COLLECTOR BOT

1. Introduction

Our population is increasing at a faster pace than the pace recorded a few decades ago. An important issue that arises out of this population explosion is food scarcity which makes it imperative to think of new methods in agriculture to increase the yield and to make food production more efficient. In a country like India, where over 55%[1] of the population depends on agriculture, it is important that we look into automating the agricultural processes to ensure higher productivity and lower wastage.

The demand-supply mismatch in crops is likely to hit more than 15% by 2020, with the gap worsening to 20-25% by 2025[2], if unaddressed. Wastage levels in our agricultural supply chain hover between 30% and 40%. One of the reasons for the wastage levels might be the delay in collecting naturally ripened fruits fallen on the ground.

Addressing this problem, e-Yantra has come up with the theme "Collector Bot". Through this, we help you discover your talent in designing and building a bot from scratch. We have divided the theme into a number of "Tasks" to build the robot in a step-by-step manner making the process easier and more interesting. You will learn things such as: microcontroller programming, robot construction, sensor interfacing, control system design, controlling a robot using the Virtual Robot Experimentation Platform (V-REP).

Let us consider a scenario where fallen fruits have to be collected in a farm. The robot which you build is the **Collector Bot** that collects the **Fresh fruits** and avoids the **Damaged fruits**. An image from the overhead camera is processed by a **Supervisor Station** to direct the Collector Bot. The task is to transfer the collected fruits to a Spark V robot referred to as **Truck** that moves through the farm in a given path.

The challenge is to complete the task of collecting Fresh fruits and transferring them to the Truck in the shortest time possible without incurring any penalties. The robots that perform the task the fastest in accordance with the rules set for this task will be declared the **WINNER**.

1. 'Indian Agriculture: A Fresh Approach Towards Green Revolution 2.0'
2. SHAPING INDIA'S FUTURE. TOGETHER.

2. Theme Description

- **Collector Bot (CB):** This is the robot that you build which is capable of navigating the Arena, communicating with the **Supervisor Station** (defined below). It has an **ArUco Marker (Refer Task 1.1)** on it with **ArUco ID 0** for its localization.
- **Supervisor Station:** A PC/Laptop with V-REP and OpenCV-Python represents the Supervisor Station. The communication between CB and Supervisor Station is done wirelessly through XBee.
- Arena is divided into 24x17 **Cells.** Rows are referenced using numerical digits 1 through 17 and Columns are referenced using English alphabet A through X.

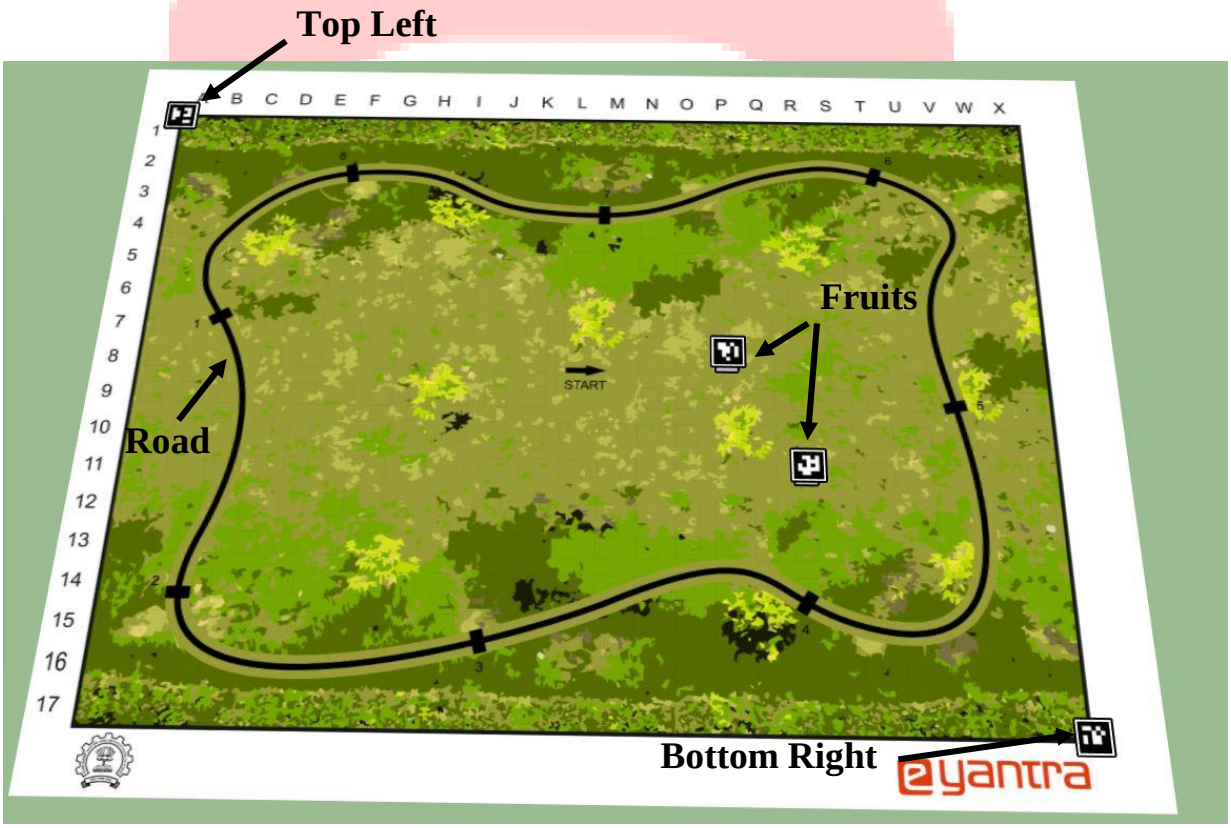

Figure 1: Arena with Areas Marked

- **Collection Stations:** Small thick segments in the Road represent Collection Stations. There are 8 Collection Stations numbered as shown in Figure 1.
- **Collection Area:** Region inside the Road is termed as Collection Area.
- **Start:** The box inside the Collection Area labelled as Start indicates the starting point of the CB. The arrow indicates the initial orientation of the CB. Front side of the CB must face in the direction of the arrow mark.
- **Fruits**: Collection Area contains cubic blocks depicting Fruits**.** There will be a maximum of 8 fruits in the Collection Area. They are classified into **Fresh Fruits** and **Damaged**

Fruits. Nature of the Fruits are determined by the ArUco marker which is placed on top of each of them. Orientation of the Fruits can be random with respect to the overhead camera. Instructions for making Fruits are provided below.

- **Truck:** This is a Spark V robot with a bin to collect the Fresh Fruits which moves on the Road stopping for 10sec at each Collection Station. The truck is identified by the ArUco marker on it with **ArUco ID 1**. It is without a communication module. So, it moves independently on the Road. Collection Station 1 is the starting point of the Truck.
  The ArUco markers are to be placed as mentioned in Table 1.
- **Road**: The black line represents the Road for the Truck.

Table 1: ArUco IDs and corresponding objects

ArUco ID	Referring Object	Dimensions(cm x cm)
0	CB	12 x 12
1	Truck	12 x 12
2	Fresh Fruit	9 x 9
3	Fresh Fruit	9 x 9
4	Fresh Fruit	9 x 9
5	Fresh Fruit	9 x 9
6	Damaged Fruit	9 x 9
7	Damaged Fruit	9 x 9
8	Damaged Fruit	9 x 9
9	Damaged Fruit	9 x 9
10	Top left	9 x 9
11	Bottom right	9 x 9

Input:

A **Fruit Location Table** will be given as input which provides the locations of the Fruits corresponding to the ArUco IDs. Each location starts with row number and ends with column number. This table is used only for setting up the arena and should not be used anywhere in the code. Your code should be generic to find the locations.

Table 2 shows an example Fruit Location Table for placement of Fruits. Note that, if this Fruit Location Table is given, the Fruits will be placed as shown in Figure 2.

Table 2: An example Fruit Location Table

ArUco ID	Location
2	13G
4	8P
5	10I
6	11R
8	7F
9	6M

Figure 2: Example Input

Note: The arena shown in Figure 2 is specific to the example considered. During the competition, the Fruit Location Table will be different.

In summary, the theme involves the following:

- Fruits in the arena are set up using Fruit Location Table.
- CB starts from the Start facing in the direction of the arrow mark. Truck starts from the Collection Station 1 facing towards Collection Station 2.
- An overhead camera, mounted above the center of the arena, captures the entire arena. Instructions for mounting the camera are provided in section 3D.
- Supervisor Station processes the camera feed, plans the path using V-REP and guides CB on the Arena through commands. Simultaneously, V-REP emulates the Arena (Refer Task 3.2).
- CB has to deposit all the Fresh Fruits into the Truck avoiding collision with Damaged Fruits and the Truck.

3. Arena

Preparing the arena:

Each team has to prepare the arena. Preparing the arena consists of

A. Printing the arena design on flex sheet
B. Fruits construction
C. ArUco markers Construction
    a) CB and Truck
    b) Arena
D. ArUco markers on the Arena
E. Setting up overhead camera

A. Printing the arena design on flex sheet:

Flex design is shown in Figure 3. A Portable Document Format(.pdf) file containing the flex design is provided to the teams. Each team prints the flex design according to the directions given in the Readme file

WARNING: Please be careful while handling the flex sheet – avoid folding it like a bed-sheet since the resultant folds will cause problems while the robot moves. One way of "flattening" flex if it has been compromised is to hang it for a few hours in the sun – it tends to straighten out. Never attempt ironing it or applying heat of any kind – it may be a fire hazard.

NOTE: Teams are not allowed to make any changes in the arena design. Any team making unauthorized modifications will be disqualified from the competition.

Dimensions of arena are as shown in Figure 3:

- Outer dimension of arena is 7 x 9 feet (marked by red border in Figure 3).
- Inner dimension of arena is 5.9 x 8 feet (marked by black border in Figure 3).
- Dimension of each Cell is 6cm x 6 cm (marked by blue lines in Figure 3).

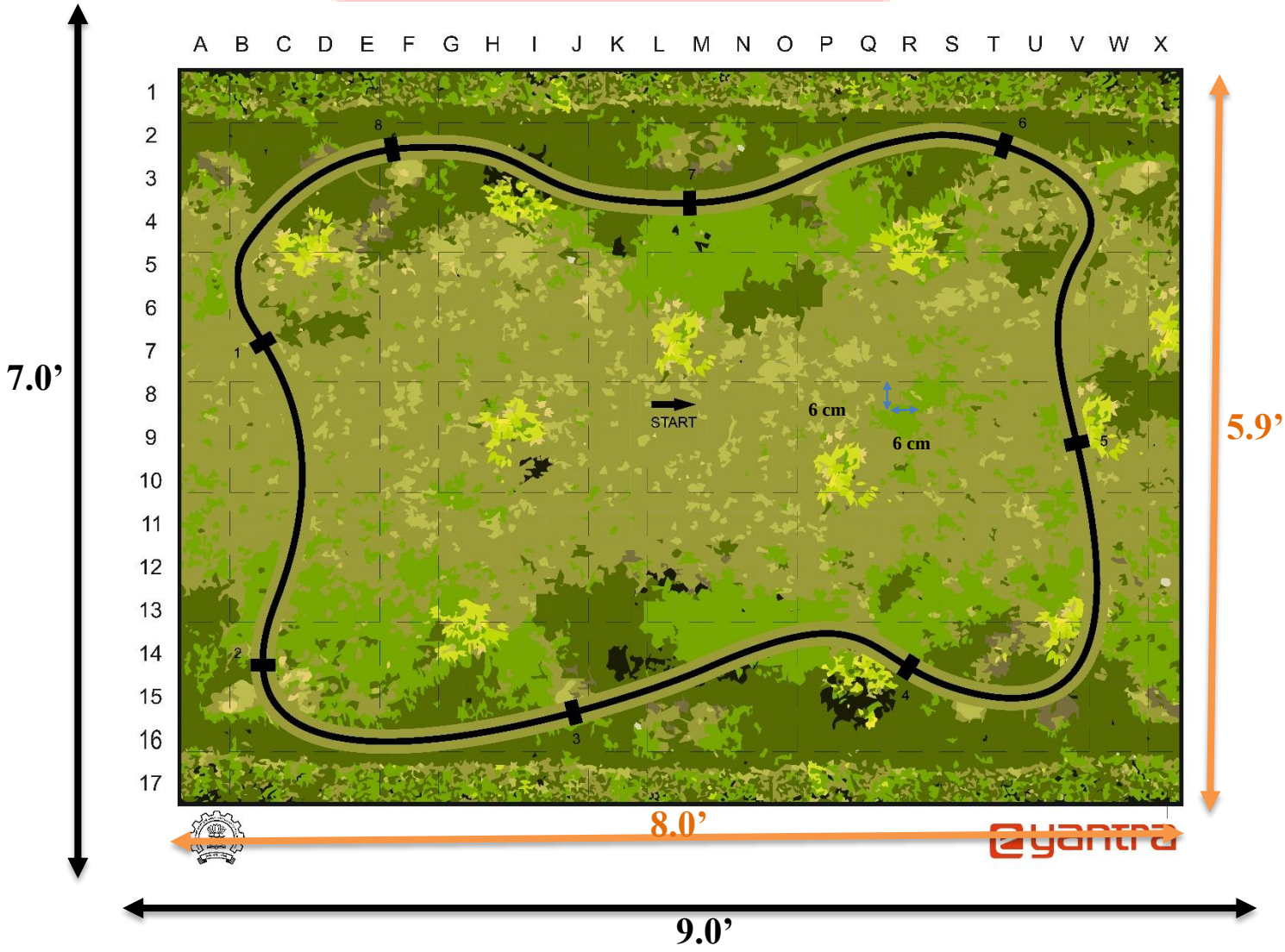

Figure 3: Arena with Dimensions

B. Fruits Construction

Material required for making the Fruits are:

1. Thermocol Sheets
2. Sunboard
3. A4 papers for printing the ArUco markers

Steps to be followed:

- Cut out block of 6cm x 6cm x 6cm from the thermocol sheet. Figure 4 shows a block.

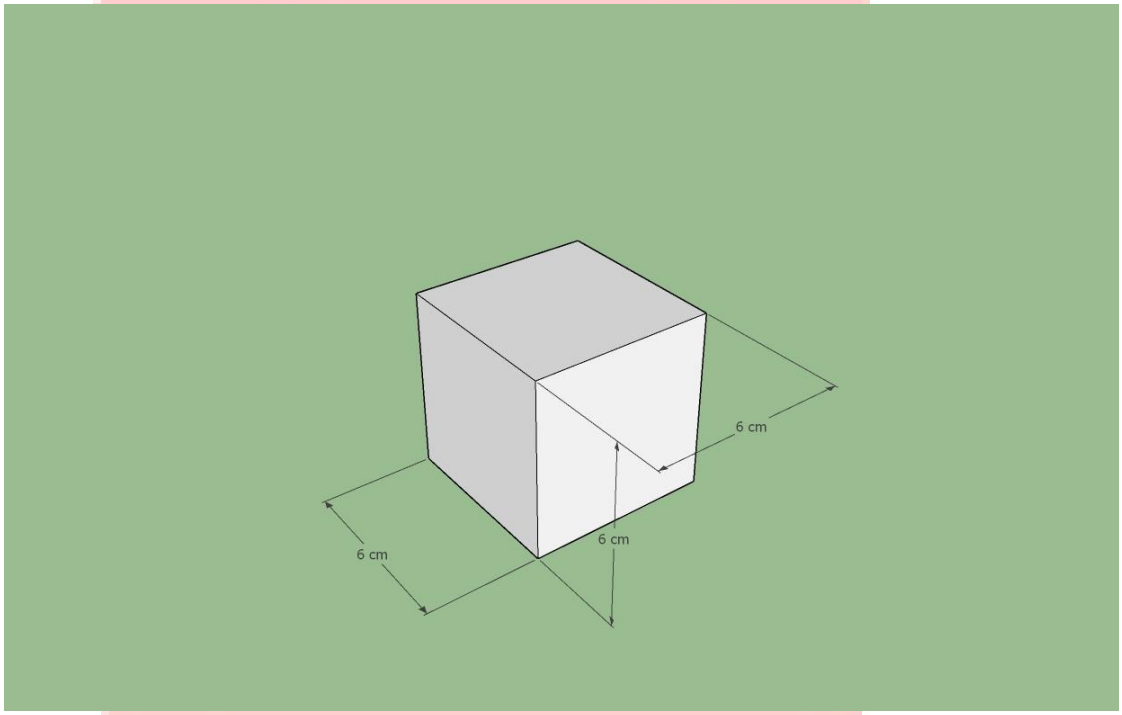

Figure 4: Thermocol block

- Cut the Sunboard into rectangular sheet of dimensions 9cm x 9cm. Use the sunboard of width 3mm. Figure 5 shows the sunboard sheet.

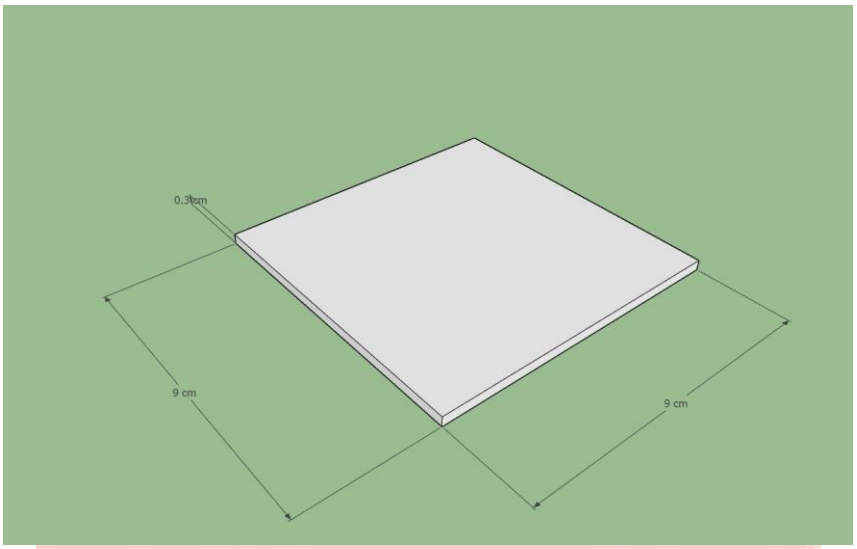

Figure 5: Sunboard sheet

- Cut the ArUco marker with padding as given in the *ArUco_Markers_Fruit.pdf* (provided in Task 3).
- Paste the ArUco marker on the sunboard using glue or double sided tape. The ArUco marker must be pasted on sunboard as shown in Figure 6.

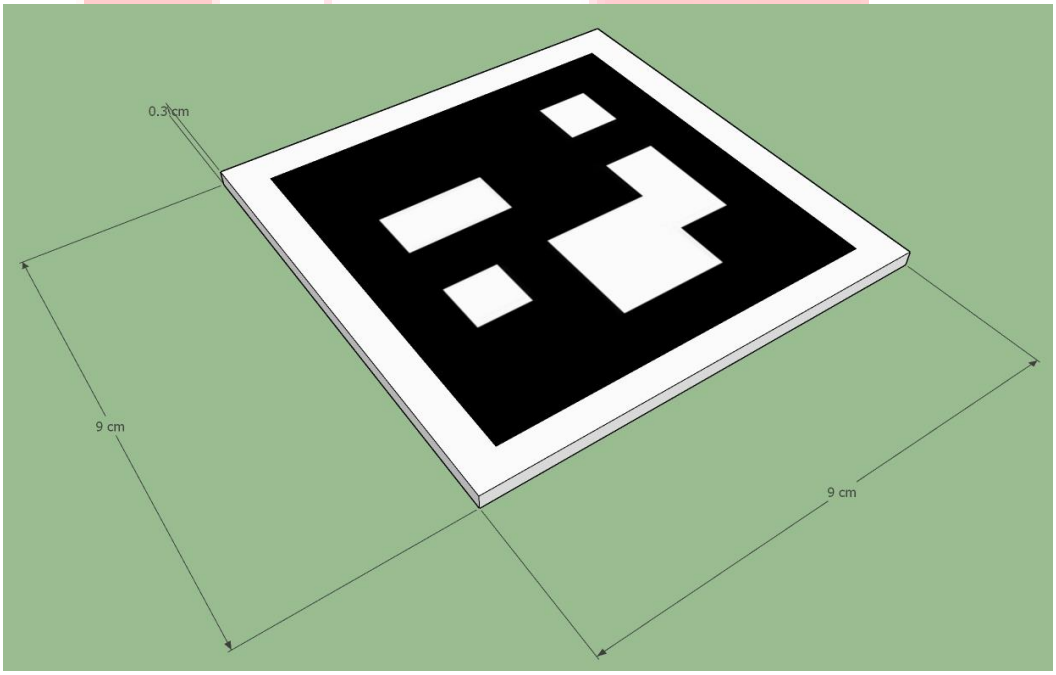

Figure 6: ArUco marker on sunboard

- Place the sunboard on the block. Use double sided tape so that the sunboard remains flat with respect to the block's face. The final "Fruit" should be as shown in Figure 7.

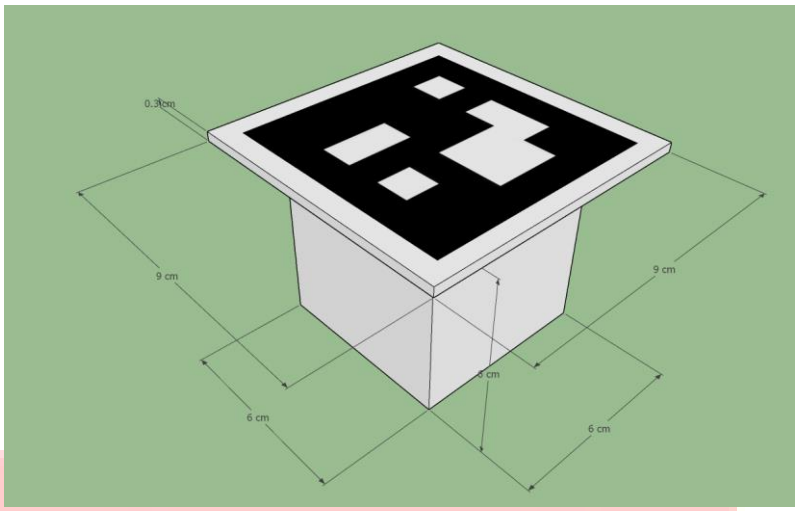

Figure 7: Fruit

C. ArUco marker Construction

a) For CB and Truck

- Cut the rectangular sheet of sunboard with the dimensions 12 cm x 12 cm.
- Cut the ArUco marker with padding as given in the *ArUco_Markers_Bots.pdf* (provided in Task 3).
- Paste the ArUco marker on the sunboard using glue or double sided tape. The ArUco marker must be pasted on sunboard should be as shown in Figure 8.
- Now, paste this construction on to the CB and the Truck in such a way that it's always visible through the overhead camera.

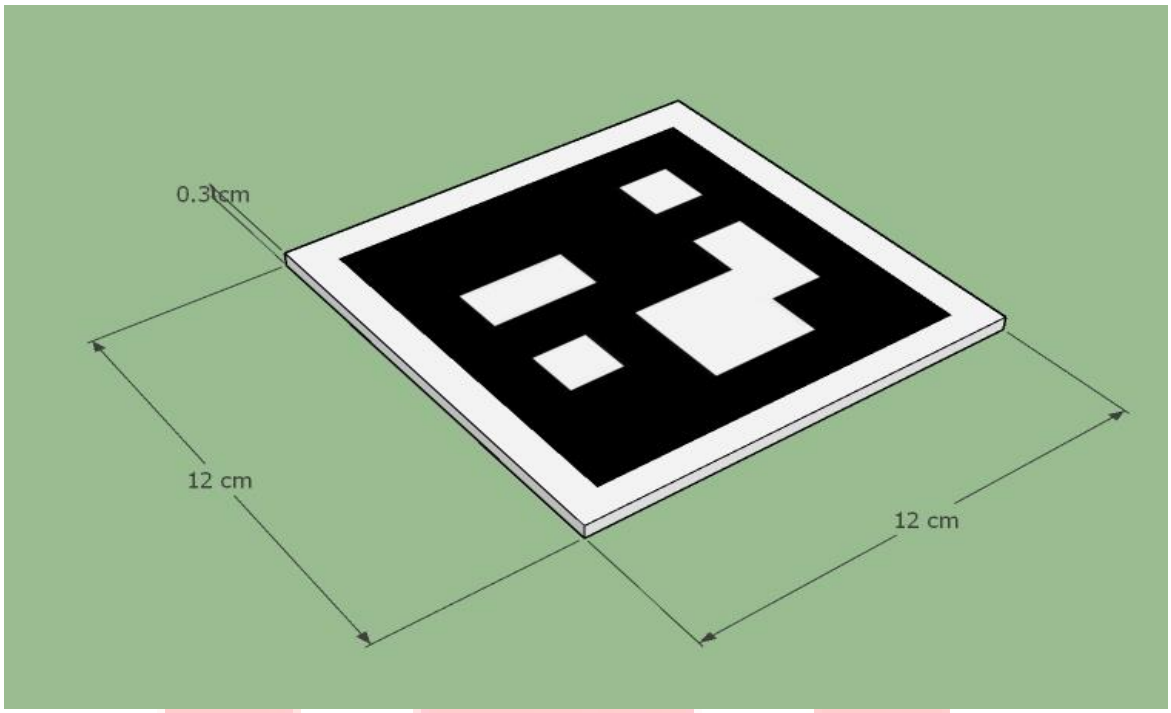

Figure 8: ArUco marker construction for CB and Truck

b) For Arena

- Cut the rectangular sheet of sunboard with the dimensions 9 cm x 9 cm.
- Cut the ArUco markers with padding as given in the *ArUco_Markers_Arena.pdf* (provided in Task 3).
- Paste the ArUco marker on the sunboard using glue or double sided tape.
- Now, paste this construction on to the top left and bottom right spaces given in the Arena as shown in Figure 9.

Note:

- **Colour print ArUco_Markers_Fruits.pdf, ArUco_Markers_Bots.pdf and ArUco_Markers_Arena.pdf (provided in Task 3) for better detection.**
- **Make sure that you use the ArUco markers accordingly as mentioned in Table 1.**

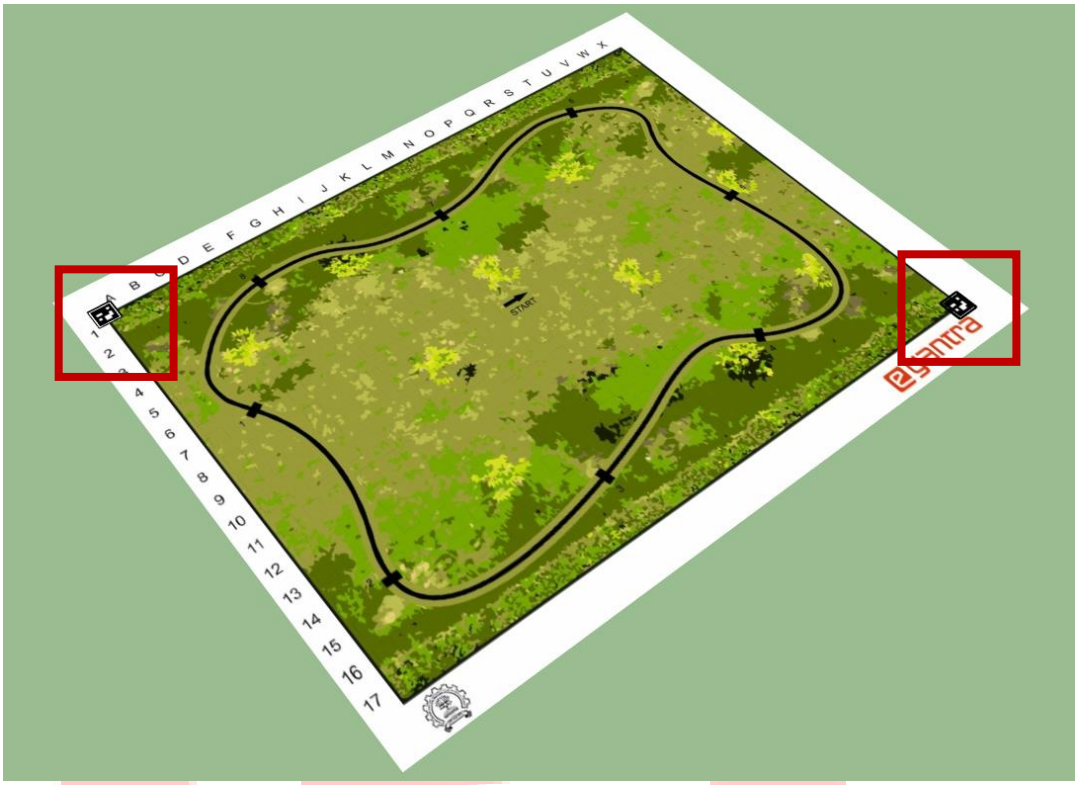

Figure 9: Arena with ArUco markers at corners

D. Setting up of overhead camera

- Team is provided with a USB camera and USB to USB extension cable.
- The provided camera must be mounted such that it has a complete top view of the arena. Camera should be mounted above the center of the arena (Top Dead Centre) at an approximate height of 8ft.
- Teams are expected to use their creativity to design an arrangement to mount the camera, for example, hang it from a ceiling, construct a frame etc.
- USB-to-USB extension cable is to connect the USB camera to the PC/laptop. Figure 9 shows an example setup for overhead camera.

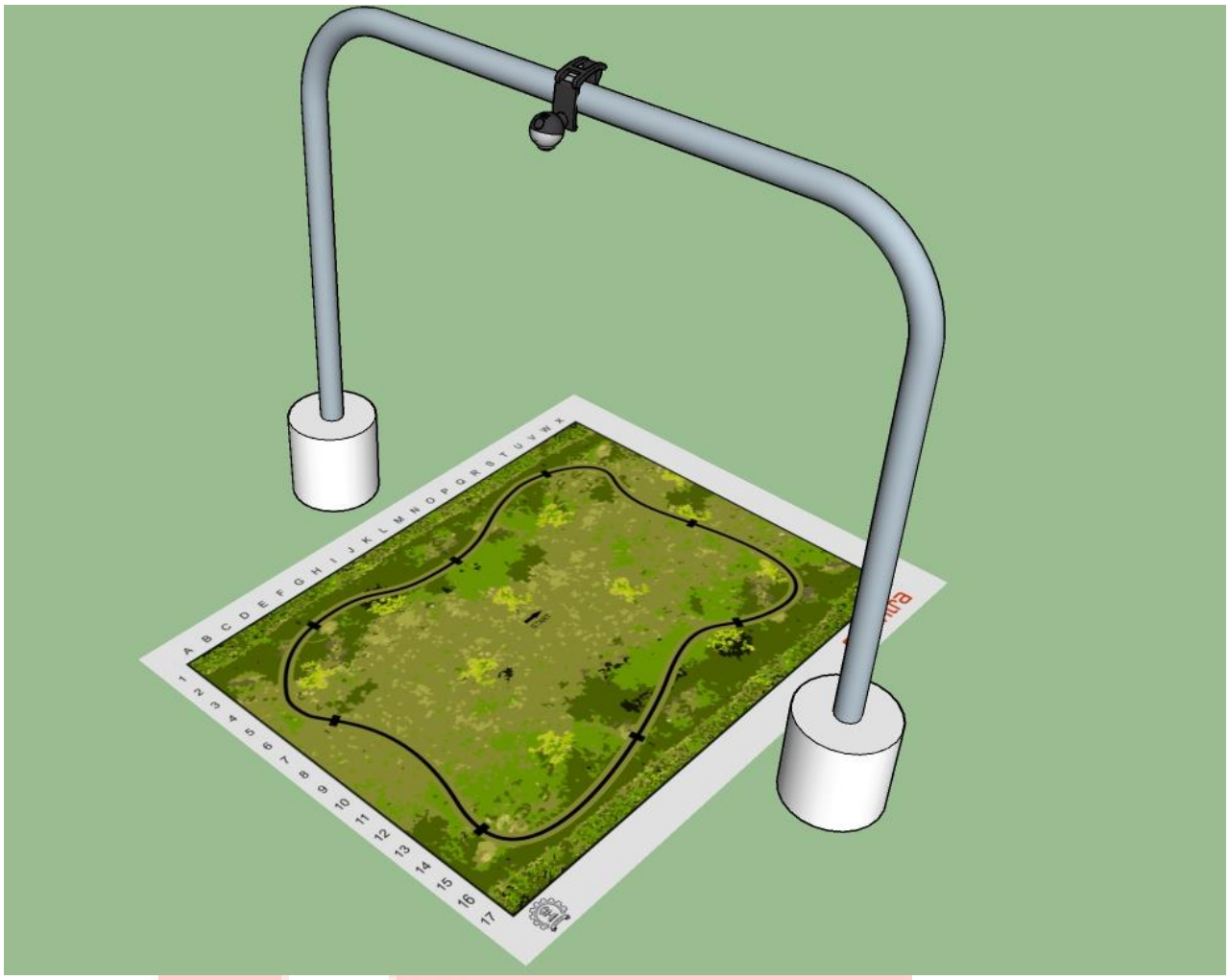

Figure 9: Overhead camera setup

E.Final Arena Setup

As specified in the Fruit Location Table in Theme Description section, place the Fruits on the Arena. Figure 10 shows an example of the final arena setup.

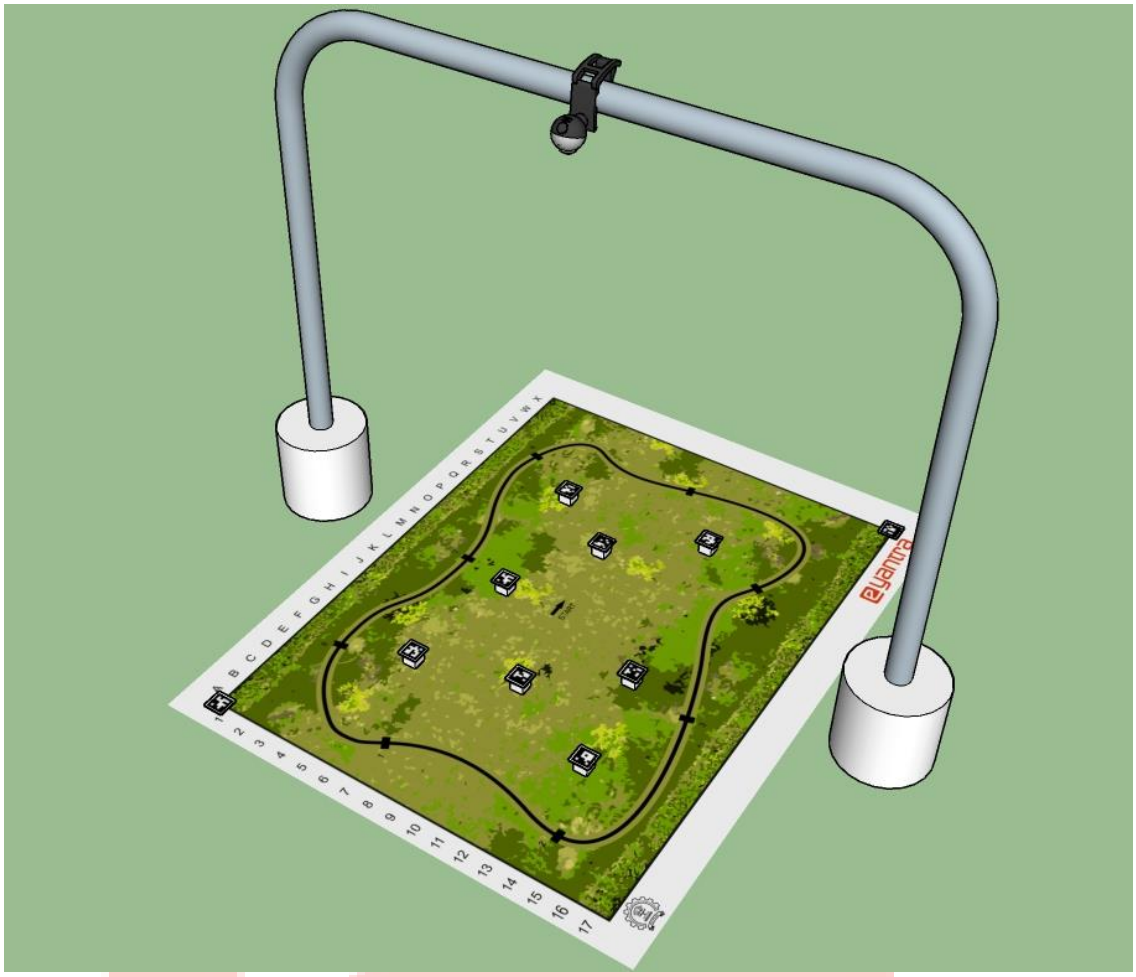

Figure 10: An example of final arena setup

Note: The arena shown in Figure 10 is just for illustration. Placement and orientation of Fruits may be random.

Please maintain the arena in a good condition. If the arena is found damaged or in a condition not good enough to properly evaluate the team, e-Yantra has the right to disqualify the team. **The final decision is at the discretion of e-Yantra.**

4. Hardware Specifications

a) **Use of Components:**

- All the participating teams must use only the components which were sent to them in the kit. You can use an extra actuator only with the permission of the e-Yantra team.
- The robot should be completely autonomous. The team is not allowed to use any wireless remote or any other communication protocol for manual control of the robot.

- Team are allowed to create any type of mechanical mount for structure of CB.
- The maximum area of the Truck (including bin) is 50 cm x 25 cm (where 50cm corresponds to the length of the truck and 25 cm corresponds to the width of the truck).

b) **Power supply:**

- The robot can be powered through Li-ion battery power supply. There are supplied with the kit.
- The team cannot use any other power source for powering the robot.

Note: No other expansion and/or microcontroller-based board shall be attached to ATmega2560.

5. Software Specifications

- e-Yantra has provided all teams with V-REP- a free simulation software and Arduino IDE for programming the microcontroller.
- The teams must use Lua, Python to write their code.
- Use of any non-open source libraries/external python modules is not allowed and will result in disqualification.
- As per e-Yantra policy, all your code and documents is open-source and maybe published on the e-Yantra website.

6. Theme Rules

- CB is placed at the Start facing in the direction of the arrow. Truck is placed at the Collection Station 1 with its face towards Collection Station 2.
- The maximum time allowed to complete the task is 10 minutes. A maximum of two runs will be given to a team (the better score from the two runs will be considered as the team's score). A maximum of two re-positions (explained below) will be allowed in each run.
- The team must detect the position and orientation of the robot using the overhead camera.
- The teams must use the XBee modules to communicate between Supervisor Station and the CB. There must not be any mode of communication between Truck and CB or between Truck and the Supervisor Station.

- The teams should place CB and the Truck in their respective start positions. Teams must switch on CB and execute the Python script along with all the initialization when told to do so by the reviewer. Then, team should switch on the Truck. This is the start of a run. The timer will start at the same time.

- Once the Truck is switched on, human intervention is **NOT allowed.** Any human intervention is considered as Re-position (Re-position rules are mentioned below).

- A run ends and the timer is stopped if:
  - CB deposits all the fresh fruits in the Truck and a pop up window appears in the V-REP with the text "**FRUITS COLLECTED**".
  - The maximum time limit for completing the task is reached
  - The team needs re-positioning but has used both re-positioning options of that run.

- Task will be considered incomplete and time will be considered maximum (600 seconds) if:
  - CB does not deposit any Fruit in the Truck.
  - CB or Truck needs re-positioning after using their maximum re-positions.

- The CB can follow any order to collect the Fruits given in the Fruit Location Table.

- Second run starts once again whilst resetting the score, timer and arena. The score of both runs is recorded and best of two runs is considered the team's score.

- For second run, teams are not allowed to make any software changes. Hardware changes are allowed.

- Participants are not allowed to keep anything inside the arena other than the CB and Truck.

- The time measured by the reviewer is final and will be used for scoring the Teams.

- Time measured by any participant by any other means is not acceptable for scoring.

- CB and Truck are not allowed to make any marks while traversing the arena. If found damaging the arena, they will be immediately stopped; re-positioning will be allowed as per the rules. **The final decision is at the discretion of the e-Yantra team.**

- Fruit is said to be deposited correctly only if the deposited Fruit stays completely inside the bin (of the Truck) for the entire run.

- **Emulation Rules:**
  - Team must use the given V-REP template *final_arena.ttt* (provided in Task 4).

- Team can use either ***Collector Bot.ttm*** *(Refer Task1.2)* or a model similar to their robot for representing CB. Team can use either ***Truck.ttm*** (*Refer Task3.2*) or a model similar to their Truck. Team who build their own model of their CB, Truck will be awarded bonus marks in Finals.
- To represent Fresh Fruits, cylinders with names *FreshFruit1*, *FreshFruit2*, *FreshFruit3*, *FreshFruit4* should be used. Similarly, to represent Damaged Fruits, cylinders with names *DamagedFruit1*, *DamagedFruit2*, *DamagedFruit3*, *DamagedFruit4* should be used.
- The current target Fruit which is going to be picked by CB should be colored BLUE.
- The cylinders corresponding to the Fruits which were successfully deposited should be replaced to a position outside the working arena.

- **Re-position rules:**
  - Teams can ask for re-position if the robot gets stuck in the arena or goes off the arena.
  - Each team is allowed a maximum of three re-positions for either CB or Truck in each run. All re-positions require the approval from e-Yantra; the team stands disqualified if the robot is handled within the arena without approval.
  - During re-position, CB should be placed at the Start with orientation towards the arrow and the Truck should be placed just before its previous node on the Road.
  - If Fruits in Collection Area are displaced, they are placed back in the original locations. If this is caused by collision with CB, teams will be penalized according to the Judging and Scoring parameters.
  - Any arena setup during re-position is done by members of e-Yantra team.
  - For a re-position, a team can choose either to keep the robot powered ON or restart it.
  - During a re-position, the timer keeps running.
  - Team cannot make any changes in robot code during a re-position.
  - Team is allowed to restart the execution of Python program. However, team is not allowed to make any changes in the code.

NOTE:

- **You will be given Fruit Location Table 24 hour before the submission of Task 4: Video Submission along with instructions to complete this task.**
- **After completion of all tasks, teams will be selected as finalists based on their cumulative scores across all the tasks. Complete rules and instructions for the finals at IIT Bombay will be sent to those teams that qualify for the finals.**

In case of any disputes/ discrepancies, e-Yantra's decision is final and binding. e-Yantra reserves the rights to change any or all of the above rules as we deem fit. Any change in rules will be highlighted on the website and notified to the participating teams.

7. Judging and Scoring System

- The competition time for a team starts from the moment the team starts the execution of code. The timer will start at the same time.
- The timer will stop as soon as the robot finishes the task. The better score of the two runs for a team will be considered the final score of the team. (Refer to Section 6 - Theme Rules for details).
- The team's total score is calculated by the following formula:

  Total Score= (600-T) + FV*50 + CP*100 + CD*200 - P*40 +B

  Where:

  T - Time taken to complete task (in sec)

  FV- Fruit Visited. It will be marked if any part of the robot touches the target fresh fruit (which is marked blue in V-REP).

  CP - Correct Pick. It will be marked if the CB correctly picks the Fresh Fruit.

  CD - Correct Deposition. It is incurred when the robot correctly deposits the Fresh Fruit into the Truck as per the rules explained above. Correct depositions will be counted at the end of the run

  P - Penalty is incurred each time when the CB touches/ displaces any other object in the arena except the current target.

  B - Theme Bonus of 100 if there is a perfect run i.e., no penalties, all correct picks, correct deposits and no re-positions taken.

All the Best!!