinct websites: figshare and Roboflow. The Roboflow dataset contained more than 1421 photographs, of which we used all the data. In a similar vein, a dataset with almost 6000 photos was removed from the figshare site since the model's training accuracy was below 0.60. The preprocessing section includes details on the five classes that is, the five categories into which the Roboflow dataset is divided that make up the dataset. The preparation section contains thorough information on augmentation. The pre-labeled and annotated online dataset we collected aided in the model creation process. The model was tested exclusively using the second dataset, which was gathered from nearby farms. The images were taken from various perspectives, postures, and backgrounds, ensuring that the model's testing would be appropriate for a variety of environments.

Figure 1. displays the real photos from our dataset, which consists of 614 total images. After the augmentation process which is covered in the preprocessing section the number of images increased to 1421. The image resolution for the dataset before preprocessing is 640x640 pixels. The data set is divided in to 85% training,10% validation and 5% testing[27]. Photographs of individual cotton bolls on the plant are included in the dataset to aid the model in identifying cotton bolls up close, while photographs of several cotton bolls on a single plant are included to aid in the detection of cotton bolls at a distance.

Fig. 1. Image Dataset

V. Data Preprocessing

As part of the data analysis process, data preprocessing transforms unprocessed data into a format that can be understood and interpreted by computers and machine learning. To get raw data for our study, we annotated the photos by placing an anchor box around the check that has to be detected. In this instance, there are various stages of the cotton boll's growth, including split, mature, early, and flower. This is divided into five categories by first defining all classes for every growth stage and then, during the annotating process, choosing a certain class each time a bounding box is made. Once every image has been annotated, the next step is data augmentation. This process involves increasing the size of the data by doing things like rotating the images 90 degrees clockwise and counterclockwise, flipping them vertically and horizontally, and adjusting the exposure of the photos between -12% and +12%.

Figure 2. shows the platform where the data annotation and augmentation was done and the dataset was exported in the v5 PyTorch compactible format [27].

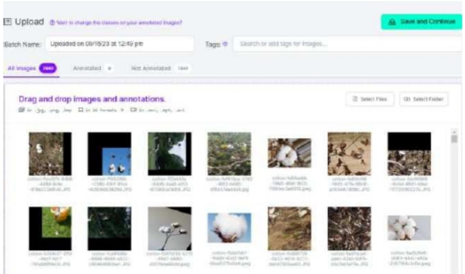


Fig. 2. Annotated Dataset

VI. Generalized Methodology

Explains in detail how YOLOv5, a pre-trained model based on deep learning, can be specifically trained for a dataset of cotton and, once deployed, be able to identify cotton in any environment. The selection of YOLOv5 or any other ML model is contingent upon the particular tasks at hand and the availability of data for the model's training. YOLO models are employed for high-performance object detection. An image is divided into grid systems by YOLO, and every grid knows what's inside of it.

Several YOLO versions are contrasted in Table 1. Among them, v5 is the most suitable for our use in cotton detection since it is open source, lighter than v7, and more accurate than v4. As can be seen in the table below, version 4 and 7 solely use the COCO dataset, while version 5 employ a variety of D5 datasets for data training. The 's' model is used in the research for cotton detection.

Table I. Comparison of YOLO versions

Parameter	YOLOv4	YOLOv5	YOLOv7
Speed	Varies based on the model selected.	Has good balance	Fastest
Accuracy	varies according to the selected mode	Offers good balance	Highest
Open-source	No	Yes	No
Training data	COCO dataset	Diverse D5 dataset	COCO dataset
Parameters and Computation	Higher generally	Low than v4	Lowest

The explanation of the YOLO cotton detecting model is provided by Fig. 3 :

Cotton Image: Gathering data is the first step in training a model. We have gathered this data from a variety of sources, such as cotton cultivated in a lab or a greenhouse, etc. The training dataset comes from Roboflow.

Image Annotation: An image is annotated using machine learning and artificial intelligence algorithms. Frequently, image annotation is done by human annotators using animage annotation tool to tag relevant information or label images, for as by giving appropriate classes to various items in an image. As stated in the section on image datasets, we developed two classes for our model. Pre-trained models are frequently available for fundamental tasks like classification and segmentation, and with the aid of Transfer Learning and little data, these models may be customized to particular use cases. The data preprocessing section goes into detail about the platform called Roboflow, where the annotation was completed.

Annotated Dataset: Following the platform's annotation process, the data is given to the Colab for model training, with the received data divided into three sections: test, validation, and train.

Image augmentation and preprocessing: The dataset is first enlarged using the augmentation procedure, which is described in detail in the data pretreatment section, prior to exporting it to Colab.

YOLOv5 training: We begin by exporting our previously processed information from the Roboflow platform in v5 Pytorch compatible format, which is necessary to train our v5 model on our custom dataset. Upon completion, a repository code is generated. After using the code to import the dataset into Colab, we set the parameters to begin training. First, we set the image size, to the same as the export size. Next, we set the epochs for this model. We experimented with epochs ranging from 50 to 200 to train our model, however, 150 epoch and batch size of 32 produced the best results. Using this input parameter, we were able to get an accuracy of 0.83 [16] [17].

Train Model Evaluation: Following the completion of testing on unseen data, we apply the trained model to the task of object detection in test set images. Following object detection, the performance is assessed, and measures such as mAP, precision, and the accuracy and efficacy of the model in object detection are analyzed [10].

Detection: Following cotton detection, a box surrounding the cotton appears, seemingly indicating the level of confidence. This level simply indicates how much confidence that the object being recognized is cotton or not (as an example, if the level is 0.8, it indicates an 80% confidence on detected cotton).

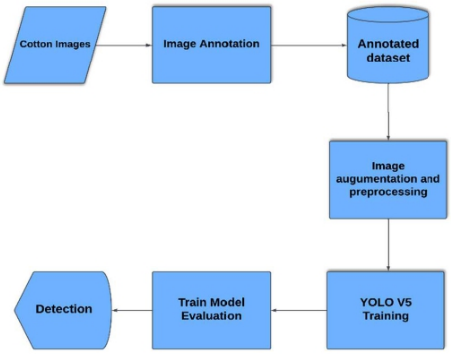


Fig. 3. Generalized flow of YOLOv5 cotton detection model.

VII. Performance Metrics

A confusion matrix, also called an error matrix, is a specific table arrangement used in the field of machine learning, specifically with regard to statistical classification problems. It makes the performance of an algorithm easier to visualize. Typically, this algorithm is supervised learning-related; in unsupervised learning, it is commonly referred to as a matching matrix.

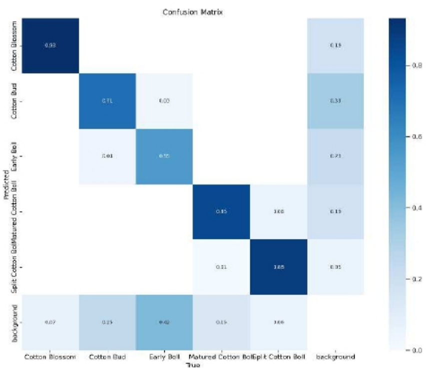


Fig. 4. Confusion Matrix

From Figure 4. we can see confusion matrix that true value for the cotton blossom matches the projected values by 0.93 times, the true value for the bud matches by 0.71 times, and the true value for the early boll matches by 0.55 times. Both the split cotton forecast and the matured boll prediction match the true value by 0.88 times and 0.85, respectively. The background is clearly influencing the values of the cotton buds and the early boll.

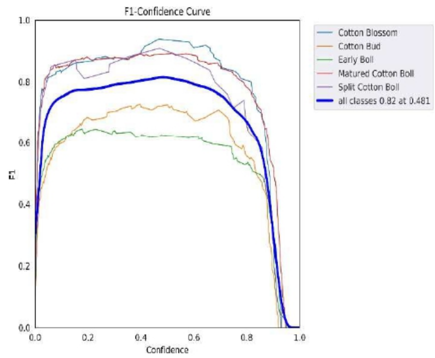


Fig. 5. F1 confidence curve

In Figure. 5. the F1 curve as a reference for all classes, the confidence value of 0.481 maximizes both precision and recall. A greater confidence value is preferred in many situations. This model's confidence value must be 0.8, which isn't far from its highest confidence of 0.82.

$$F1 = 2\left[\frac{precision.recall}{precisio+recall}\right] \quad (1)$$

Where,

$$precision = \frac{TP}{TP+FP} \quad (2)$$

$$recall = \frac{TP}{TP+FN} \quad (3)$$

$$accuracy = \frac{TP+TN}{TP+FP+TN+FN} \quad (4)$$

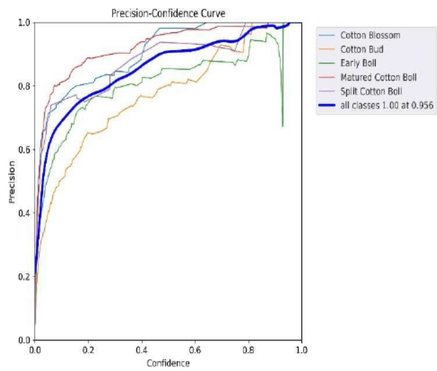


Fig. 6. Precision confidence curve

Figure 6 illustrates the relationship between the model's confidence and precision.

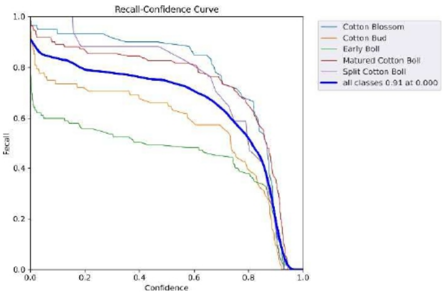


Fig. 7. Precision recall confidence curve

Figure 7 shows the relationship between the trained model's recall and confidence.

VIII. Conclusion

Using the PyTorch compactible dataset and YOLOv5, we were able to successfully build a cotton detection model using the Google Colab platform. Figures 8 and 9 illustrate the model's detection.

Fig. 8. Labeled image

These annotated photos were uploaded to Google Colab to train the model, as seen in Figure 8. As stated in the pre-processing section, the photos were categorized into five categories. With the help of the bounding boxes, the model was able to identify the characteristics in the fed data.
The model was able to predict the existence of the cotton boll after completing its training. When fig. 8 was entered into the model for testing, the expected output (fig.9.) resembled as the same image which was used for training.

Fig. 9. Predicted image

IX. Future Scope

Integration of a robotic arm with real-time detection: Based on real-time detection from the video feed, the robotic arm can use sensors and actuators to pluck the cotton boll.

Combining Various Sensor Systems: Use a range of sensors, including LiDAR and infrared sensors, to provide the robot with a thorough grasp of the surroundings in the cotton field.

Personalized Path Planning and Self-governing Navigation: To improve the robot's agility in the field, create complex algorithms for autonomous navigation and dynamic path planning.

Technological Developments in Image Processing: Investigate and apply state-of-the-art image processing techniques to improve cotton bloom detection accuracy and speed.

X. References

1. A.S. Deshmukh and A. Mohanty, "Cotton mechanisation in india and across globe: a review," International Journal of Advance Research in Engineering, Science & Technology, vol. 3, no. 1, pp. 2393–9877, 2016.
2. Li, Haolu, et al. "Identifying cotton fields from remote sensing images using multiple deep learning networks."Agronomy 11.1 (2021): 174.
3. Xu, Rui, et al. "Aerial images and convolutional neural network for cotton bloom detection." Journal Of Display Technology, Vol. 8, No. 1,January 2012
4. Saleem, Muhammad Hammad, Johan Potgieter, and Khalid Mahmood Arif. "Automation in agriculture by machine and deep learning techniques: A review of recent developments."Precision Agriculture 22 (2021): 2053-2091.
5. K. Fue, W. Porter, E. Barnes, C. Li, and G. Rains,"Center-articulated hydrostatic cotton harvesting rover using visual-

servoing control and a finite state machine," Electronics, vol. 9, no. 8, p. 1226, 2020.

6. Z. Xu, M. A. Latif, S. S. Madni, A. Rafiq, I. Alam, and M. A. Habib,"Detecting white cotton bolls using high-resolution aerial imagery acquired through unmanned aerial system," IEEE Access, vol. 9, pp. 169068–169081, 2021.

7. A. Issac, H. Yadav, G. Rains, and J. M. Velni, "Dimensionality reduction of high-throughput phenotyping data in cotton fields," IFAC-PapersOnLine, vol. 55, no. 32,pp. 153–158, 2022.

8. A. I. Oliveira, T. M. Carvalho, F. F. Martins, A. C. Leite, K. T. Figueiredo, M. M.Vellasco, and W. Caarls, "On the intelligent control design of an agricultural mobile robot for cotton crop monitoring," in 2019 12th International Conference on Developments in eSystems Engineering (DeSE), pp. 563–568, IEEE, 2019.

9. E. Barnes, G. Morgan, K. Hake, J. Devine, R. Kurtz, G. Ibendahl, A. Sharda,G. Rains, J. Snider, J. M. Maja, et al., "Opportunities for robotic systems and automation in cotton production,"AgriEngineering, vol. 3,no. 2, pp. 339–362, 2021.

10. Zhang, Yan, et al. "An improved YOLO network for unopened cotton boll detection in the field." Journal of Intelligent & Fuzzy Systems 42.3 (2022): 2193-2206.

11. Y. Wang, X. Zhu, and C. Ji, "Machine vision based cotton recognition for cotton harvesting robot," in Computer And Computing Technologies In Agriculture, Volume II: First IFIP TC 12 International Conference on Computer and Computing Technologies in Agriculture (CCTA 2007), Wuyishan, China, August 18-20, 2007 1,pp. 1421–1425, Springer, 2008.

12. N. A. Sanjay, N. Venkatramani, V. Harinee, and V. Dinesh, "Cotton harvester through the application of machine learning and image processing techniques", Materials Today: Proceedings, vol. 47, pp. 2200–2205, 2021.

13. K. Fue, T. Georgia, W. Porter, E. Barnes, and G. Rains, "Visual row detection using pixel-based algorithm and stereo camera for cotton-picking robot," 2019 ASABE Annual International Meeting, Boston, Massachusetts, 2019.

14. K. G. Fue, E. M. Barnes, W. M. Porter, and G. C. Rains, "Visual control of cotton-picking rover and manipulator using a ros-independent finite state machine," in 2019 ASABE Annual International Meeting, p. 1, American Society of Agricultural and Biological Engineers, 2019.

15. S. Fountas, I. Malounas, L. Athanasakos, I. Avgoustakis, and B. Espejo-Garcia, "Ai-assisted vision for agricultural robots," AgriEngineering, vol. 4, no. 3, pp. 674–694,2022.

16. Liu, Z., Wang, L., Liu, Z., Wang, X., Hu, C., & Xing, J. (2023). Detection of Cotton Seed Damage Based on Improved YOLOv5. Processes, 11(9), 2682.

17. Yadav, Pappu Kumar, et al. "Computer Vision for Volunteer Cotton Detection in a Corn Field with UAS Remote Sensing Imagery and Spot Spray Applications." arXiv preprint arXiv:2207.07334 (2022).

18. Bhavan, S. Abhinand. "YOLOv5 Crop Detection Deep Learning Model using Artificial Intelligence (AI) and Edge Computing." 2022 International Conference on Augmented Intelligence and Sustainable Systems (ICAISS). IEEE, 2022.

19. Sun, Ming, et al. "Cotton boll localization method based on point annotation and multi-scale fusion." Frontiers in Plant Science 13 (2022): 960592.

20. Shah, S.K., Mishra, R., Prasanna, D. and Mohapatro, G., 2019. Fabrication and deviation analysis of a 5-axis robotic arm using image processing technique. Materials Today: Proceedings, 18, pp.4622-4629.

21. Reddy, R. and Nagaraja, S.R., 2014, December. Integration of robotic arm with vision system. In 2014 IEEE International Conference on Computational Intelligence and Computing Research (pp. 1-5). IEEE.

22. Rai, Neerparaj, Bijay Rai, and Pooja Rai. "Computer vision approach for controlling educational robotic arm based on object properties." In 2014 2nd International Conference on Emerging Technology Trends in Electronics, Communication and Networking, pp. 1-9. IEEE, 2014.

23. Micheletto, Matias J., Carlos I. Chesñevar, and Rodrigo Santos. "Methods and Applications of 3D Ground Crop Analysis Using LiDAR Technology: A Survey." Sensors 23.16 (2023): 7212.

24. Shi, Jiayou, et al. "Row Detection BASED Navigation and Guidance for Agricultural Robots and Autonomous Vehicles in Row-Crop Fields: Methods and Applications." Agronomy 13.7 (2023): 1780.

25. Gharakhani, Hussein, J. Alex Thomasson, and Yuzhen Lu. "Integration and preliminary evaluation of a robotic cotton harvester prototype." Computers and Electronics in Agriculture 211 (2023): 107943.

26. Adke, Shrinidhi, et al. "Supervised and weakly supervised deep learning for segmentation and counting of cotton bolls using proximal imagery." Sensors 22.10 (2022): 3688.

27. Cotton Boll https://universe.roboflow.com/proj1-gyxkz/cotton_data/dataset/2/images, 31 Jan 2024.

A.3.2 Publication Copyright

IEEE COPYRIGHT AND CONSENT FORM

To ensure uniformity of treatment among all contributors, other forms may not be substituted for this form, nor may any wording of the form be changed. This form is intended for original material submitted to the IEEE and must accompany any such material in order to be published by the IEEE. Please read the form carefully and keep a copy for your files.

Cotton Detection Using YOLOv5.

Rahul Mapari, Abhimanyu Kanase, Aditya Deshmukh, Anshu Varghese, Atharva Junonikar, Ayushi Singh and Prajit Nair

2024 5th International Conference for Emerging Technology (INCET)

COPYRIGHT TRANSFER

The undersigned hereby assigns to The Institute of Electrical and Electronics Engineers, Incorporated (the "IEEE") all rights under copyright that may exist in and to: (a) the Work, including any revised or expanded derivative works submitted to the IEEE by the undersigned based on the Work; and (b) any associated written or multimedia components or other enhancements accompanying the Work.

GENERAL TERMS

1. The undersigned represents that he/she has the power and authority to make and execute this form.
2. The undersigned agrees to indemnify and hold harmless the IEEE from any damage or expense that may arise in the event of a breach of any of the warranties set forth above.
3. The undersigned agrees that publication with IEEE is subject to the policies and procedures of the IEEE PSPB Operations Manual.
4. In the event the above work is not accepted and published by the IEEE or is withdrawn by the author(s) before acceptance by the IEEE, the foregoing copyright transfer shall be null and void. In this case, IEEE will retain a copy of the manuscript for internal administrative/record-keeping purposes.
5. For jointly authored Works, all joint authors should sign, or one of the authors should sign as authorized agent for the others.
6. The author hereby warrants that the Work and Presentation (collectively, the "Materials") are original and that he/she is the author of the Materials. To the extent the Materials incorporate text passages, figures, data or other material from the works of others, the author has obtained any necessary permissions. Where necessary, the author has obtained all third party permissions and consents to grant the license above and has provided copies of such permissions and consents to IEEE

You have indicated that you DO wish to have video/audio recordings made of your conference presentation under terms and conditions set forth in "Consent and Release."

CONSENT AND RELEASE

1. In the event the author makes a presentation based upon the Work at a conference hosted or sponsored in whole or in part by the IEEE, the author, in consideration for his/her participation in the conference, hereby grants the IEEE the unlimited, worldwide, irrevocable

permission to use, distribute, publish, license, exhibit, record, digitize, broadcast, reproduce and archive, in any format or medium, whether now known or hereafter developed: (a) his/her presentation and comments at the conference; (b) any written materials or multimedia files used in connection with his/her presentation; and (c) any recorded interviews of him/her (collectively, the "Presentation"). The permission granted includes the transcription and reproduction of the Presentation for inclusion in products sold or distributed by IEEE and live or recorded broadcast of the Presentation during or after the conference.

2. In connection with the permission granted in Section 1, the author hereby grants IEEE the unlimited, worldwide, irrevocable right to use his/her name, picture, likeness, voice and biographical information as part of the advertisement, distribution and sale of products incorporating the Work or Presentation, and releases IEEE from any claim based on right of privacy or publicity.

BY TYPING IN YOUR FULL NAME BELOW AND CLICKING THE SUBMIT BUTTON, YOU CERTIFY THAT SUCH ACTION CONSTITUTES YOUR ELECTRONIC SIGNATURE TO THIS FORM IN ACCORDANCE WITH UNITED STATES LAW, WHICH AUTHORIZES ELECTRONIC SIGNATURE BY AUTHENTICATED REQUEST FROM A USER OVER THE INTERNET AS A VALID SUBSTITUTE FOR A WRITTEN SIGNATURE.

Rahul Mapari	10-04-2024
Signature	Date (dd-mm-yyyy)

Information for Authors

AUTHOR RESPONSIBILITIES

The IEEE distributes its technical publications throughout the world and wants to ensure that the material submitted to its publications is properly available to the readership of those publications. Authors must ensure that their Work meets the requirements as stated in section 8.2.1 of the IEEE PSPB Operations Manual, including provisions covering originality, authorship, author responsibilities and author misconduct. More information on IEEE's publishing policies may be found at http://www.ieee.org/publications_standards/publications/rights/authorrightsresponsibilities.html Authors are advised especially of IEEE PSPB Operations Manual section 8.2.1.B12: "It is the responsibility of the authors, not the IEEE, to determine whether disclosure of their material requires the prior consent of other parties and, if so, to obtain it." Authors are also advised of IEEE PSPB Operations Manual section 8.1.1B: "Statements and opinions given in work published by the IEEE are the expression of the authors."

RETAINED RIGHTS/TERMS AND CONDITIONS

- Authors/employers retain all proprietary rights in any process, procedure, or article of manufacture described in the Work.
- Authors/employers may reproduce or authorize others to reproduce the Work, material extracted verbatim from the Work, or derivative works for the author's personal use or for company use, provided that the source and the IEEE copyright notice are indicated, the copies are not used in any way that implies IEEE endorsement of a product or service of any employer, and the copies themselves are not offered for sale.
- Although authors are permitted to re-use all or portions of the Work in other works, this does not include granting third-party requests for reprinting, republishing, or other types of re-use.The IEEE Intellectual Property Rights office must handle all such third-party requests.
- Authors whose work was performed under a grant from a government funding agency are free to fulfill any deposit mandates from

that funding agency.

AUTHOR ONLINE USE

- **Personal Servers**. Authors and/or their employers shall have the right to post the accepted version of IEEE-copyrighted articles on their own personal servers or the servers of their institutions or employers without permission from IEEE, provided that the posted version includes a prominently displayed IEEE copyright notice and, when published, a full citation to the original IEEE publication, including a link to the article abstract in IEEE Xplore. Authors shall not post the final, published versions of their papers.
- **Classroom or Internal Training Use.** An author is expressly permitted to post any portion of the accepted version of his/her own IEEE-copyrighted articles on the author's personal web site or the servers of the author's institution or company in connection with the author's teaching, training, or work responsibilities, provided that the appropriate copyright, credit, and reuse notices appear prominently with the posted material. Examples of permitted uses are lecture materials, course packs, e-reserves, conference presentations, or in-house training courses.
- **Electronic Preprints.** Before submitting an article to an IEEE publication, authors frequently post their manuscripts to their own web site, their employer's site, or to another server that invites constructive comment from colleagues. Upon submission of an article to IEEE, an author is required to transfer copyright in the article to IEEE, and the author must update any previously posted version of the article with a prominently displayed IEEE copyright notice. Upon publication of an article by the IEEE, the author must replace any previously posted electronic versions of the article with either (1) the full citation to the IEEE work with a Digital Object Identifier (DOI) or link to the article abstract in IEEE Xplore, or (2) the accepted version only (not the IEEE-published version), including the IEEE copyright notice and full citation, with a link to the final, published article in IEEE Xplore.

Questions about the submission of the form or manuscript must be sent to the publication's editor.
Please direct all questions about IEEE copyright policy to:
IEEE Intellectual Property Rights Office, copyrights@ieee.org, +1-732-562-3966

A.3.3 Publication Certificate


Jain College of Engineering
Belagavi, India

IEEE BANGALORE SECTION

5th International Conference of Emerging Technology
(INCET 2024)

24th – 26th May 2024

Certificate

This is to certify that Dr./Prof./Mr./Ms. Abhimanyu Rajesh Kanase has presented paper entitled Cotton Detection Using YOLOv5. in 5th International Conference of Emerging Technology (INCET 2024) during 24th to 26th May 2024.

Dr. Krupa Rasane
Convener - INCET 2024

Dr. J. Shivakumar
General Chair - INCET 2024


Jain College of Engineering
Belagavi, India

IEEE BANGALORE SECTION

5th International Conference of Emerging Technology
(INCET 2024)

24th – 26th May 2024

Certificate

This is to certify that Dr./Prof./Mr./Ms. Aditya Prasad Deshmukh has presented paper entitled Cotton Detection Using YOLOv5. in 5th International Conference of Emerging Technology (INCET 2024) during 24th to 26th May 2024.

Dr. Krupa Rasane
Convener - INCET 2024

Dr. J. Shivakumar
General Chair - INCET 2024

Jain College of Engineering
Belagavi, India

IEEE
BANGALORE SECTION

5^{th} International Conference of Emerging Technology (INCET 2024)

24^{th} – 26^{th} May 2024

Certificate

*This is to certify that Dr./Prof./Mr./Ms. **Anshu Biju Varghese** has presented paper entitled **Cotton Detection Using YOLOv5.** in 5^{th} International Conference of Emerging Technology (INCET 2024) during 24^{th} to 26^{th} May 2024.*

Dr. Krupa Rasane
Convener - INCET 2024

Dr. J. Shivakumar
General Chair - INCET 2024

A.4 Patent Documents

A.4.1 Patent Draft

TITLE OF INVENTION: Cotton picking rover using computer vision

FIELD OF THE INVENTION:

[0001] This invention is associated with agritech, which is the application of technology in agriculture to enhance yield quality and quantity by computer vision-based identification and selective picking of cotton bolls, hence mitigating the need for human labour.

BACKGROUND OF THE INVENTION:

[0002]Cotton was traditionally picked by hand, with the use of mechanical stripping, chemical defoliation, manual picking equipment, etc. Typically, farmers begin hand-picking

Cotton bolls in the afternoon and work non stop until dusk.

[0003] Throughout the season, cotton bolls open at various periods. A bloom typically takes about 1.5 months to develop and become ready for harvesting; however, high temperatures accelerate this process and make it more difficult to harvest the cotton boll since different bud open at different times.

[0004] These methods presented a number of difficulties, including labor-intensive tasks, sluggish processes, inefficient chemical use, ongoing oversight, etc. It takes longer to pluck the cotton bolls as a result of these procedures.

[0005] The utilization of vision-based systems in harvesting robots gained attention mostly due to its prospective benefits, including reduced equipment and maintenance expenses and the capacity to do selective picking. Because they are small and have a low weight, these tiny robots also have the benefit of entering a field without causing any damage to the soil.

OBJECTIVES OF THE INVENTION

[0006] The main objective of this presented invention is to provide a rover that can contribute to the Agritech for picking and collecting the cotton bolls using the computer vision based system.

[0007] Secondary objective of this is to reduce the physical work of picking the cotton bolls which is the traditional way and increase the production in much lesser time. The rover can go to the field multiple times for the purpose of plucking.

[0008] Another objective is to present a system based on Computer -vision that identifies the cotton ball in real time and separates it from the plant and collect it in a bucket.

[0009] This system uses Deep Learning that enabled the rapid detection, localisation and recognition of the object from the image. Deep learning are now being used in many applications related to agriculture and farming for detection, location and classification of the object in crops.

[0010] The robotic arm that is capable of accurately plucking the bolls and that is lightweighted and won't damage the whole plant in itself. This invention also makes sure that the maintenance is easy and the model is cost efficient with less complications.

SUMMARY OF THE INVENTION

[0011] The aim of this invention is to reduce the human power by some amount and help the farmers to have surplus amount with good quality. The delay in plucking the cotton bolls affects both the quality and the quantity of the final product. Weather conditions also comes into play and can have extremely negative impact.

[0012] The aim of this invention is to identify the presence of the cotton bolls , pluck it and collect it without damaging the rest of the plant. It's small size won't affect the soil and will move through the spacing between plants.

[0013] Another aspect of this present invention is to collect and make a dataset containing sufficient amount of images of cotton plants with different buds and bunches. Some cotton plants have a bunch of 4-5 Cotton bolls while others can have only 2-3.

[0014] Another aspect of this present invention is to use that dataset for training , testing and deploying the model for real time identification , recognition, and processing of the cotton images and picking it with the robotic arm to yield maximum production in much less time.

[0015] Another aspect of this present invention is to recognize the cotton bold by its position, colour, orientation , shape with the help of training the model through multiple images that were collected in the dataset.

<u>Detailed Description:</u>

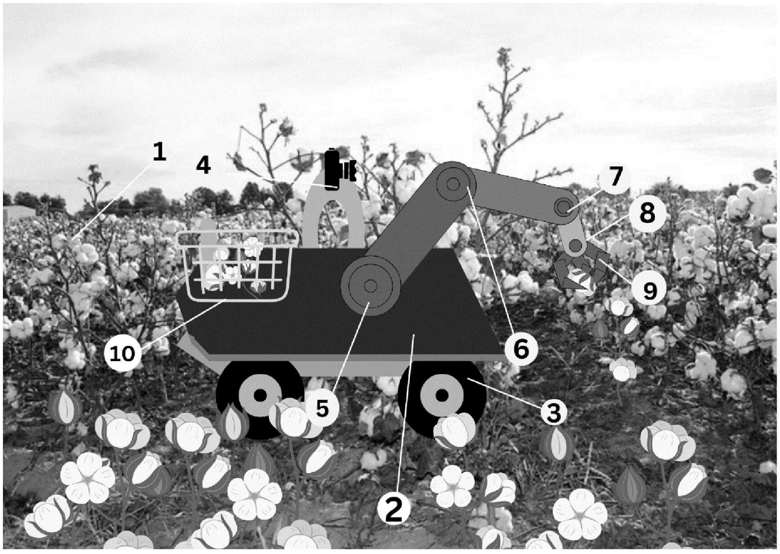
[0016] The autonomous cotton picking rover comprises of a platform that is equipped with wheels for traversal through cotton fields. There is a hand extension that is mounted on the rover capable of reaching and gently plucking mature cotton bolls from plants.

[0017] The rover's cameras and sensors allow it to take detailed pictures of the cotton plants. Computer vision techniques are utilized to process these images in real-time, enabling the identification and differentiation of mature cotton bolls from other plant elements including leaves and stems. The computer vision system precisely identifies mature cotton bolls by analyzing multiple visual cues, such as size, texture, and color.

[0018] The rover's control system determines the best path and location for the hand extension to reach and pluck a mature cotton boll after it has been spotted. Because the hand extension has actuators, it may be used to carefully and precisely remove the cotton boll from the plant.

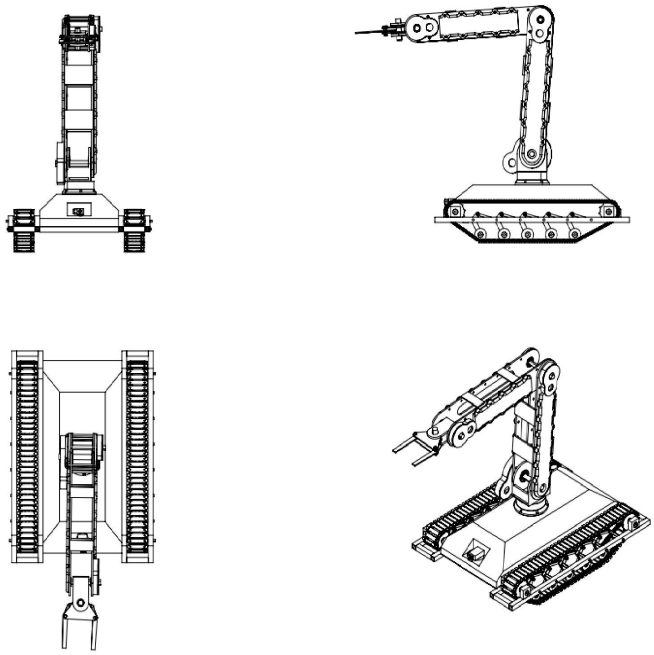
[0019] For effective field coverage while preventing collisions with obstructions, it is configured with established paths and obstacle avoidance algorithms.

BIEF DESCRIPTION OF THE DRAWINGS



[0020]The image depicts a cotton field (1) with rows of mature cotton plants stretching into the distance.

[0021] In the foreground of the image, an autonomous cotton picking rover (2) is positioned amidst the cotton plants. The rover is a compact, wheeled vehicle (3) with a sturdy frame designed for rough outdoor environments.



[**0022]** Reference is made first to FIG.1. are the different angles in which the rover is being displayed.

Fig 1.1 Shows the schematics of front view of the rover .

Fig 1.2 Shows the schematics of side view of the rover .

Fig 1.3 Shows the schematics of top view of the rover .

Fig .4 Shows the schematics of the side-top view of the rover.

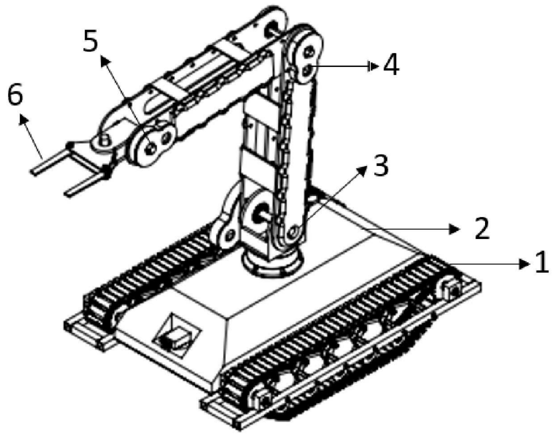


Fig.2

[0023] Fig2. shows the complete clear view of the rover.

[0024] The (1)belt chain underneath helps the rover to navigate through the rough patches of the field without causing any damage to the soil .

[0025] The surface (2) on which the rover arm is mounted supports and provides the solid surface to the arm. The rover's specialized hand extension mechanism is prominently featured, extending outward from the front of the vehicle.

[0026] The hand extension consists of multiple articulated segments(3) (4)(5), allowing it to bend and flex with precision, resembling the movements of a human hand.

[0025] At the end of the hand extension are delicate grippers (6) equipped with soft, rubberized pads designed to gently grasp and pluck ripe cotton bolls from the plants without causing damage.

[0026] At the end of the hand extension, delicate grippers (6) are fixed, equipped with soft, rubberized pads to ensure a gentle touch. These grippers are specifically designed to selectively grasp and pluck ripe cotton bolls from the plants with utmost care, avoiding any damage to the delicate fibers or surrounding vegetation.

We Claims:

1. An autonomous cotton picking rover comprising:

   a. Vehicle designed to move across the terrain of cotton fields.

   b. A custom-designed extension arm mechanism, installed on the mobile platform, is employed to harvest mature cotton bolls from plants.

   c. Cameras and sensors for capturing images of cotton plants,

   d. Computer vision system for processing images and selectively detecting the cotton bolls,

   e. An actuators and grippers for manipulating the hand extension to pluck cotton bolls,

   f. A control system for coordinating the operation of the rover and hand extension, and

   g. A navigation system for autonomous traversal through cotton fields.

2. The autonomous cotton picking rover of claim 1, wherein the computer vision system analyzes visual cues including color, texture, and size to identify mature cotton bolls.

3. The autonomous cotton picking rover of claim 1, wherein the hand extension mechanism is designed to mimic the precision of human hands without causing damage to the plant.

4. The autonomous cotton picking rover of claim 1, further comprising obstacle avoidance algorithms to navigate through the cotton field while avoiding collisions with obstacles.

ABSTRACT

COMPUTER VISION BASED COTTON PICKING ROVER

The current invention illustrates an autonomous cotton picking rover equipped with and extended hand for selecting the mature cotton bolls from their plants. The rover deploys the cutting edge robotics technology, that has an platform transversing through the cotton fields with precision. Its specialized extended hand, noticeably positioned at the front of the vehicle, comprises of segments that mimic the dexterity of a human hand. At the end of extension there is a grippers with soft rubberized pads, that make soft and delicate plucking possible. Utilizing the computer vision for image processing, the rover identifies and targets mature cotton bolls that ensures the efficient and precise harvesting. This innovative solution aims to revolutionize cotton harvesting practices, offering increased efficiency , reduced labor costs, and improved yield for cotton farmers.

A.4.2 Patent

Welcome Dipali Kedar Shende Sign out

Controller General of Patents, Designs & Trade Marks

सत्यमेव जयते

INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS
GEOGRAPHICAL INDICATIONS

G.A.R.6
[See Rule 22(1)]
RECEIPT

Docket No 50912 **Date/Time 2024/05/26 12:18:59**

To
Dipali Kedar Shende

UserId: dipalik

'Safalya', Plot no 27, SR No.32/2k, Near Tambe School, Datta Colony Rahatni Road, Pimpri

CBR Detail:

Sr. No.	App. Number	Ref. No./Application No.	Amount Paid	C.B.R. No.	Form Name	Remarks
1	202421040821	TEMP/E-1/47760/2024-MUM	1600	24705	FORM 1	COMPUTER VISION BASED COTTON PICKING ROVER

TransactionID	Payment Mode	Challan Identification Number	Amount Paid	Head of A/C No
N-0001425082	Online Bank Transfer	2605240002577	1600.00	1475001020000001

Total Amount : ₹ 1600.00
Amount in Words: Rupees One Thousand Six Hundred Only

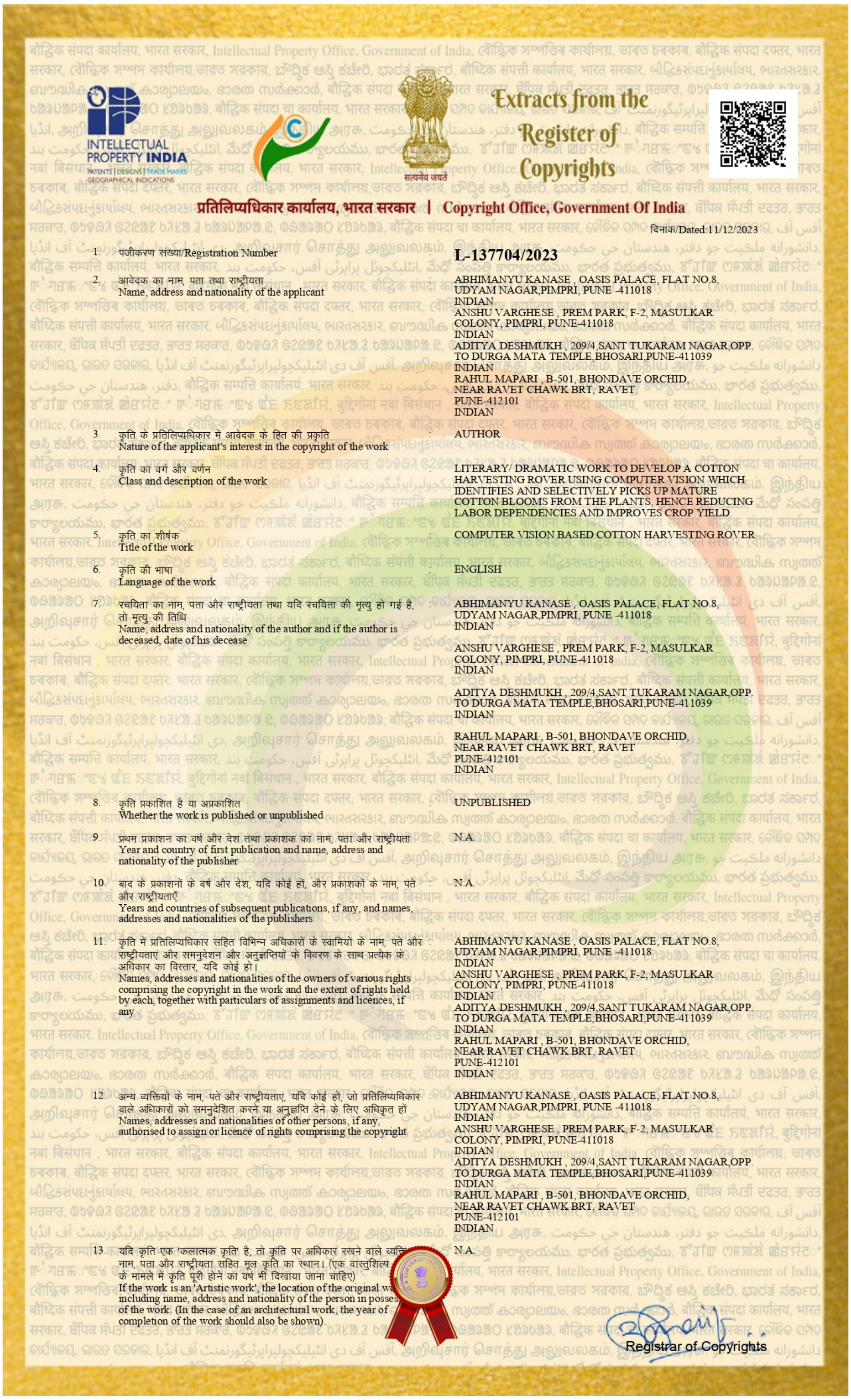
Received from Dipali Kedar Shende the sum of ₹ 1600.00 on account of Payment of fee for above mentioned Application/Forms.
* This is a computer generated receipt, hence no signature required.

Print

Home About Us Contact Us

A.5 Copyright Certificate and Work Uploaded

A.5.1 Copyright Certificate



INTELLECTUAL PROPERTY INDIA
PATENTS | DESIGNS | TRADE MARKS
GEOGRAPHICAL INDICATIONS

सत्यमेव जयते

Extracts from the Register of Copyrights

प्रतिलिप्यधिकार कार्यालय, भारत सरकार | Copyright Office, Government Of India

दिनांक/Dated: 11/12/2023

1.	पंजीकरण संख्या/Registration Number	L-137704/2023
2.	आवेदक का नाम, पता तथा राष्ट्रीयता Name, address and nationality of the applicant	ABHIMANYU KANASE , OASIS PALACE, FLAT NO 8, UDYAM NAGAR,PIMPRI, PUNE -411018 INDIAN ANSHU VARGHESE , PREM PARK, F-2, MASULKAR COLONY, PIMPRI, PUNE-411018 INDIAN ADITYA DESHMUKH , 209/4,SANT TUKARAM NAGAR,OPP. TO DURGA MATA TEMPLE,BHOSARI,PUNE-411039 INDIAN RAHUL MAPARI , B-501, BHONDAVE ORCHID, NEAR RAVET CHAWK BRT, RAVET PUNE-412101 INDIAN
3.	कृति के प्रतिलिप्यधिकार में आवेदक के हित की प्रकृति Nature of the applicant's interest in the copyright of the work	AUTHOR
4.	कृति का वर्ग और वर्णन Class and description of the work	LITERARY/ DRAMATIC WORK TO DEVELOP A COTTON HARVESTING ROVER USING COMPUTER VISION WHICH IDENTIFIES AND SELECTIVELY PICKS UP MATURE COTTON BLOOMS FROM THE PLANTS, HENCE REDUCING LABOR DEPENDENCIES AND IMPROVES CROP YIELD.
5.	कृति का शीर्षक Title of the work	COMPUTER VISION BASED COTTON HARVESTING ROVER
6.	कृति की भाषा Language of the work	ENGLISH
7.	रचयिता का नाम, पता और राष्ट्रीयता तथा यदि रचयिता की मृत्यु हो गई है, तो मृत्यु की तिथि Name, address and nationality of the author and if the author is deceased, date of his decease	ABHIMANYU KANASE , OASIS PALACE, FLAT NO 8, UDYAM NAGAR,PIMPRI, PUNE -411018 INDIAN ANSHU VARGHESE , PREM PARK, F-2, MASULKAR COLONY, PIMPRI, PUNE-411018 INDIAN ADITYA DESHMUKH , 209/4,SANT TUKARAM NAGAR,OPP. TO DURGA MATA TEMPLE,BHOSARI,PUNE-411039 INDIAN RAHUL MAPARI , B-501, BHONDAVE ORCHID, NEAR RAVET CHAWK BRT, RAVET PUNE-412101 INDIAN
8.	कृति प्रकाशित है या अप्रकाशित Whether the work is published or unpublished	UNPUBLISHED
9.	प्रथम प्रकाशन का वर्ष और देश तथा प्रकाशक का नाम, पता और राष्ट्रीयता Year and country of first publication and name, address and nationality of the publisher	N.A.
10.	बाद के प्रकाशनों के वर्ष और देश, यदि कोई हों, और प्रकाशकों के नाम, पते और राष्ट्रीयताएँ Years and countries of subsequent publications, if any, and names, addresses and nationalities of the publishers	N.A.
11.	कृति में प्रतिलिप्यधिकार सहित विभिन्न अधिकारों के स्वामियों के नाम, पते और राष्ट्रीयताएं और समनुदेशन और अनुज्ञप्तियों के विवरण के साथ प्रत्येक के अधिकार का विस्तार, यदि कोई हो। Names, addresses and nationalities of the owners of various rights comprising the copyright in the work and the extent of rights held by each, together with particulars of assignments and licences, if any	ABHIMANYU KANASE , OASIS PALACE, FLAT NO 8, UDYAM NAGAR,PIMPRI, PUNE -411018 INDIAN ANSHU VARGHESE , PREM PARK, F-2, MASULKAR COLONY, PIMPRI, PUNE-411018 INDIAN ADITYA DESHMUKH , 209/4,SANT TUKARAM NAGAR,OPP. TO DURGA MATA TEMPLE,BHOSARI,PUNE-411039 INDIAN RAHUL MAPARI , B-501, BHONDAVE ORCHID, NEAR RAVET CHAWK BRT, RAVET PUNE-412101 INDIAN
12.	अन्य व्यक्तियों के नाम, पते और राष्ट्रीयताएं, यदि कोई हों, जो प्रतिलिप्यधिकार वाले अधिकारों को समनुदेशित करने या अनुज्ञप्ति देने के लिए अधिकृत हों Names, addresses and nationalities of other persons, if any, authorised to assign or licence of rights comprising the copyright	ABHIMANYU KANASE , OASIS PALACE, FLAT NO 8, UDYAM NAGAR,PIMPRI, PUNE -411018 INDIAN ANSHU VARGHESE , PREM PARK, F-2, MASULKAR COLONY, PIMPRI, PUNE-411018 INDIAN ADITYA DESHMUKH , 209/4,SANT TUKARAM NAGAR,OPP. TO DURGA MATA TEMPLE,BHOSARI,PUNE-411039 INDIAN RAHUL MAPARI , B-501, BHONDAVE ORCHID, NEAR RAVET CHAWK BRT, RAVET PUNE-412101 INDIAN
13.	यदि कृति एक 'कलात्मक कृति' है, तो कृति पर अधिकार रखने वाले व्यक्ति नाम, पता और राष्ट्रीयता सहित मूल कृति का स्थान। (एक वास्तुशिल्प के मामले में कृति पूरी होने का वर्ष भी दिखाया जाना चाहिए) If the work is an 'Artistic work', the location of the original wo including name, address and nationality of the person in posses of the work. (In the case of an architectural work, the year of completion of the work should also be shown).	N.A.

Registrar of Copyrights

14.	यदि कृति एक 'कलात्मक कृति' है जो किसी भी माल या सेवाओं के संबंध में उपयोग की जाती है या उपयोग किए जाने में सक्षम है, तो आवेदन में प्रतिलिप्यधिकार अधिनियम, 1957 की धारा 45 की उप–धारा (i) के प्रावधान के अनुसार व्यापार चिह्न रजिस्ट्रार से प्रमाणन शामिल होना चाहिए। If the work is an 'Artistic work' which is used or capable of being used in relation to any goods or services, the application should include a certification from the Registrar of Trade Marks in terms of the provision to Sub-Section (i) of Section 45 of the Copyright Act, 1957.	:	N.A.
15.	यदि कृति एक 'कलात्मक कृति' है, तो क्या यह डिजाइन अधिनियम 2000 के अंतर्गत पंजीकृत है? यदि हां, तो विवरण दें। If the work is an 'Artistic work', whether it is registered under the Designs Act 2000, if yes give details.	:	N.A.
16.	यदि कृति एक 'कलात्मक कृति' है, जो डिजाइन अधिनियम 2000 के तहत एक डिजाइन के रूप में पंजीकृत होने में सक्षम है, तो क्या यह औद्योगिक प्रक्रिया के माध्यम से किसी वस्तु पर प्रयुक्त की गई है और यदि हाँ, तो इसे कितनी बार पुनरुत्पादित किया गया है? If the work is an 'Artistic work', capable of being registered as a design under the Designs Act 2000.whether it has been applied to an article though an industrial process and ,if yes ,the number of times it is reproduced.	:	N.A.
17.	टिप्पणी, यदि कोई हो/Remarks, if any	:	

डायरी संख्या/Diary Number: 27107/2023-CO/L

आवेदन की तिथि/Date of Application: 11/10/2023

प्राप्ति की तिथि/Date of Receipt: 11/10/2023

Registrar of Copyrights

A.5.2 Synopsis

Diary Number:27107/2023-CO/L

Project Title: Computer Vision Based Cotton Harvesting Rover

Abstract:-

Cotton Harvesting has always been a labor-intensive and time-consuming task which involved significant challenges. Manual harvesting resulted in inconsistencies in yield and quality. In traditional systems the cotton blooms could not be detected accurately due to obstruction due to leaves, or detecting the sky instead of the cotton based on features like color, etc. To address thisissue Cotton Harvesting Rover implements a robotic system which can detect cotton blooms accurately using computer vision technology. The system autonomously identifies the cotton blooms amongst the fields based on particular features and then picks them using a robotic arm. The novelty of this project is that it identifies the cotton blooms from all perspectives so that inaccuracy can be avoided. With the help of the rover it becomes convenient to keep plucking the mature cotton blooms and detecting them simultaneously. This solution helps in reducing thelabor work, increasing yield and quality and reduction of usage of harmful chemicals. The expected outcomes of this idea is that the model should identify the mature cotton blooms accurately and the robotic arm should pick the cotton without much delay thus ensuring improved cotton harvesting.

Introduction:-

Traditionally cotton picking was done by using methodologies such as hand picking, chemical defoliation, mechanical stripping, manual picking machines etc.The idea of the project is to develop an advanced cotton picking robot that incorporates computer vision to enhance and upgrade the efficiency and accuracy of cotton harvesting. Computer vision can be used in various applications such as detection of face, video capturing, tracking moving objects. Using image processing and computer vision the cotton bolls can be detected based on its features andthe robotic arm aims to pick them and store it in a container. The rover's functionality will be tomove autonomously through the cotton fields. The system will be equipped with cameras and image processing capabilities to analyze each cotton bloom particularly and identify the ripe ones.

Aim and Objectives:

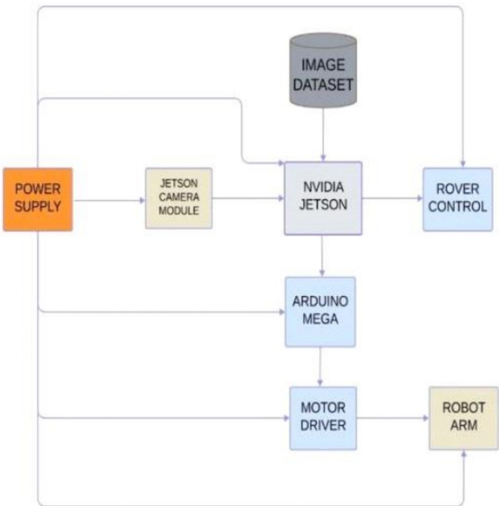
Aim:

"To develop a cotton harvesting rover using computer vision which identifies and selectively picks up mature cotton blooms from the plants, hence reducing labor dependencies and improves crop yield."

ves:

- To develop an image processing model which accurately identifies cotton bolls amongstother plants.
- To ensure that plucked cotton bolls are not damaged.
- To minimize total initial cost for the system.
- To ensure that hardware setup and software model are well integrated.
- To distinguish mature cotton blooms from pre-matured ones
- To make certain that the system is portable, robust and has increased mobility.
- To make sure that repair and maintenance is easy and cost efficient.

Block Diagram/Flow Diagram:



ation:-

The system is equipped with cameras which capture images i.e., data required for processing from the cotton fields. These images include various features like color, shape, size. The captured images are then processed using computer vision which identifies the cotton blooms from the data. It also helps in classifying the mature cotton blooms and the pre-matured ones, as the robot must only pick the ripe cotton bolls. Convolutional Neural Network (CNN) is a type of machine learning model which is trained using the labeled dataset of images which are further annotated to identify the mature cotton boll. Once model is trained it is deployed on the module which processes the information received from the camera feed. When ripe cotton boll is detected, the

robotic arm is activated and it carefully picks the boll from the plant and stores it in a container. The functionality of the rover is to move efficiently through the field.

Advantages:-

- There is no need for human intervention as the robot can work autonomously.
- Real-time image processing improves crop yield and making the process moreefficient.
- Improved accuracy of cotton detection and chances of missing or damaging thecotton is less.
- Using computer vision the probability of unripe cotton being harvested is less,thereby ensuring minimal wastage.
- Reducing need for chemical defoliation, machine learning based detectioncontributes to environment friendly practices.

Disadvantages:-

- The initial setup and training of the model is time consuming.
- Gathering sufficient labeled dataset for the model requires significant effort.
- Changes in the weather conditions may alter the accuracy and impact onperformance.
- The system requires regular maintenance and the models must be retrained withupdated data.
- Implementation cost of hardware, software can be costly.

ıtions:-

- Crop yield estimation
- Textile industry
- Disease and pest detection
- Crop health monitoring

References :-

- Xu, Zhongjian, et al. "Detecting white cotton bolls using high-resolution aerial imageryacquired through unmanned aerial system." *IEEE Access* 9 (2021): 169068-169081.

- Barnes, Edward, et al. "Opportunities for robotic systems and automation incotton production." *AgriEngineering* 3.2 (2021): 339-362.

- Issac, Amanda, et al. "Dimensionality Reduction of High-throughput Phenotyping Data inCotton Fields." *IFAC-PapersOnLine* 55.32 (2022): 153-158.

- Fue, K. G., et al. "Visual row detection using pixel-based algorithm and stereo camera for cotton-picking robot." 2019 ASABE Annual International Meeting, Boston, Massachusetts,2019.

- KIVRAK, Oğuzhan, and Mustafa Zahid GÜRBÜZ. "Performance Comparison of YOLOv3, YOLOv4 and YOLOv5 Algorithms: A Case Study for Poultry Recognition." *Avrupa Bilim ve Teknoloji Dergisi* 38 (2022): 392-397.

- John, Anand, and Divyakant Meva. "A comparative study of various object detection algorithms and performance analysis." *International Journal of Computer Sciences and Engineering* 8.10 (2020): 158-163.

- Wang, Yong, Xiaorong Zhu, and Changying Ji. "Machine vision based cotton recognition for cotton harvesting robot." *Computer And Computing Technologies In Agriculture, VolumeII: First IFIP TC 12 International Conference on Computer and Computing Technologies inAgriculture (CCTA 2007), Wuyishan, China, August 18-20, 2007 1.* Springer US, 2008.

- Fountas, Spyros, et al. "AI-assisted vision for agricultural robots." *AgriEngineering* 4.3(2022): 674-694.

Applicant Details:-

Name of Party	Address of Party	Nationality
ABHIMANYU KANASE	OASIS PALACE, FLAT NO.8,UDYAM NAGAR, PIMPRI, PUNE-411018	INDIAN
ANSHU VARGHESE	PREM PARK, F-2, MASULKAR COLONY, PIMPRI, PUNE-411018	INDIAN
ADITYA DESHMUKH	209/4, SANT TUKARAM NAGAR, OPP. TO DURGA MATA TEMPLE, BHOSARI,PUNE-411039	INDIAN
RAHUL TAPARI	B-501, BHONDAVE ORCHID, NEAR RAVET CHAWK BRT, RAVET, PUNE-412101	INDIAN

A.5.3 Form 14

FORM XIV
APPLICATION FOR REGISTERATION OF COPYRIGHT
[SEE RULE 70]

Diary Number: 27107/2023-CO/L

To

The Registrar of Copyrights,
Copyright Office,
Department of Industrial Policy & Promotion,
Ministry of Commerce and Industry,
Boudhik Sampada Bhawan,
Plot No. 32, Sector 14, Dwarka,
New Delhi-110075
Email Address: copyright@nic.in
Telephone No.: (Office) 011-28032496, 08929474194
Sir,

In Accordance with Section 45 of the Copright Act, 1957 (14 of 1957), I hereby apply for registration of Copyright and request that enteries may be made in the Register of Copyrights as in the enclosed Statement of Particulars.

1. I also send herewith duly completed the Statement of further Particulars relating to the work. (for Literary/Dramatic, Musical, Atristic works only) **Literary/ Dramatic works**

2. In accordance with rule 16 of the Copyright Rules, 1958, I have sent by prepaid registered post copies of this letter and of the Statement of Particulars and Statement of Further Particulars to other parties concerned as shown below:

Name of Party	Address of Party	Date of Dispatch
ABHIMANYU KANASE	OASIS PALACE, FLAT NO.8,UDYAM NAGAR, PIMPRI, PUNE-411018	10/10/2023
ANSHU VARGHESE	PREM PARK, F-2, MASULKAR COLONY, PIMPRI, PUNE-411018	10/10/2023
ADITYA DESHMUKH	209/4, SANT TUKARAM NAGAR, OPP. TO DURGA MATA TEMPLE, BHOSARI,PUNE-411039	10/10/2023
RAHUL MAPARI	B-501, BHONDAVE ORCHID, NEAR RAVET CHAWK BRT, RAVET, PUNE-412101	10/10/2023

[See columns 7,11,12, and 13 of the Statement of Particulars and party referred in col.2 (e) of the Statement of Further Particulars.]

3. The prescribed fee has been paid, as per details below: **500/-**

Payment ID	Payment Date	Amount	Bank Name	Payment Mode
325912	11/10/2023	500		

4. Communications on this subject may be addressed to:

ABHIMANYU KANASE
OASIS PALACE, FLAT NO.8,
UDYAM NAGAR,PIMPRI, PUNE -411018
9890415402

5. I hereby declare that to the best of my knowledge and belief, no person, other than to whom a notice has been sent as per paragraph 2 above any claim or interest or dispute to my copyright of this work or its use by me.

6. I hereby verify that the particulars given in this Form and the Statement of Particulars and Statment of Further Particulars are true to the best of my knowledge, belief and information and nothing has been concealed there from.

List of Enclosures:

1. 2 Copies of Work
2. DD/IPO of Rs.500 Per Work
3. Authorization from author/publisher
4. If the application is being filed through attorney , a specific Power of Attorney in original duly signed by the applicant and accepted by the attorney

Place:

Date: **11/10/2023**

For : ABHIMANYU KANASE

Kanase.

Proprietor

STATEMENT OF PARTICULARS

Diary Number: 27107/2023-CO/L

1.	Registration Number	
2.	Name, Address and Nationality of the Applicant	NAME: ABHIMANYU KANASE, ADDRESS: OASIS PALACE, FLAT NO.8, UDYAM NAGAR,PIMPRI, PUNE -411018, Indian NAME: ANSHU VARGHESE, ADDRESS: PREM PARK, F-2, MASULKAR COLONY, PIMPRI, PUNE-411018, Indian NAME: ADITYA DESHMUKH, ADDRESS: 209/4,SANT TUKARAM NAGAR,OPP. TO DURGA MATA TEMPLE,BHOSARI,PUNE-411039, Indian NAME: RAHUL MAPARI, ADDRESS: B-501, BHONDAVE ORCHID, NEAR RAVET CHAWK BRT, RAVET PUNE-412101, Indian
3.	Nature of the Applicant's interest in the Copyright of the work	Author
4.	Class and description of the work	Literary/ Dramatic Work
5.	Title of the work	Computer Vision Based Cotton Harvesting Rover
6.	Language of the work	English
7.	Name, Address and Nationality of the Author and if the Author is deceased, the date of decease.	NAME: ABHIMANYU KANASE, ADDRESS: OASIS PALACE, FLAT NO.8, UDYAM NAGAR,PIMPRI, PUNE -411018, Indian, NAME: ANSHU VARGHESE, ADDRESS: PREM PARK, F-2, MASULKAR COLONY, PIMPRI, PUNE-411018, Indian, NAME: ADITYA DESHMUKH, ADDRESS: 209/4,SANT TUKARAM NAGAR,OPP. TO DURGA MATA TEMPLE,BHOSARI,PUNE-411039, Indian, NAME: RAHUL MAPARI, ADDRESS: B-501, BHONDAVE ORCHID, NEAR RAVET CHAWK BRT, RAVET PUNE-412101, Indian,
8.	Whether the work is Published or Unpublished	Unpublished
9.	Year and Country of first publication, and Name, Address and Nationality of the publisher	N/A
10.	Year and Countries of subsequent publications, if any, and Name, Address and Nationality of the publisher	N/A
11.	Name, Address and Nationality of the Owners of the various rights comprising the copyright in the work and extent of rights held by each, together with particulars of assignments and licence. If any	NAME: ABHIMANYU KANASE, ADDRESS: OASIS PALACE, FLAT NO.8, UDYAM NAGAR,PIMPRI, PUNE -411018, Indian NAME: ANSHU VARGHESE, ADDRESS: PREM PARK, F-2, MASULKAR COLONY, PIMPRI, PUNE-411018, Indian NAME: ADITYA DESHMUKH, ADDRESS: 209/4,SANT TUKARAM NAGAR,OPP. TO DURGA MATA TEMPLE,BHOSARI,PUNE-411039, Indian NAME: RAHUL MAPARI, ADDRESS: B-501, BHONDAVE ORCHID, NEAR RAVET CHAWK BRT, RAVET PUNE-412101, Indian
12.	Name and address and nationality of other persons, if any authorized to assign or licence the rights comprising the copyright	NAME: ABHIMANYU KANASE, ADDRESS: OASIS PALACE, FLAT NO.8, UDYAM NAGAR,PIMPRI, PUNE -411018, Indian NAME: ANSHU VARGHESE, ADDRESS: PREM PARK, F-2, MASULKAR COLONY, PIMPRI, PUNE-411018, Indian NAME: ADITYA DESHMUKH, ADDRESS: 209/4,SANT TUKARAM NAGAR,OPP. TO DURGA MATA TEMPLE,BHOSARI,PUNE-411039, Indian NAME: RAHUL MAPARI, ADDRESS: B-501, BHONDAVE ORCHID, NEAR RAVET CHAWK BRT, RAVET PUNE-412101, Indian
13.	If the work is an 'Artistic work', the location of the original work, including name, address and nationality of the person in possession of the work,	N/A

	(In the case of an architectural work, the year of completion of the work should also be shown)	
14.	If the work is an 'Artistic work' which is used or capable of being used in relation to any goods or services, the application should include a certification from the Registrar of Trade Marks in terms of the provision to Sub-Section (i) of Section 45 of the Copyright Act, 1957	N/A
15.	If the work is an 'Artistic work' whether it is registered under the Desings Act 2000 if yes give details.	N/A
16.	If the work is an 'Artistic work' capable of being registrar as a design under the Designs Act 2000, whether is has been applied to an article though an industrial process and,if yes ,then number of times it is reproduced	N/A
17.	Remarks, if any	

Place:
Date: **11/10/2023**

For : ABHIMANYU KANASE

AKanase.

Proprietor

STATEMENT OF FURTHER PARTICULARS

(For Literary/Dramatic, Musical and Artistic works only)

Diary Number: 27107/2023-CO/L

1. Is the work to be registered

(a) an orginal work? : Yes

(b) a translation of a work in the public domain? : N.A.

(c) a translation of a work in which Copyright subsists? : N.A.

(d) an adaptation of a work in the public domain? : N.A.

(e) an adaptation of a work in which Copyright subsists? : N.A.

2. If the work is a translation or adaptation of a work in which copyright subsists

(a) Title of the original work : N.A.

(b) Language of the original work : N.A.

(c) Name, address, and nationality of the author of the original work and if the author is deceased, the date of decease : N.A.

(d) Name, address, and nationality of the publisher, if any, of the original work : N.A.

(e) Name, address, and nationality of the publisher, or adaptation including the name, address and nationality of party authorizing : N.A.

3. Remarks, if any

Place:
Date: **11/10/2023**

For : ABHIMANYU KANASE

Kanase.

Proprietor