Planter Bot

1. Introduction

The need for automation in agriculture and allied activities and services is increasing manifold. This is due to factors such as: lack of labor caused by migration to cities, health hazards posed by working on the farm using bare hands in different climates and one's own capacity to do physical work. In spite of these deterrent factors, nearly 58% of the rural population is engaged in some kind of agricultural activity for their livelihood. Given the fact that agriculture is one of the major contributors to GDP in India, we are compelled to take this situation more seriously and think of solutions to automate various farming activities.

e-Yantra has come up with one such theme called “Planter Bot” to address the most preliminary and basic farming task of seedling and sapling plantation. The idea is to build a robot which is able to traverse the field with good accuracy in path detection with the aid of vision. The robot traverses a path having different Zones growing distinct types of plants. Each Zone has an associated requirement for seedlings of a particular kind to be planted. The robot plants the seedlings as per the requirement in each Zone which is simulated using image overlay.

The challenges in this theme include: designing and building a robot with basic components given, Python programming and Image Processing. Teams get to learn image processing techniques to overlay images over a given background in real-time.

The team that finishes the given task in the least amount of time whilst incurring the least penalties is declared the WINNER.

All the best!!

2. Theme Description

The Arena is as shown in Figure 1. The Arena represents a vast acreage of **Plantation Land** for cultivation. With reference to Figure 1, we define the following:

Nursery: is the starting point of the **Planter Bot (PB).** It is marked by a black solid rectangle of dimension 2x7 inches, spanning across **Cells** Q3-Q4 and marked as "Nursery". The Planter Bot must be placed at the Nursery in the Cell R3 facing towards Cell N3.

Shed: is the terminating point of the PB. It is marked by a black solid rectangle of dimension 2x7 inches, spanning across Cells Q15-Q16 and marked as "Shed".

Path: connects the Nursery with the Shed. The Path takes the form of different **Terrains**.

Terrains: There are Four types of Terrains (highlighted by red rectangular boxes in Figure 1) which are listed below:

1. Hill Side Road (HR)
2. Berms (BE)
3. Cliff Roads (CR)
4. Inverted Plains (IP)

Cell: The columns of grid are identified by A, B, C….., R. The rows of the grid are identified by 1, 2, 3, 4….., 17. The Arena consists of a grid of 18x17 Cells. Hence each Cell in the grid can be addressed using the notation C9 and Q13 as highlighted by blue rectangular boxes in Figure 1. The dimension of each Cell of the grid is 12.8 x 12.8 cm.

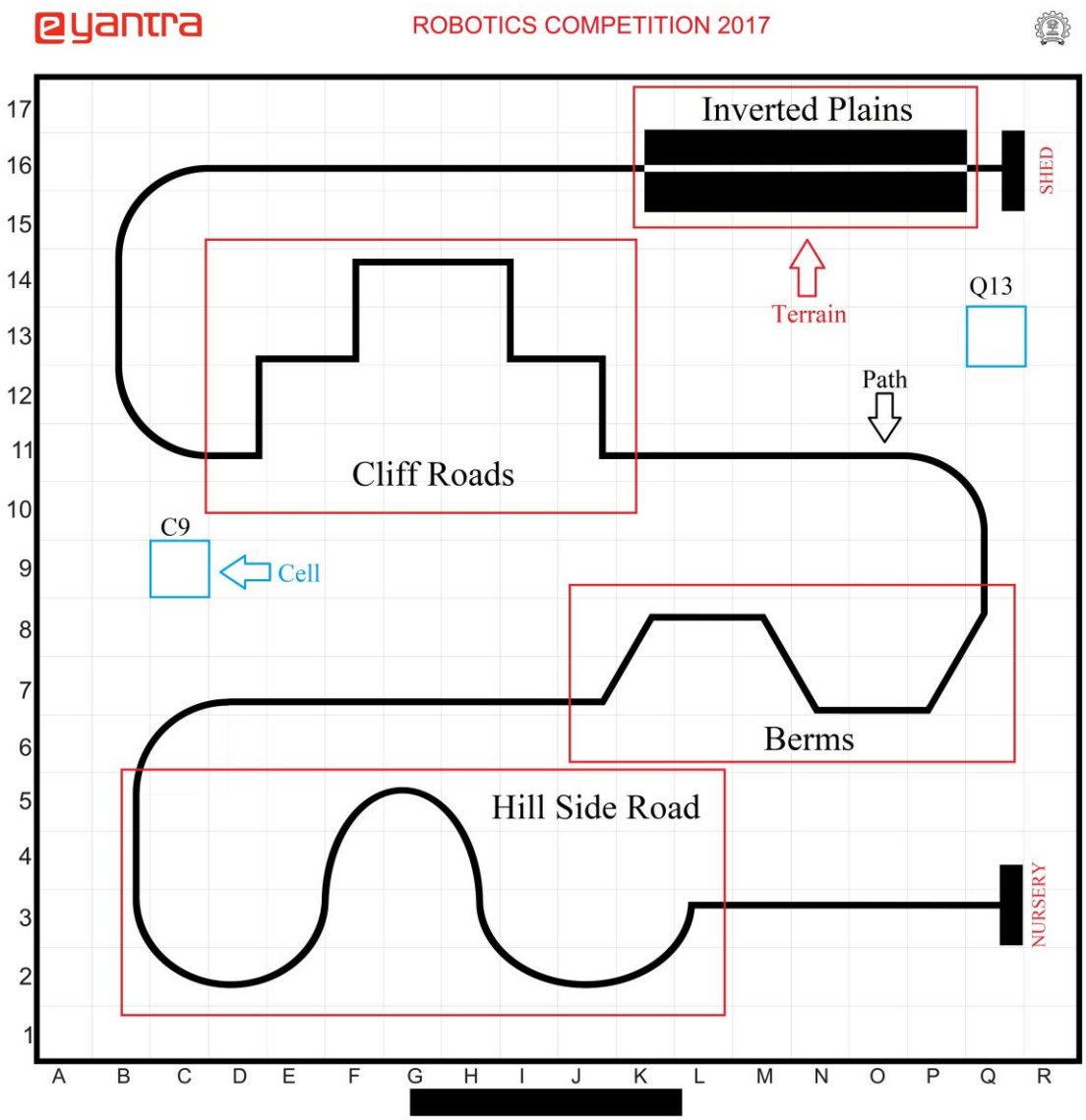

Figure 1: Basic elements of Arena

The objective of the theme is to build a robot that will traverse the Path from Nursery to Shed. While traversing the Path, it should plant **Seedlings** at **Planting Zones** as per **Requirement**.

We define the terms and the Input given to set up the Arena below:

Zone Indicator (ZI): it is a solid black rectangular box that marks the start of the Planting Zone (defined below). There can be a maximum of 5 ZIs in the Arena. Details for preparing and placing the ZIs are provided in Section 3.4. Note that the ZI represents the start of a Planting Zone.

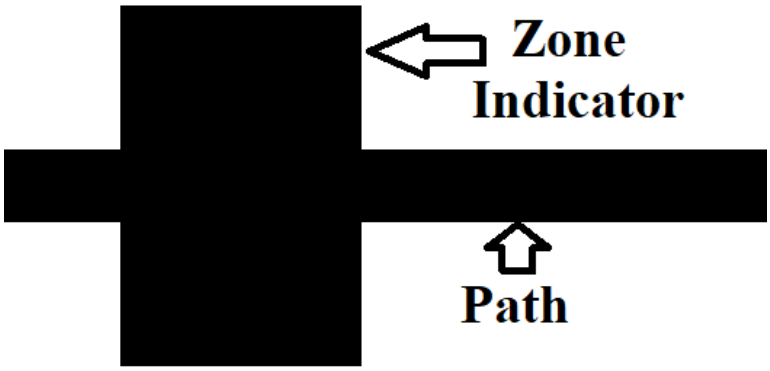

Figure 2: Zone Indicator

Planting Zone (PZ): A PZ represents the part of Plantation Land where Seedlings are to be planted. Each PZ has a Requirement for a particular **Type** and **Count** of Seedlings to be planted. There can be a maximum of 4 PZs.

Type: Type of a Seedling is expressed by using two properties: (i) **Color** and (ii) **Shape** of a **Color Marker (CM)**. Color can be **Red**, **Blue** or **Green** and Shape is **Square**, **Circle** or **Triangle**. There are a maximum of 9 combinations of these 2 properties to make a unique CM.

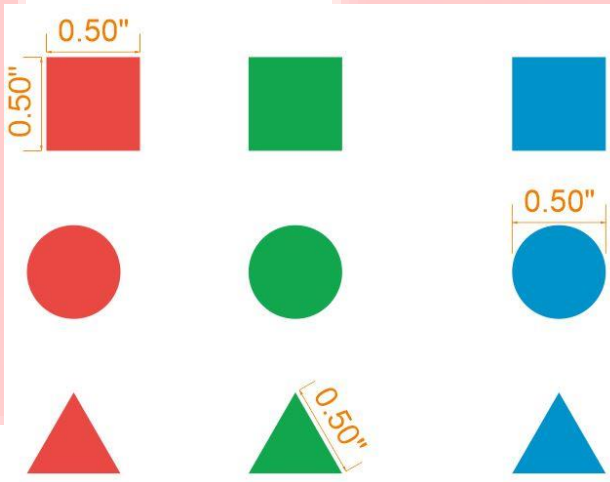

Figure 3: Color Markers

Count: The number of Seedlings to be planted in a PZ is given by Count and is represented by the number of CMs placed in a PZ. Count can be 0-4.

Requirement: is depicted in the **Seedling Configuration Table**. Let us consider an example, given in Table 1 for Sample arena in Figure 4:

Table 1: Seedling Configuration Table

Sr. No.	ZI Placement	Type of Seedling		Count	Overlay Image Name
		Color	Shape		
1	O3	Red	Square	3	tulipred.png
2	H7	Green	Square	4	hibiscusyellow.png
3	Q9	Red	Circle	4	carnation.png
4	F16	Blue	Triangle	4	morningglory.png
5	J16	-	-	0	-

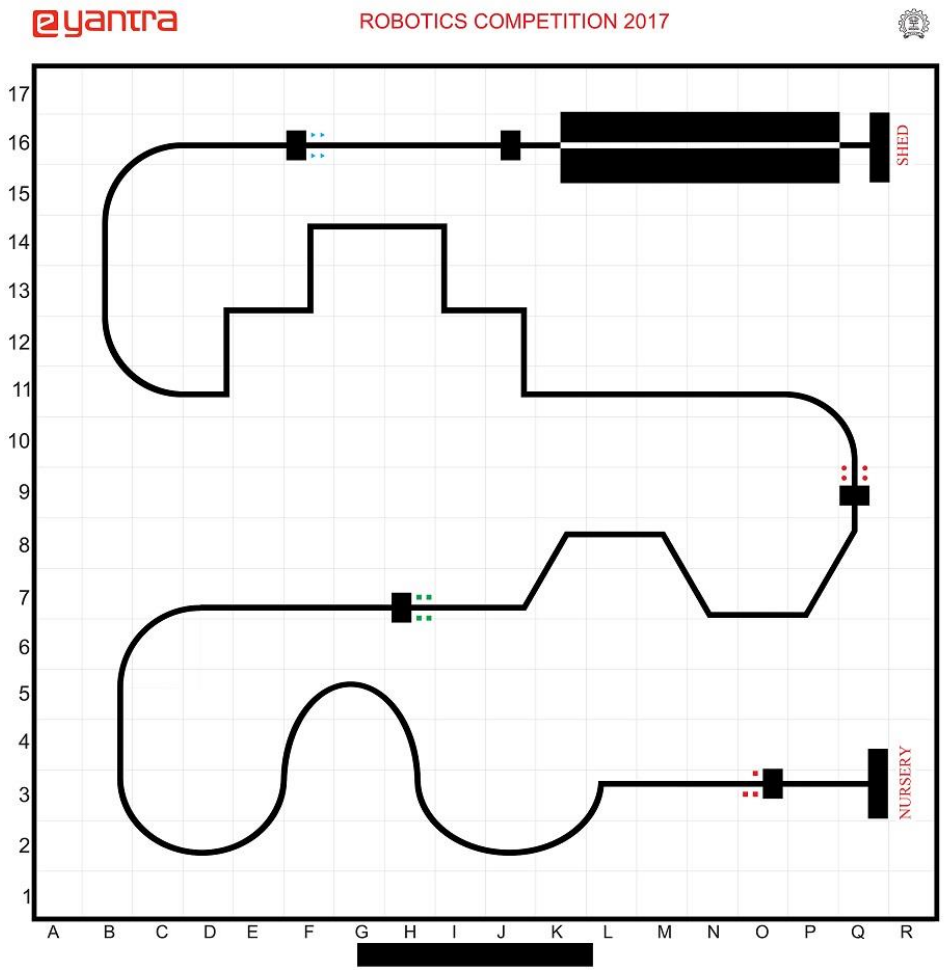

Figure 4: Example Arena Setup

The following parameters are defined in Table 1:

ZI placement: this is the Cell number where each ZI is placed. Details for preparing and placing the ZIs are provided in Section 3.4. Note that the ZI represents the start of a PZ.

Type of Seedling: Color and Shape of each CM to be placed in the corresponding PZ is specified.

Count: Number of CMs to be placed in a given PZ is specified.

Overlay Image Name: This name defines the image to be retrieved from an image folder termed **Seedlings folder** that is overlaid on a given **Plantation Background**. Seedlings folder can be found at this link. The table showing the name of the image to be fetched from the folder which corresponds to the Type of Seedling, is defined in Table 2, called **Input Table**.

Plantation background: The Plantation background is a static image provided in the **Plantation Folder**. Plantation folder can be found at this link. Plantation background image is divided into PZs to be cultivated by overlaying Seedling images. These PZs are marked as **PZ-A**, **PZ-B**, **PZ-C** and **PZ-D** in the Figure 5. For each PZ in the Arena there is a respective PZ on the Plantation background, where the overlay of Seedling image must be done for that PZ.

> **For example:** The overlaying of Seedling Images for first PZ on the Arena must be done on PZ-A. Similarly overlaying of Seedling Images for second PZ on the Arena must be done on PZ-B and so on.

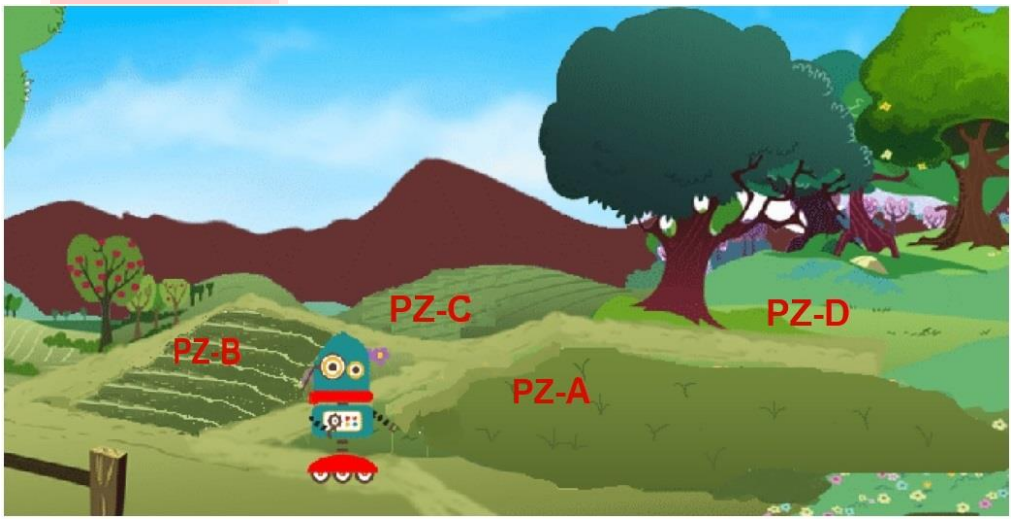

Figure 5: Planting Zones on Plantation background

An Input Table in **".csv"** format will be provided to teams **15 minutes** prior to the start of competition. Table 2 shows a sample Input Table. This file will have all 9 combinations of CM properties and name of Seedling images associated with the CM types. These Seedling images are provided to teams in the Seedling folder. There are 18 Seedling images in this folder.

Note: Table 2 is an example and the configuration in it will be different during the competition.

Table 2: Input Table

Color	Shape	Seedling Image
Red	Circle	assorted.png
Red	Triangle	carnation.png
Red	Square	gerber.png
Green	Circle	hibiscusred.png
Green	Triangle	marigold.png
Green	Square	hydrangeablue.png
Blue	Circle	hydrangeayellow.png
Blue	Triangle	lilac.png
Blue	Square	lily.png

Important:

1. **ZIs and PZs will be placed on the path in between Terrains and never within a Terrain.**
2. **The IP Terrain is a piece of barren land where Seedlings are never planted (Refer to last row in Table 1).**
3. **The PB always traverses the Path from Nursery to Shed.**

In summary, each team builds the PB with the following features:

1. PB is equipped with **PiCam** to track and follow the Path. It should be able to follow a white line or a black line using Image processing techniques to traverse the Path starting from Nursery to Shed.

2. During the traversal when it encounters a PZ, it should identify the Type of the Seedling (by sensing the Color and Shape of the CM) and the Count, if any. Based on these it does the following:
    - Blinks the corresponding color in the **RGB-LED** mounted on it as many times as the Count. Details are provided in Section 6.18.1.
    - Fetches the corresponding image of the Seedling from the Seedlings folder and overlays it on the Plantation background. Note that you have completed the Overlay process in Task 1B on a video input. Here the input is a static image- Plantation background.
3. Repeats Step 2 for all the PZs till it reaches the Shed. At Shed PB blinks the RGB-LED in the same sequence of Color of CMs encountered at the PZs.

For the Sample Arena (Figure 4), the final display of the Plantation after overlaying Seedling images for all PZs without any fault will look like the image below:

Figure 6: Final Plantation image after all correct overlay for Sample Arena.

3. Arena

Each team has to prepare the Arena. Preparing the Arena consists of four major steps:

1. Printing the Arena design on flex sheet
2. Constructing the ZI
3. Constructing the PZ requirement by using CMs
4. Placing the ZIs and requirements of PZs

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

3.1 Printing the Arena design on flex sheet

Flex Design is shown in Figure 7. A Portable Document Format (.pdf) file containing the flex design is provided to the teams in Task 2. Each team prints the flex design according to the directions given in the "Read Me.pdf" file of Task 2 folder.

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" the 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.

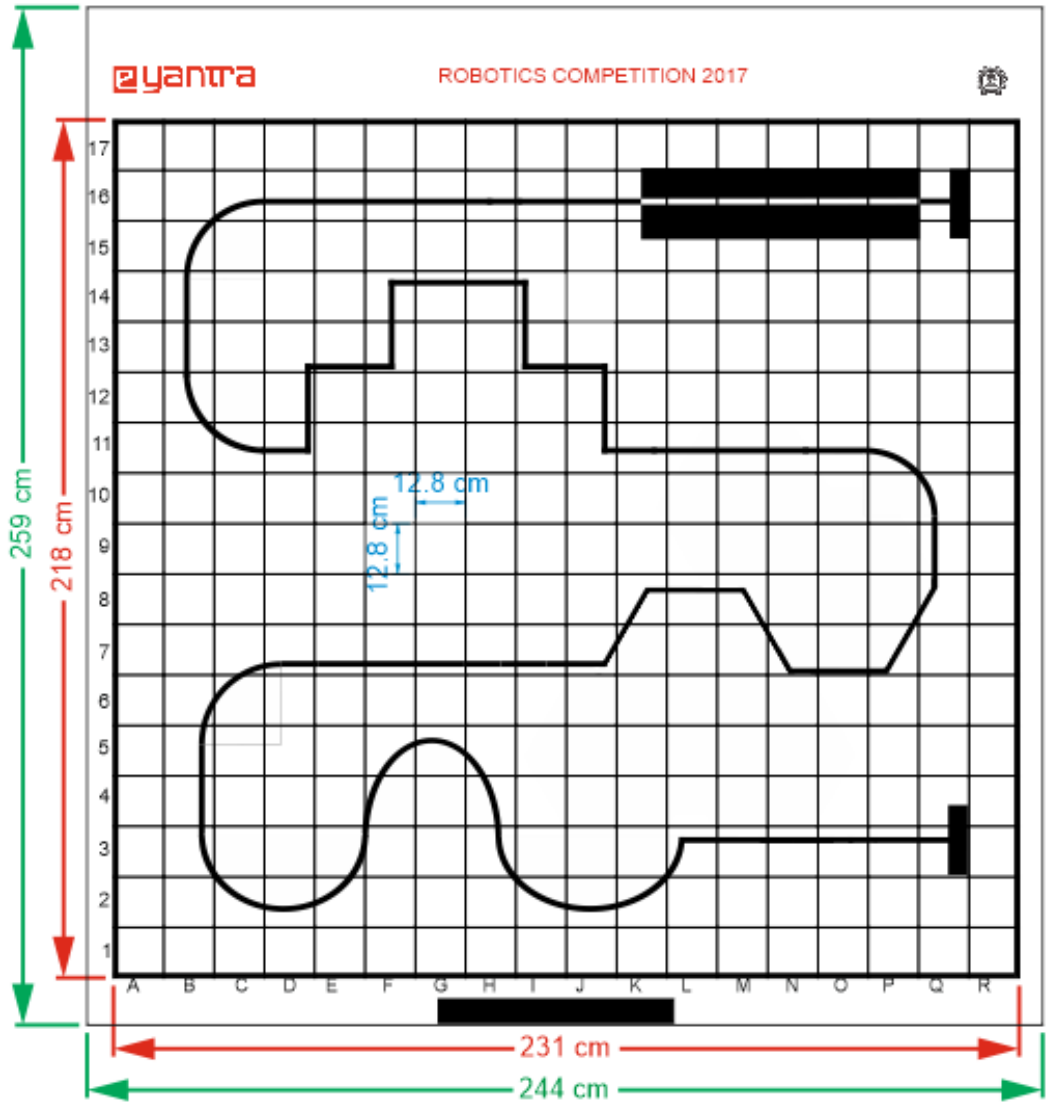

Figure 7: Flex Design with dimensions

Dimensions of Arena are as shown in Figure 7:

Outer Dimension: 244 x 259 cm (marked by Green lines).

Inner Dimension: 231 x 218 cm (marked by Red lines).

Individual Cell Dimension: 12.8 x 12.8 cm (marked by Blue lines).

Track width: 1.50 cm

3.2 Constructing Zone Indicator

A ZI is a black solid rectangle of dimension 2x3 inches. ZI is placed on the Arena such that its midpoint is aligned with the midpoint of the Path.

A black strip (60cm x 6cm) is present at the bottom of the flex sheet. Teams should cut out this strip and use it for constructing the ZIs of size 2x3 inches.

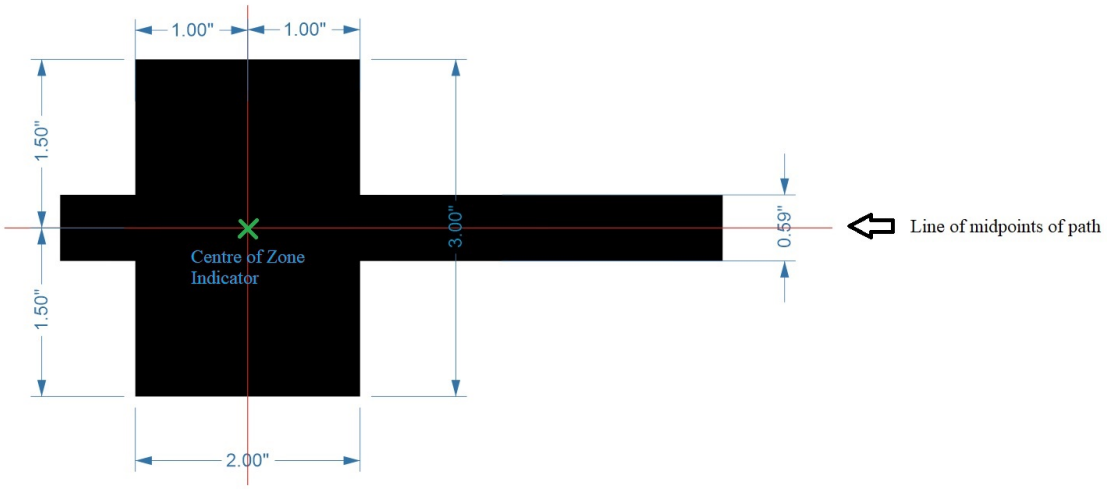

Figure 8: Constructing ZI

3.3 Constructing the PZ requirement by using CMs

The requirements at any PZ are made up of number and properties of CM. Each CM has a basic dimension of 0.5 inches (refer Figure 3). At any PZ there can be 1-4 CMs representing the number of Seedlings to be planted. No CMs are associated with the barren land i.e. Inverted Plains.

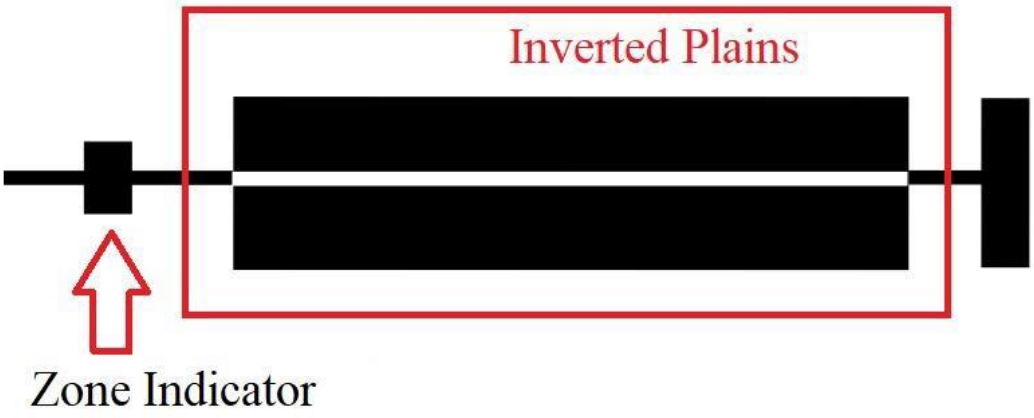

Figure 9: Barren Terrain - IP

Reference CMs are given in Color_Markers.pdf which was provided in Task-2. Print this file as per instructions in "Read Me.pdf" file received in Task 2 folder. Cut out the Circle, Square and Triangle shaped CMs for use.

3.4 Placing the ZIs and requirements of PZs

This includes the alignment of ZI & CMs with respect to each other as well as their alignment with respect to the Path.

3.4.1 Alignment of ZI with Path

ZI is placed in the Cell and on the Path such that Path's midpoint and center of the ZI overlap with each other (refer Figure 8).

3.4.2 Alignment of CM with Path

CMs are always placed parallel to Path and separated by a distance of 0.5 inch from the path (refer Figures 10, 11 and 12).

3.4.3 Alignment of CM with ZI

CMs and ZIs are separated by a distance of 0.5 inch. CMs are to be placed next to the ZIs (refer Figures 10, 11 and 12).

3.4.4 Separations between CMs

CMs are placed on both the sides of the Path such that they are separated by a distance of 1.60 inch from each other (refer Figures 10, 11 and 12).

CMs on the same side of path are separated by a distance of 0.5 inch (refer Figures 10, 11 and 12).

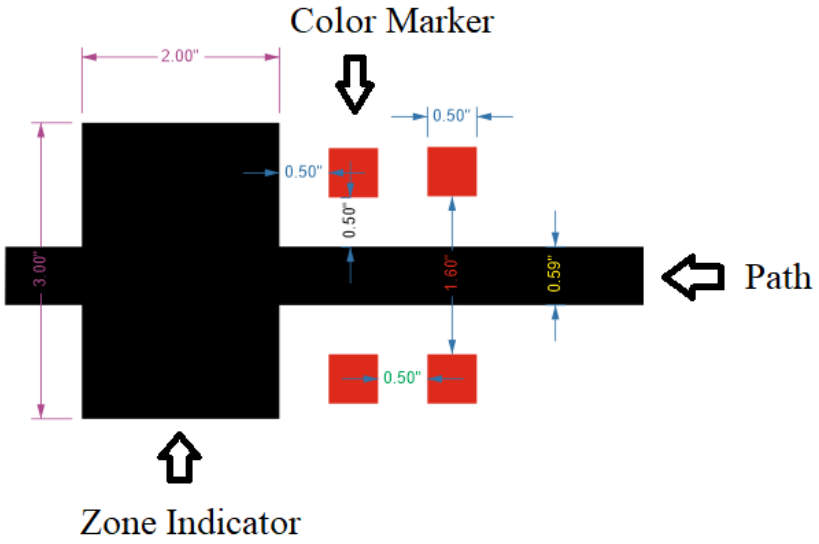

Figure 10: Zone Indicator & Color Marker (Square) arrangement with dimensions.

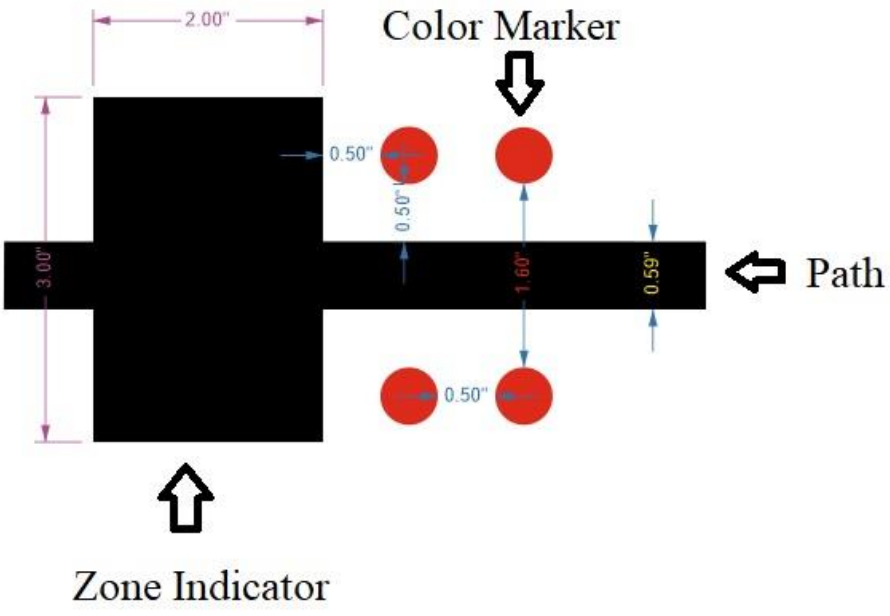

Figure 11: Zone Indicator & Color Marker (Circle) arrangement with dimensions.

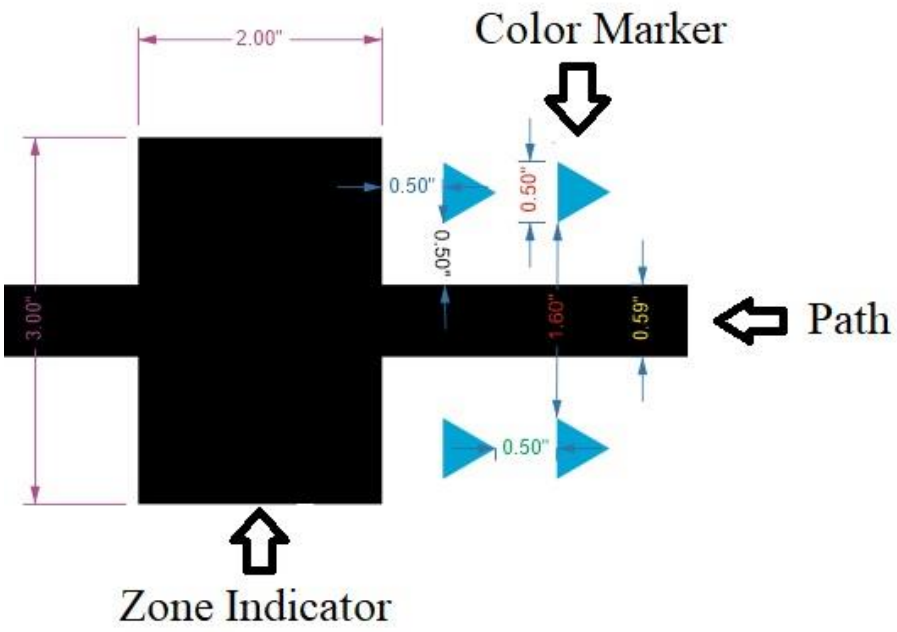

Figure 12: Zone Indicator & Color Marker (Triangle) arrangement with dimensions

Please maintain the Arena in a good condition. If the Arena is found damaged or in a condition that is 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

4.1 Use of Raspberry Pi

All participating teams must use only the Raspberry Pi sent to them in the kit. Only one Raspberry Pi is allowed per team.

The Planter Bot assembled by the teams should be completely autonomous.

4.2 Use of other components provided in the kit

Along with the Raspberry Pi, teams shall receive a PiCam, a 16GB memory card, Intex 6000 mAh Power Bank, Battery, DC Motors, L clamps, Motor Driver circuit and wheels.

The team is NOT allowed to use any other component apart from those provided in the kit by e-Yantra and those mentioned in Section 4.3.

4.3 Use of components NOT provided in the kit

1. Teams will have to design their own chassis for building the Planter Bot.
2. Discrete components like Resistors, Capacitors, Jumper wires etc.

3. Additional wheels, shafts, L clamps etc.
4. Stand for PiCam.

5. Software Specifications

5.1 You can use OpenCV 3.3.1, Python 2.7, Numpy, Scipy, Matplotlib, Imutils, PIL, OpenGL etc.

5.2 Use of any non-open source software is not allowed and will result in disqualification of the team.

5.3 As per e-Yantra policy, all your code and documents are open source and may be published on the e-Yantra website.

6. Theme Rules

6.1 The maximum time allotted to complete the task is 10 minutes. A maximum of two runs will be given to a team. The best of two scores from the two runs will be considered as the team's final score. A maximum of two repositions will be allowed in each Run (as explained in Section 6.19).

6.2 The team must use OpenCV-3.3.1 and Python2.7 primarily for the task, however in addition to these software, participants may use compatible open source libraries and software utilities, provided they are indicated and disclosed clearly to the e-Yantra Team.

6.3 To communicate between Computer and the robot, teams have to setup the WiFi network as explained in Hardware testing documents. In finals at IIT-Bombay, WiFi network will be provided by e-Yantra.

6.4 At start of a Run, PB should be switched ON and placed in the Cell R3 facing the Cell N3.

6.5 The team should start the execution of code when told to do so by the e-Yantra reviewer. This is the start of a Run. The timer will start at the same time.

6.6 Once the robot is switched on, intervention by any participant or team is NOT allowed.

6.7 Any human intervention is considered as reposition (a reposition can be done by e-Yantra team member only on the request of the participant and approval of the e-Yantra reviewer). Rules for repositions are explained in Section 6.19.

6.8 A Run ends and the timer is stopped if any of the following conditions is satisfied:

6.8.1 The PB completes the task and blinks RGB-LED at the Shed as explained in Section 6.18.2.

6.8.2 The maximum time limit (600 seconds) for completing the task is reached.

6.8.3 The team needs repositioning but has used both repositioning options of that Run.

Note: Marks will be calculated on the basis of state of Run which is governed by all the elements mentioned in Scoring Formula

6.9 Correct detection of a CM includes detection of both Color and Shape of the CM correctly. Every CM in the Arena will have same weightage (mark wise).

6.10 After detecting a PZ, the PB must stop and detect the CMs properly. After detecting those CMs it must blink the RGB-LED as explained in Section 6.18.1.

Note: ZI before last terrain (i.e. IP) will always have no CMs associated with it. Therefore the RGB-LED will remain OFF at this ZI.

6.11 At the end of the Run the PB must stop and blink the RGB-LED in the same sequence as explained in point number Section 6.18.2.

6.12 Second Run starts after resetting the score, timer and Arena. The score of both runs is recorded and best of the two runs is considered as the team's final score.

6.13 For the second Run, teams are not allowed to make any software changes. However, hardware changes are allowed with the approval of e-Yantra reviewer.

6.14 Participants are not allowed to keep anything inside the Arena other than PB.

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

6.16 Time measured by any participant or team by any other means is not acceptable for scoring.

6.17 PB is not allowed to make any marks while traversing the Arena. If PB is found damaging the Arena, it will be immediately stopped; repositioning will be allowed as per the rules. **The final decision is at the discretion of the e-Yantra team.**

6.18 RGB-LED must blink in the below mentioned format:

6.18.1 At ZI: After detecting CMs at ZI, the PB must blink the RGB-LED with the same color as that of the CMs and number of times the RGB-LED blinks must be equal to the Count of CMs detected at the current PZ, the time interval between the blinks must be 1 second.
For example: Let us assume there are 3 RED CMs in a PZ. PB must stop and detect those CMs and then blink the RGB-LED 3 times of RED color. Here the LED blink signifies only Count and Color detection, but not Shape.

6.18.2 At the end of Run: PB must stop and blink the RGB-LED in the same sequence of Colors of CMs as they appeared on the Arena at the PZ from first to last. The RGB-LED must blinks with one second interval.
For example: Suppose CMs at first PZ were Green, CMs at second PZ were Red, CMs at third PZ were Blue & CMs at fourth PZ were Red. Then at the end of the Run, PB must blink the RGB-LED at an interval of 1 second in the sequence as Green--Red--Blue--Red. Here the LED must blink just once for each PZ.

6.19 Reposition Rules

6.19.1 While traversing the Arena, if PB strays off the Path, a member of the e-Yantra team will place it at the last cell which was traversed properly, only on the request of the team and approval of the e-Yantra reviewer.

6.19.2 In case PB fails to detect the ZI, then as a reposition PB will be placed at the Cell just before the ZI, only on the request of the team and approval of the e-Yantra reviewer.

6.19.3 During Reposition, the timer will not stop and PB will not be switched off.

6.19.4 Teams are allowed a maximum of two repositions in every Run. The Run ends and timer is stopped if PB requires a reposition after both repositions have already been used.

Note: 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 timer for a Run will starts from the moment the team starts the execution of code.

The team's total score is calculated by the Scoring Formula given below:

Total Score = (600 - T) + (ZD*100) + (CMD*75) + (TT*100) + (IPP*200) + (O*25) + (B) - (P*50)

Where:

T = Total time taken for the Run

ZD = Zone Detected
Number of ZIs correctly detected.

CMD = Color Markers Detected
Number of correctly detected CMs, where correct detection is identifying both Color and Shape in the correct combination.

TT = Terrains Traversed (0-3)

When the Terrains - HR, BE & CR are traversed, these points are awarded. The count of the Terrains traversed above will vary from 0-3. Value "0" indicates that the PB was not able to traverse even a single Terrain, whereas the value "3" indicates all Terrains were traversed.

IPP = Inverted Plains Parameter (0-1)

There is a single barren Terrain – IP. On traversing this Terrain the IPP will attain a value of 1. If the PB fails to traverse this terrain in its Run then, the IPP will attain a value of 0.

O = Overlay accuracy

Clear and independent overlay of Seedling image on the Plantation background within its indicated PZ will define the accuracy. Overlay inaccuracies are explained below in Section 7.c.

B = Run bonus

Run Bonus of 100 points will be awarded to teams only for that Run in which the PB does the full Arena traversal without any penalty.

P = Penalty

Penalty (P) will occur in three scenarios:

a) Reposition:

As described in Section 6.19.

b) Inaccurate detection of CM:

Cases are discussed below

1. If there are fewer CMs and more are detected, penalty will be applied for every extra CM detected.

   For example: Suppose there are 2 CMs but the RGB-LED blinks 3 times. Then points will be awarded for 2 accurately detected CMs and a penalty will be applied for the 3rd inaccurately detected CM.

2. If there are more CMs and less or none are detected, penalty will be applied for every undetected CM.

   For example: Suppose there are 3 CMs but the RGB-LED blinks 2 times. Then points will be awarded for 2 accurately detected CMs and a penalty will be applied for the third undetected CM.

3. If the wrong color is detected, a penalty will be applied for every wrong color detection.

   For example: The color of the marker is red but RGB-LED blinks blue light. A Penalty will be applied for every wrong blink.

4. If the shape of the CM detected is wrong, a penalty will be applied for every wrong Shape detection.

For example: The Shape is a Square and a Circle is detected, this condition is checked by verifying the overlay, which is explained below.

c) Inaccurate or improper Overlay:

After CM detection, when simulating the planting process if the Overlay of the given Seedling image on the Plantation background is wrong:

1. If there are less CMs and more Seedling images are overlaid, a penalty will be applied for each extra overlay.

   For example: Suppose there are 2 Blue Circle CMs at a PZ (refer Figure 13). This indicates that 2 Morning glory Seedling images (refer Figure 14) are to be planted; however 3 Morning glory Seedling images are overlaid (refer Figure 15). The team will be awarded points for 2 correct overlays and penalized for the extra (third) overlay.

Figure 13: Zone Indicator with 2 Blue Circle Color Markers

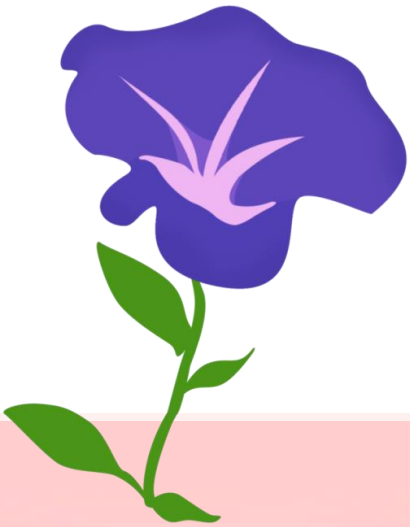

Figure 14: Blue Morning Glory Seedling Image for Red Square Color Markers

Figure 15: Extra overlaid Seedling Image.

2. If the Overlay Image is superimposed at one position only, a penalty will be applied for every hidden overlay.

   For example: There are 3 Red Square CMs (refer Figure 16) and the corresponding 3 Red Tulip Seedling images (refer Figure 17) are overlaid on top of each other (refer Figure 18). The team will be awarded points for single clear

and independent overlay and penalty will be applied for the 2 completely hidden overlays.

Figure 16: Zone Indicator with 3 Red Square Color Markers

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Figure 17: Red Tulip Seedling Image for Red Square Color Markers

Figure 18: All Seedling Images overlaid on one another.

3. If the Overlay is partially overlapping, penalty will be applied for every partial overlay.

   For example: There are 3 Red Square CMs (refer Figure 16) and the corresponding 3 Red Tulip Seedling images (refer Figure 17) are partially overlapped (refer Figure 19). In this case, the team will be awarded points only for the upper most Seedling image which is in full view and the 2 partially hidden Seedling image overlays will be penalized.

Figure 19: All Seedling Images overlaid partially on one another.

4. If the Overlay is not synchronized in location, penalty will be applied for every overlay at inappropriate location.

   For example: If there are 4 Green Triangle CMs (refer Figure 20) and the corresponding overlays of 3 Marigold Seedling images (refer Figure 21) are clear on the Plantation background but the 4th Marigold Seedling image is randomly displayed on the Plantation background; not within its indicated PZ; then a penalty for 1 Marigold Seedling image overlay will be applied (refer Figure 22).

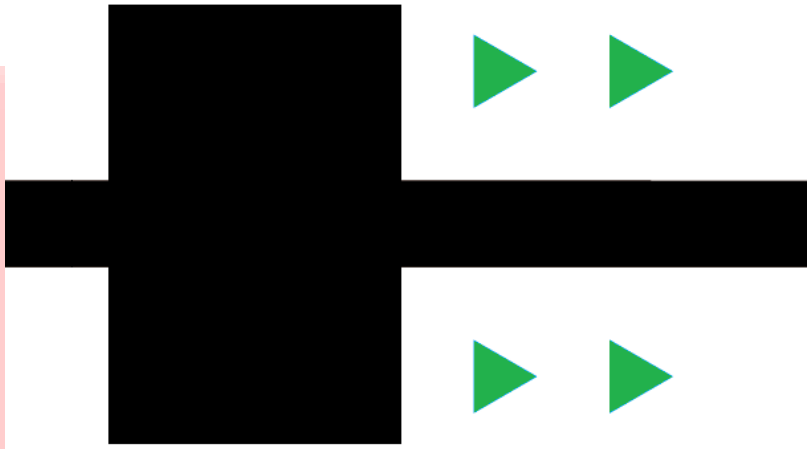

Figure 20: Zone Indicator with 4 Green Triangle Color Markers.

Figure 21: Yellow Marigold Seedling Image for Green Triangle Color Markers

Figure 22: Yellow Marigold Seedling Image overlaid outside Planting Zone.

5. If the Overlay is not synchronized in size, a penalty will be applied for every inappropriately sized overlay.

   For example: If there are 4 Green Triangle CMs (refer Figure 20) and the overlay is a Marigold Seedling image (refer Figure 21). Suppose 3 overlays are correct in size but the fourth one is much larger or much smaller; compared to the others; then a single penalty will be applied for the fourth overlay (refer Figure 23).

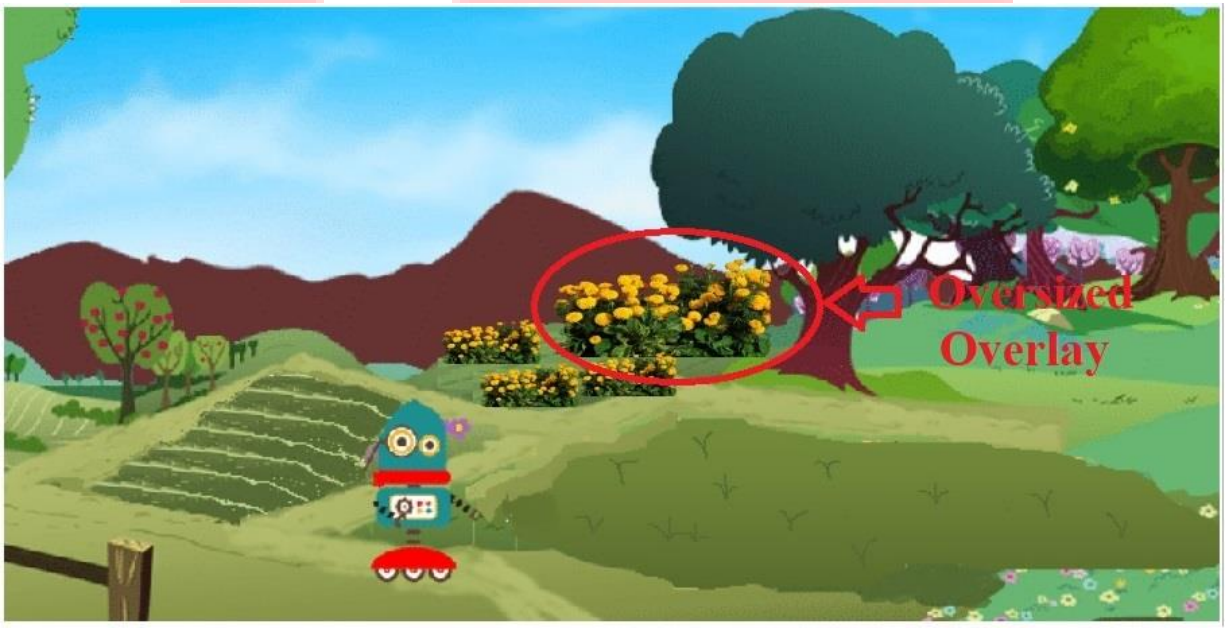

Figure 23: Yellow Marigold Seedling Image oversized overlay.

6. If the Overlay is not synchronized in Shape, a penalty will be applied for every deformed overlay.

   For example: If there are 4 Green Triangle CMs (refer Figure 20) and the overlay is a Marigold Seedling image (refer Figure 21). Suppose 2 overlays are correct in shape but the other 2 are deformed then two penalties will be applied for the two deformed overlays (refer Figure 24).

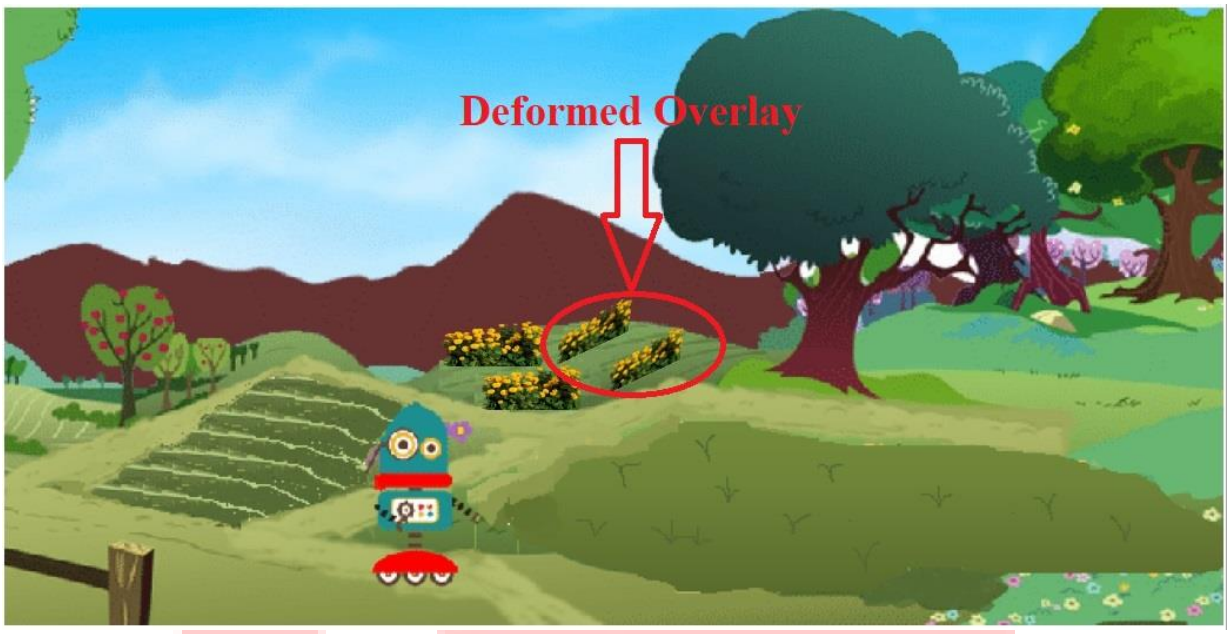

Figure 24: Yellow Marigold Seedling Image deformed overlay.