An-Najah National University

Harvester

Aisha Marmash & Salsabeel Daraghmeh

Supervised by:
Dr. Aladdin Masri & Dr. Luai Malhis

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Abstract

We build a supporting system in the agricultural field to help the farmer to harvest the ground planets as a solution for the Lack of manpower and the high wages of the workers. This inspired us to create a robot with a dataset that we collected and a model we trained on this dataset to detect the chosen crop and specifying its 3D location by using the machine learning and check the validity of it by using the image processing and pick it according to that by using its 3DOF arm. All of that is after contacting with the farmer and take all the information by an Android mobile application we built that convey the information to harvester through the WIFI, so harvester walk as a car in the nursery lines automatically searching for the demanded thing and collecting it in the basket, after finishing the mission stops.

Acknowledgements

We would like to show our sincere gratitude for Aladdin Masri and Dr. Luai Malhis, for there generous support where they were a great inspiration and motivation for us to complete this project. We also thank Abdullah Beshtawi from the Mechatronics Engineering Department at An-Najah National University for volunteering to help us in the mechanical field that is responsible about the movement of the motors that makes the robot arm and dimensional analysis.
A huge gratitude for the doctors of the Computer Engineering Department for what their efforts over our years in the university. Our genuine love and appreciation for our families and friends for encouraging us all the time and directing us to the right way.

Salsabeel & Aisha

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Chapter 1

Introduction

1.1 Problem Description

The world is witnessing a decline in the agricultural field and it is a trend towards other industrial, commercial and economic fields. We can see this clearly in Palestine, as it has started to import agricultural crops and raw materials for industries from abroad because the agricultural field has become very weak and insufficient to meet people's needs due to abounding agricultural study, and transformation of the agricultural land to facilities and buildings. As a result, it lead this field to suffer from several problems where one of them was the decline in the number of farmers and the increase in the cost of agricultural harvest. So the process of harvesting vegetables and fruit became hard, expensive and needed a lot of time.

1.2 Motivation

As I mentioned previously because of these problems, we thought that we should move and try to solve these problems in any way, except leaving it simply turning into facilities and buildings. So why don't we exploit the development of technology in agriculture to improve it? Technology has evolved tremendously, Image processing, and machine learning have become the most advanced fields in the world. This is an opportunity that we should take advantage of to find solutions that are superior, easier and cheaper.

1.3 Objectives

In this project we aim to invent a robot called "Harvester" where its job is to harvest the plants from the agriculture ground such as tomatoes, cucumbers, peppers, strawberries, zucchini etc. without the need for a farmer, where all what the framer need to do is to select the type of plant, he wants to pick up by using a mobile application. Then, "Harvester" will automatically walk among the plants, looking for the selected plant by using image processing and machine learning, and when the selected kind found the robot arm will move to the position and pick it up putting it right away in the basket. The robot will keep walking and searching for other plants until it's all picked up.

1.4 Report Organization

This report is organized as follows. Chapter II provides background information regarding existing harvesting robots around the world. Chapter III describes the detailed methods and experimental setup used to create the robot and the application. The results are analyzed and discussed in Chapter IV. The challenges and constraints we faced are discussed in Chapter V.Finally, a conclusion of the project and future work are provided in Chapter VI.

Chapter 2

Literature Review

The idea of the Agricultural robot become real especially in America and Japan. For example, there is in America a robot called "Harvey"[3].Harvey is a miniature mobile robot made for use in nurseries and greenhouses. It can independently identify, transport, and organize potted plants in both indoor and outdoor environments.There is another robot called "Sweeper"[8] which is a cooperation between Israel and Europe whenever it sees a paper plant it directly stops and pick it up, and it can work for 20hrs/day where its accuracy is 61%. Also "Argobot"[1] it's a testing machine that picks strawberries.

Beside these real experiments, there's researches made in the university of Cambridge about using the machine learning to harvest lettuce[2] so we can recognize that this experiment is taken seriously by the countries and spend millions of dollars to use the artificial intelligence and machine learning in the Agricultural field.

Chapter 3

Methodology

This project aims to create an automated system to harvest the agriculture crops after choosing the type and quantity of it by the farmer through a mobile application. This chapter will go over the methods used to achieve this.

3.1 Dataset building

We collect images to build the dataset. We can do this for any type of crop we need, but because we built a prototype for the harvester robot, we collected the data set of tomatoes and bell pepper. We took pictures from different positions, lighting, and types of bell pepper and tomatoes, so we have a good and extensive dataset which is applicable to the available types of tomatoes and bell pepper in our country, and then by using "Roboflow"[7] we made annotations for the photos.

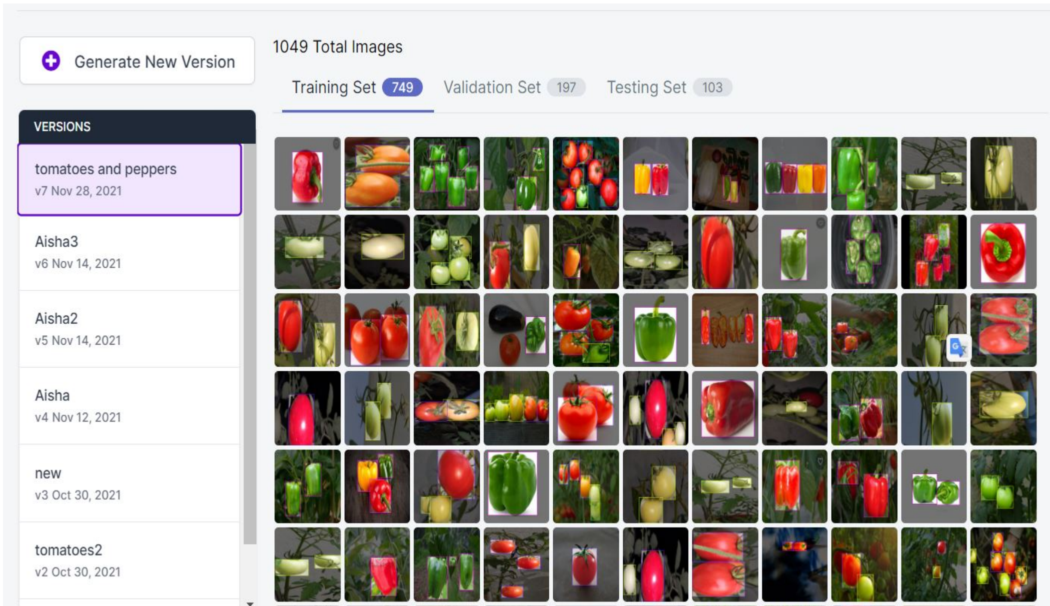


Figure 3.1: Dataset - Roboflow

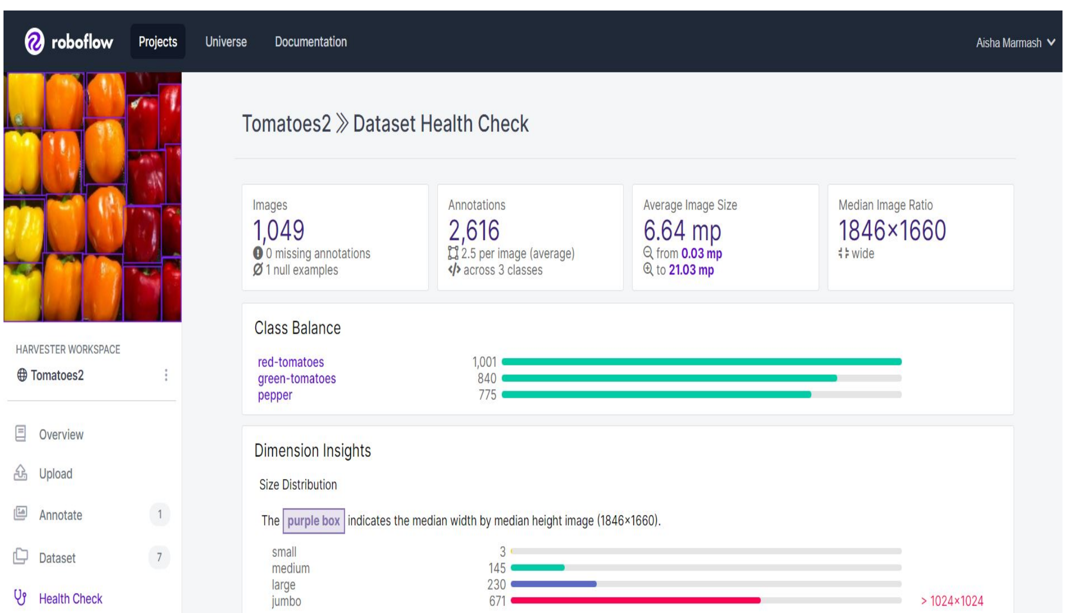


Figure 3.2: Dataset Health Check - Roboflow

3.2 Training a custom model with Yolov3

We used Google Colaboratory to implement the tiny version of YOLOv3 as a training on the dataset and after finishing it we got a new model where its accuracy rate is 90.66%.

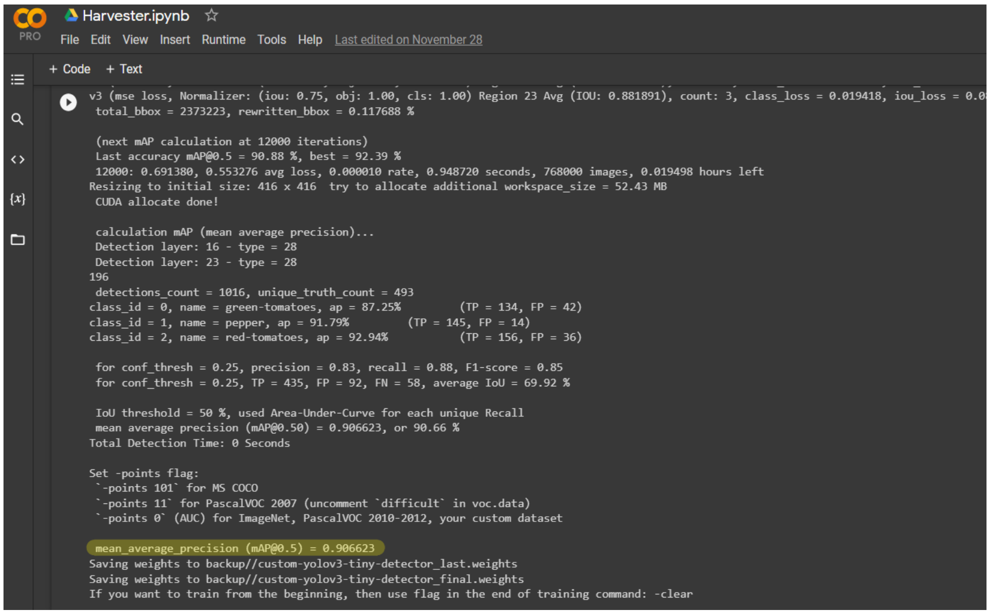


Figure 3.3: Training Result

It was successful in localizing and determining the selected type.After that, we will turn this model into an OpenVino version to deploy it on the OAK-D camera [6].

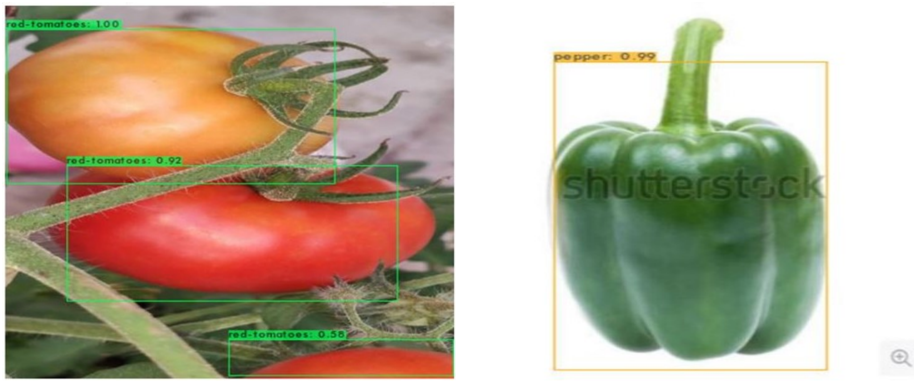


Figure 3.4: Colab Testing

3.3 Deployment on the oak device

Now, we need to detect the 3D localization of the object. While one camera can specify the object location in 2 dimensions, we used OAK-D camera that provide us with the depth of two stereo cameras and color information from a single 4K camera in the center.

Figure 3.5: oak-d camera

We took a frame from the left and right stereo camera, and after making object localization for each one of them by using landscape we do mapping between two frames. As a result of that, we specified every object location in the image in 3D (X, Y, Z) according to the left camera of the OAK-D. All of that happens through a live video.

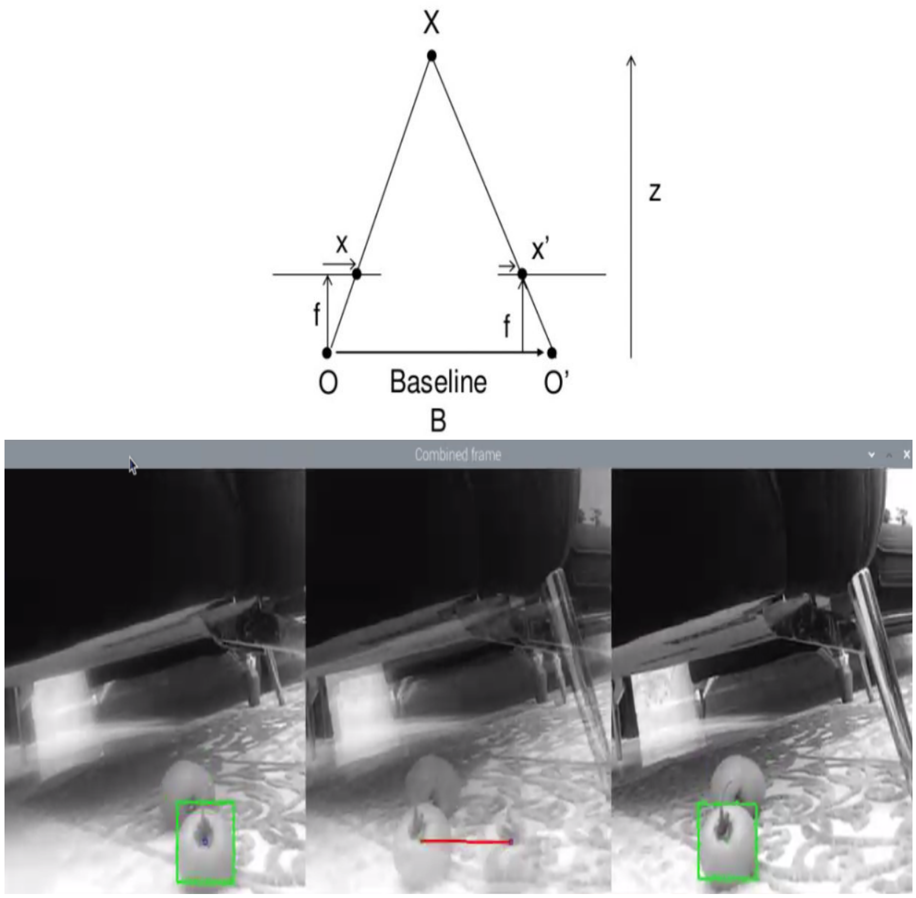


Figure 3.6: Object Depth

After the localization we make labeling (we can know which class this object undergoes) through the RGB camera which is in the center of the OAK-D camera. We're going to explain how to use the RGB camera also to specify shapes and valid crops in the next chapters.

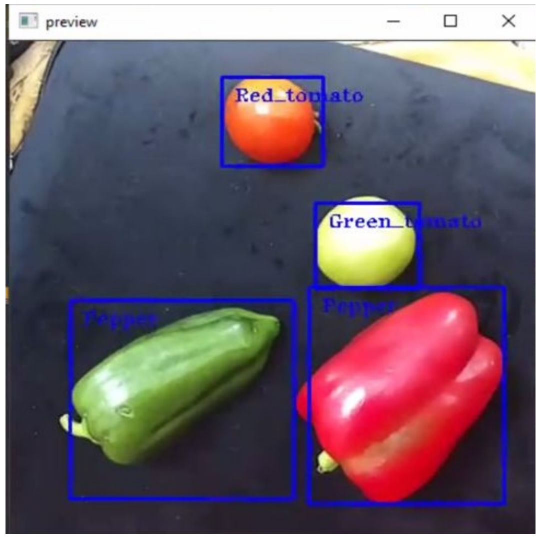


Figure 3.7: Object Depth

3.4 Hardware design and structure

Based on our knowledge about how to build and organize the farms, we built "harvester" design and structure which is a car made of four strong wheels supplied by strong motors gives it the ability to walk on the dirt. It also supplied by 2 line tracking sensors to follow the line in line follower mode and ultrasonic sensor to avoid objects crash. In addition, "harvester" holds an OAK-D camera with 3 DOF arm with a hand grip.

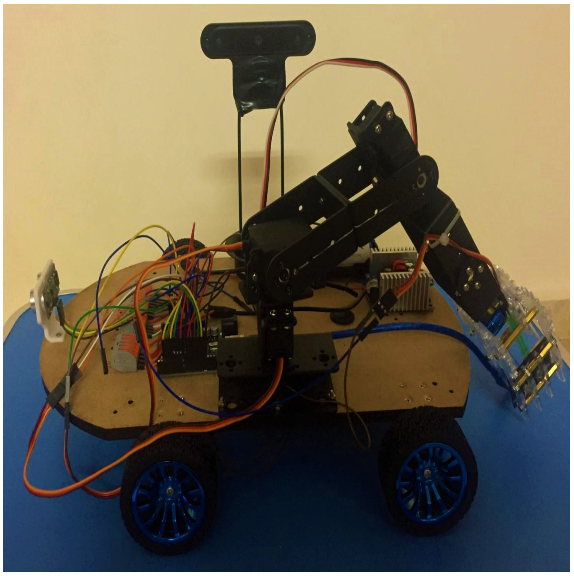


Figure 3.8: Harvester Side View

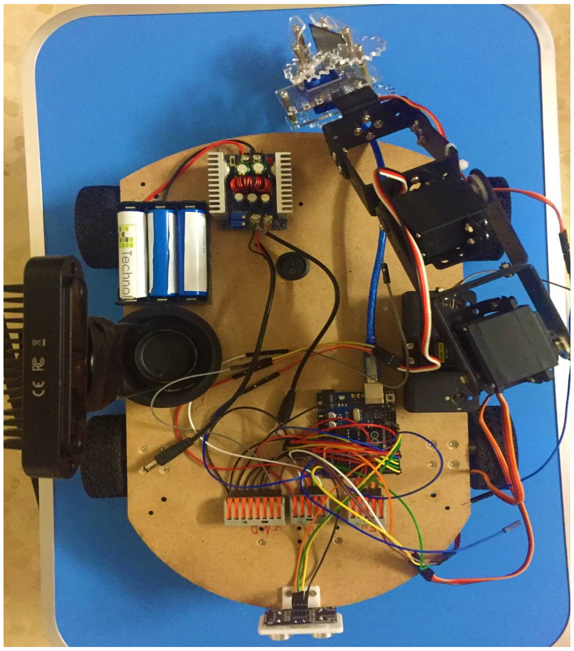


Figure 3.9: Harvester Top View

Tools:

- Geared motor :
  The geared motor has high torque, so it is difficult to stop the motor because of stone or dirt because the strength of the motor becomes greater with an external force. It is slower than other motors, but it can provide a larger load to walk on dirt and carry the weight of the fruits[4].

Figure 3.10: Geared motor

- Infrared Line Tracking Sensor FC-123 :
  We use 2 of these sensors in the bottom of the case for tracking the black line. They have an infrared emitting diode that continuously emits infrared rays. When the rays are not reflected, the input will be assigned as low and we will detect the line.

Figure 3.11: Infrared FC-123

- HC-SR04 ultrasonic :
  This is called a distance sensor. It includes an ultrasonic transmitter, a receiver and a control circuit. We use it to calculate the distance between the robot and the objects to avoid crashes.

Figure 3.12: ultrasonic sensor

- 3 DOF Arm :
  It consists of 3 servo motors and stand on the left side of the robot. At the end of it there is a CNC hand grip to hold the crops.

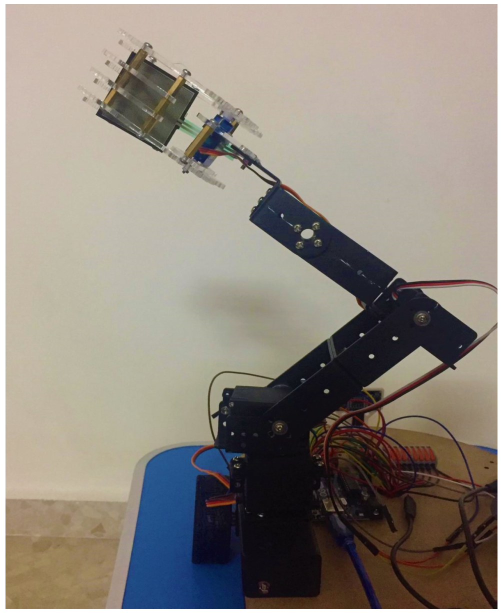


Figure 3.13: 3 DOF Arm

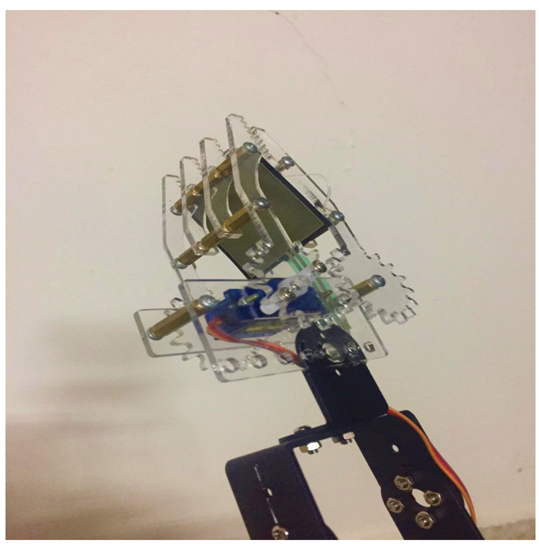


Figure 3.14: gripper

- Arduino uno :

We use the Arduino Uno board to control the movement of the robot and the arm according to the sensor readings and the data that the Arduino gets from the Raspberry Pi through the USB cable.

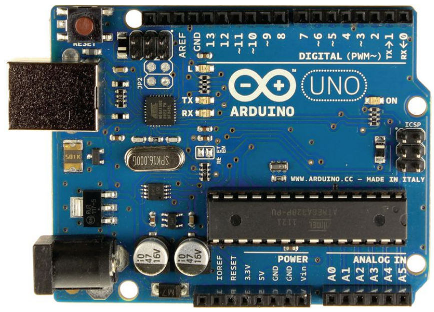


Figure 3.15: Arduino uno

- Raspberry Pi :
  We use the microcomputer "Raspberry Pi" that is connected to the camera, so it will send the information to the Arduino Uno board according to the camera's live view. In addition, it gets information from the Harvester mobile application to specify what the farmer needs about movement mode, plant type and quantity by using its on-board 802.11n Wireless LAN adapter.

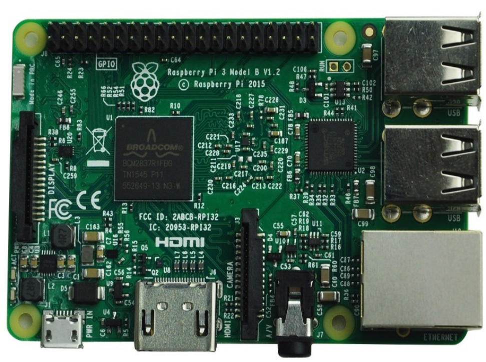


Figure 3.16: Raspberry Pi

- OAK-D Camera :

OAK—D hardware pledges with high quality USB (1 meter cable) ,OAK-D is a spatial AI powerhouse, providing depth from two stereo cameras and color information from a single 4K camera in the center need 5V power supply.

Figure 3.17: OAK-D Camera

- Force sensor :
  Force sensitive resistor with a square sensing area. Its resistance varies depending on how much pressure is being applied to the sensing area. Harder force produces lower resistance but when there is no pressure on the Force sensitive resistor its resistance will be larger than 1M. We used this sensor to get the crop without damaging it.

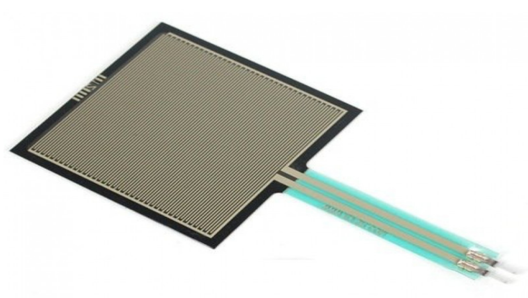


Figure 3.18: Force sensor

3.5 Functionalities

There are two Walking methods

- Line Follower :
  Harvester will start it's trip by walking on the black lines in the nursery by using its FC-123 sensors, directing its arm and camera to the left side. Ones it detects the selected object, Raspberry pi order the Arduino to stop and it send the 3D location of the object to the Arduino which by its role it directs the arm to the exact position then grape the object and put it in the basket. After that the Raspberry pi send an order to the Arduino after it finish object harvesting to walk and complete and go on until it sees the stop sign.

- Autonomous :
  We will use specific shapes each one of them have an indication such as a rectangle, triangle, arrow or circle. Harvester will automatically start walking searching for shapes. For example, if it was searching for tomato and saw the circle shape it will know that to the left is the line of tomato plants, so it should turn to the left,and do as previous, ones it detects the selected object, Raspberry pi order the Arduino to stop and it send the 3D location of the object to the Arduino which by its role it directs the arm to the exact position then grape the object and put it in the basket . The same thing happens if it saw the other mentioned shapes above, but for the arrow shape it gives it the order or information to stop. Automatically if it walked for more than 5 minutes and didn't find any crops to collect then it will stop.

While walking either in one of the two mods there is the object avoidance system where if any object blocked the way harvester can avoid it and keep walking.

3.6 Control the arm

Once the Oak-D camera on the robot detects the needed object, the Raspberry Pi orders the Arduino to stop and it sends the 3D location of the object to the Arduino (X, Y, Z) in cm which is responsible for arm movement. By using an inverse kinematics matrix, we turn them to angles moved by the 3 servo motors in the arm (servo 1, servo 2, servo 3).This was analyzed by Abdullah Kamal Bishtawi from Mechatronics Engineering Department[5].

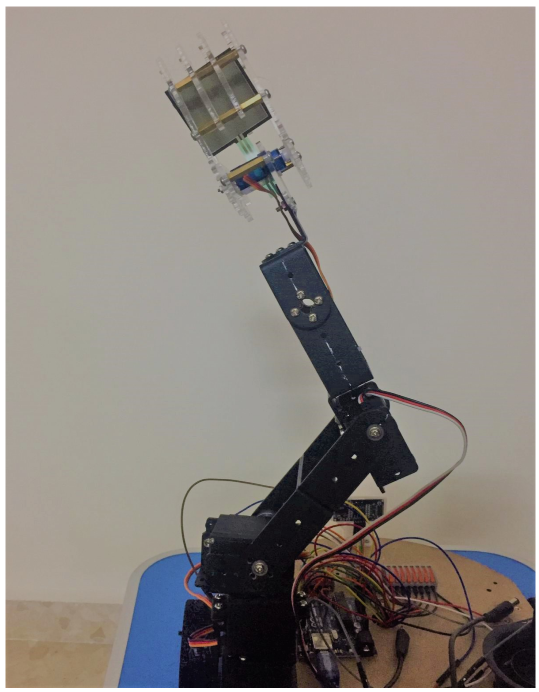


Figure 3.19: Arm Structure

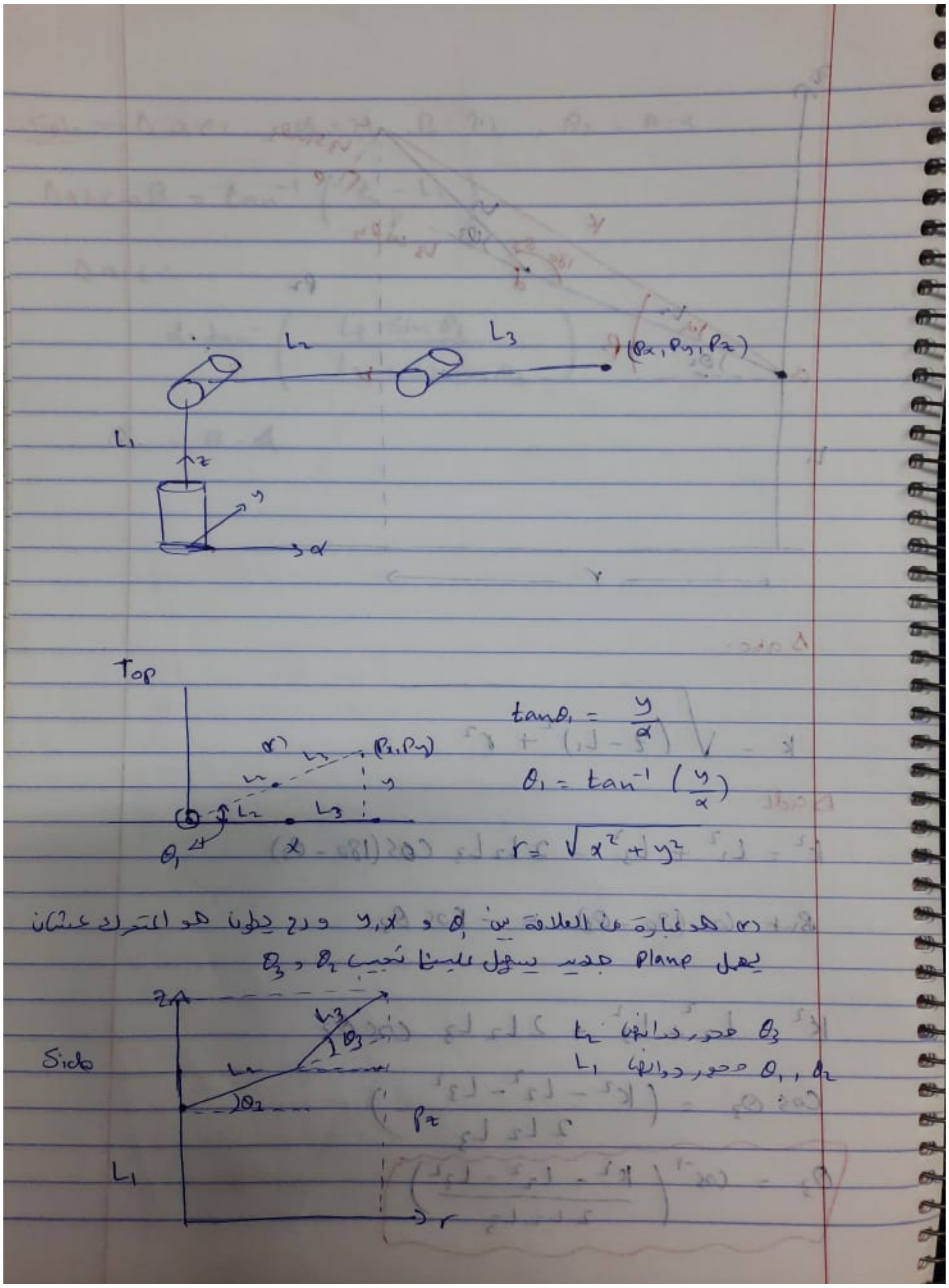


Figure 3.20: Dimensional Analysis - Part 1

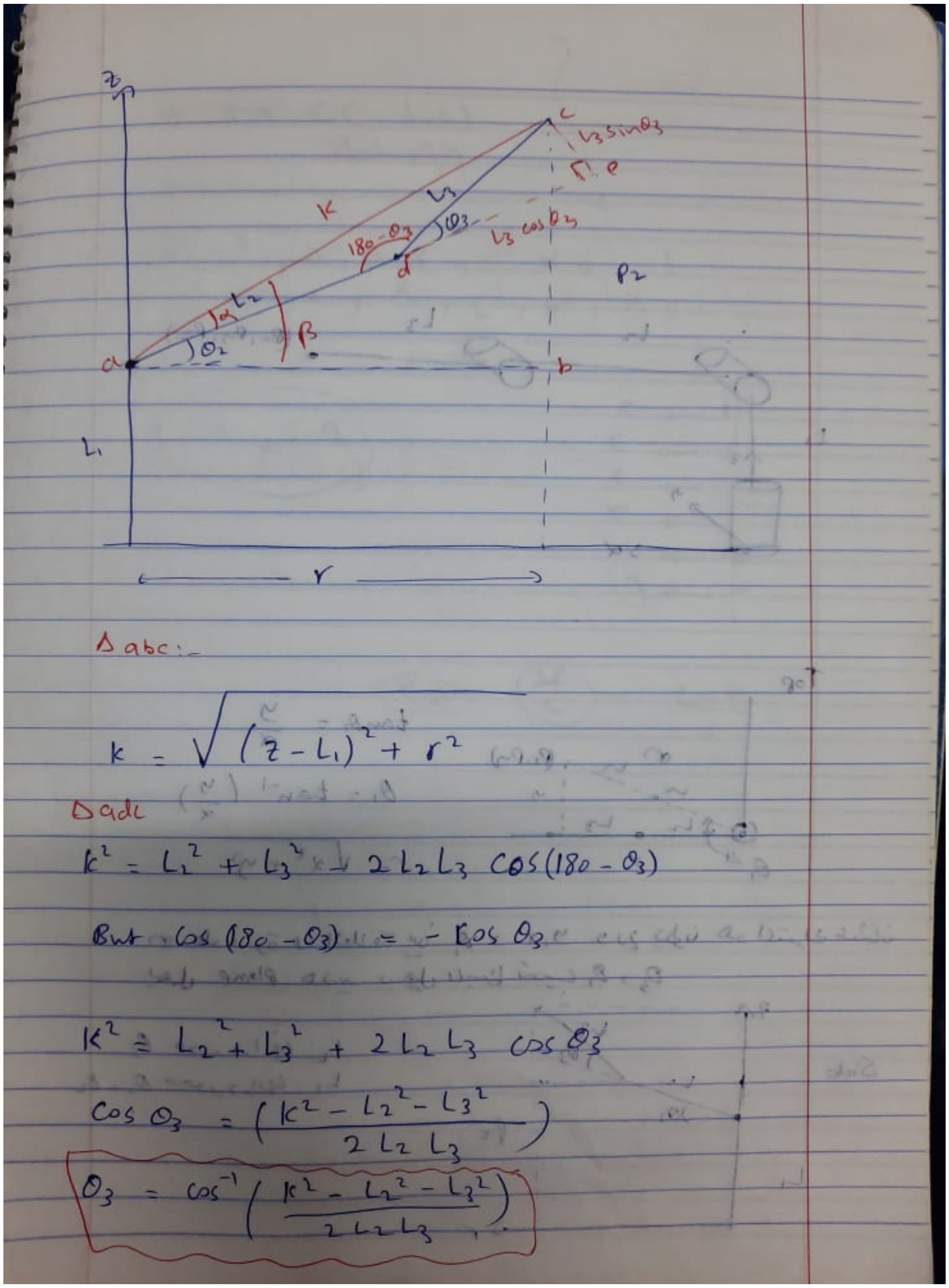
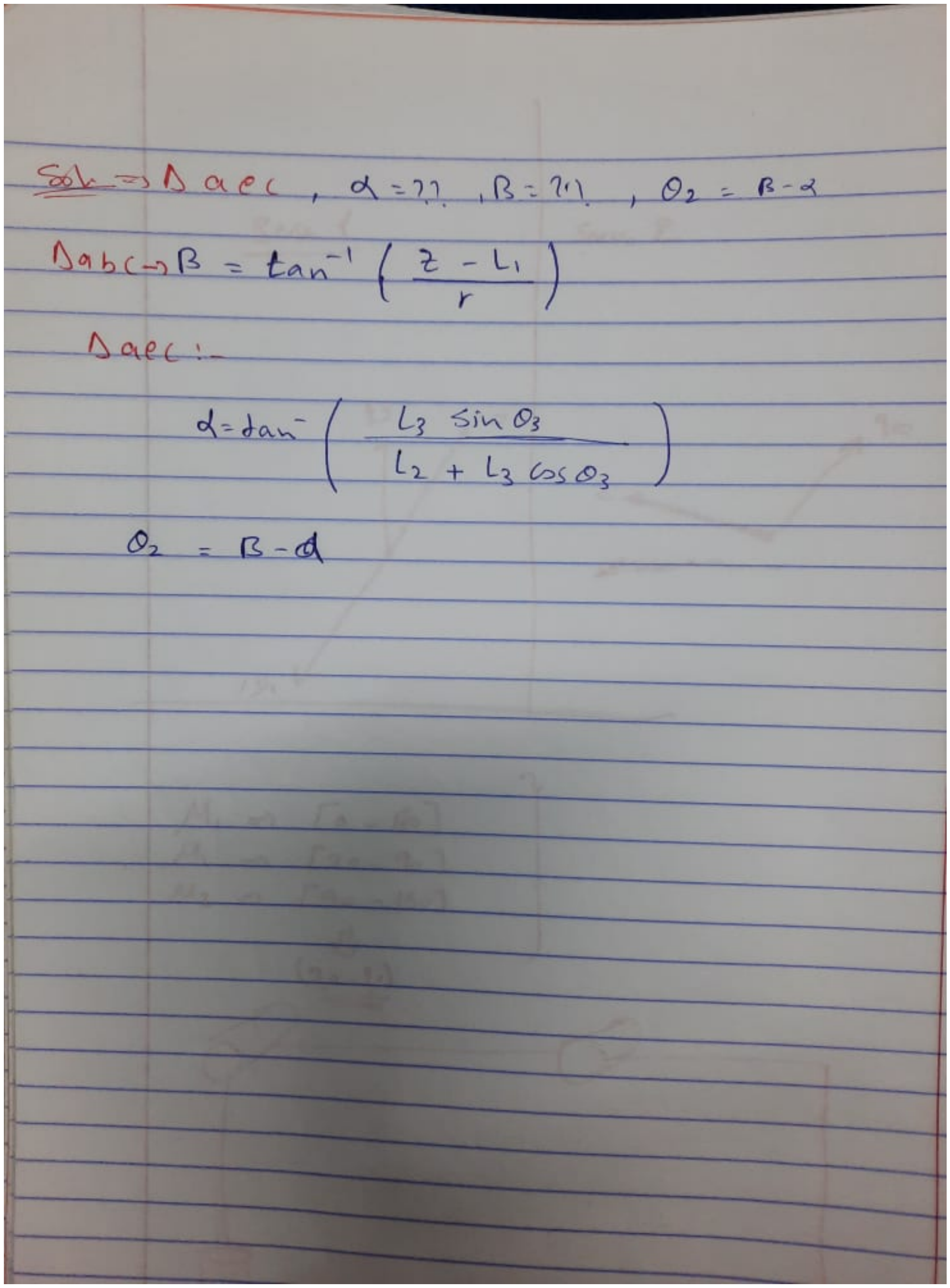


Figure 3.21: Dimensional Analysis - Part 2



Soln → Δaec , $\alpha = ??$, $\beta = ??$, $\theta_2 = \beta - \alpha$

$\Delta abc \rightarrow \beta = \tan^{-1}\left(\frac{z - L_1}{r}\right)$

Δaec :-

$$\alpha = \tan^{-1}\left(\frac{L_3 \sin\theta_3}{L_2 + L_3 \cos\theta_3}\right)$$

$$\theta_2 = \beta - \alpha$$

Figure 3.22: Dimensional Analysis - Part 3

Mobile Application

The mobile application called "Harvester" will be the connection point between the farmer and Harvester robot. In the beginning the farmer choose the type of crop that he wants it to be collected from the nursery, then the farmer will be asked to choose the number of crops he wants to be collected with having the choice "pick all" , and he have to choose one of the above-mentioned modes. Then when he approves the request, it will be sent to the Raspberry pi in harvester by using the WIFI.

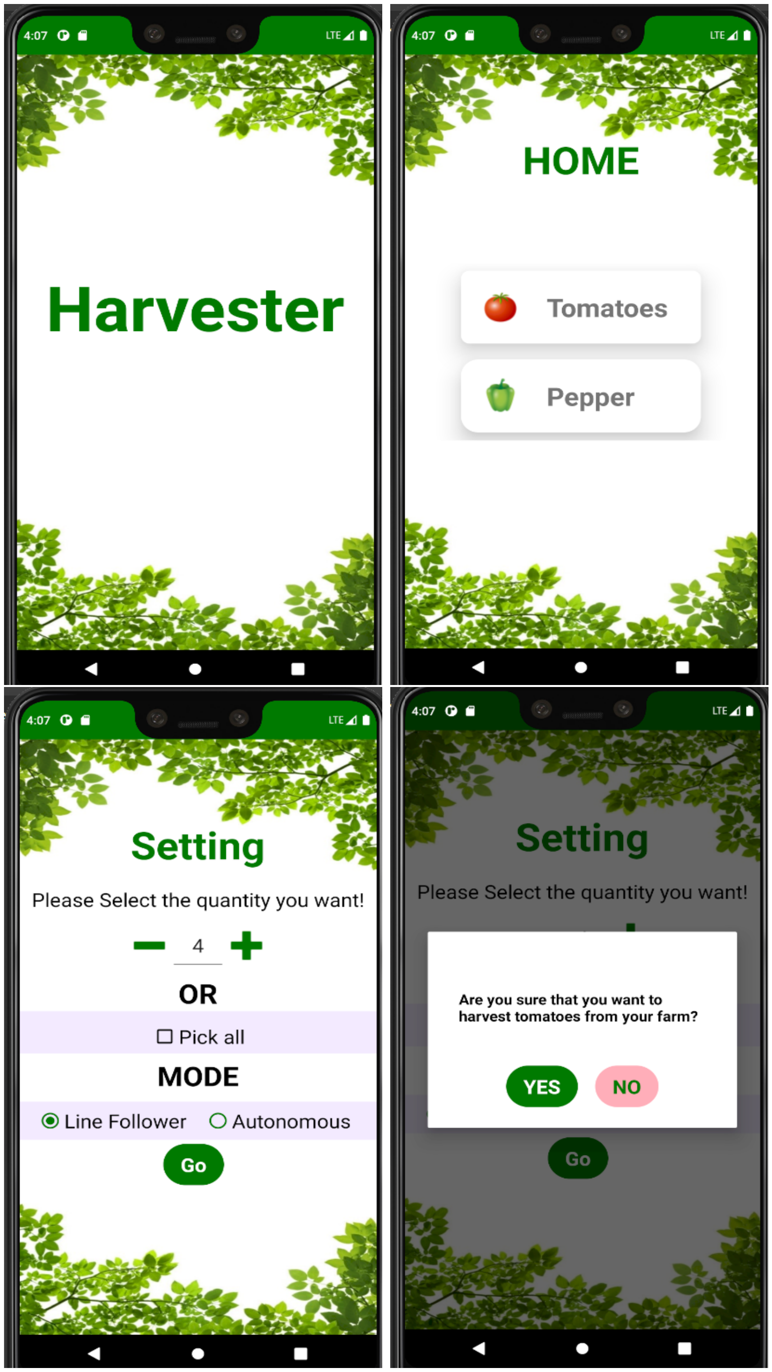


Figure 3.23: Harvester App

Chapter 4

Result and Analysis

At the end we will achieve our goal to build a robot depends on the dataset we created to collect two kinds of the crop, so the robot walks in the nursery searching for the demanded plant in the same amount that the farmer chose. Whenever it sees the crop, it specifies the location of it by using 3D and pick it by the arm Where the Operation success rate 85

Chapter 5

Challenges and Constraints

We faced a couple of challenges and constraints during designing this project. In this chapter, we will talk about the most important ones and constraints that faced us. The main problem that affected our accuracy greatly was moving the arm. Where the results of localization and positioning from OAK-D camera measured in centimeters and we needed to turn them to angles moved by the 3 motors in the arm, but this is not our specialization so we asked for help from the mechatronics engineering department to analysis the arm mechanism. This process faced a lot of huge difficulties to control the accuracy because of the tuning of the motors, so the system accuracy got affected by the accurate mechanical operations of the arm movement and the mathematical ones to calculate the object depth. To relive the effect of servo tuning problem we studied every servo error and make a balance to almost solve it.
We've should use the stepper motors instead of the servo motors because it's more accurate in the rotation, but we didn't used them because the stepper can't handle the crop weight. We used the OAK-D camera which is a new version of cameras that doesn't have those strong previous references, so that cost us double effort and time to know how to deal with it.

Chapter 6

Conclusion and future work

In fact, the agricultural field here in our country needs to take care of it, where it has a big role in the economic situation of the country, it needs to be active and let the technology play its role. We find most of the countries used technology in the agricultural filed, so we should take it seriously and stop ignoring the fact of its importance. In our project we presented a system that helps the farmers to harvest the agricultural lands automatically without the need for workers thus, save time, effort and money.
In the future, the system needs to be developed and increase its accuracy either in specifying the location of the crop or picking it. In addition, we will expansion the dataset to include all kinds of crop and give the farmer the chance to choose from it the kind of crop that is planted in his land. This project that we achieved as students it's just a prototype needs to be developed and supported by stronger equipment's in the future.

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