Soil Monitoring Bot

1. Introduction:

Soil is at the heart of agriculture and its quality directly affects the quality of the yield. While soil is regarded as the "fertile substrate" for agriculture, it is important to understand that a balance among mineral components, soil organic matter, air and water is essential for soil to make it suitable for agriculture [1].

Keeping the above scenario in mind, in eYRC 2021-22 we present the theme *Soil Monitoring Bot (SM)*, as the name suggests this comprises a robot deployed to monitor the soil conditions within an agriculture field divided into various farmlands. The robot swiftly navigates through them and monitors the soil condition. It then goes to the storage unit and supplies the necessary mineral, nutrients, organic matter, etc. as required by the soil.

In this theme, the team will build the *SM Bot* to deploy it on an arena that is the abstraction of the agriculture field. The brain of the robot is powered by an FPGA (Field Programmable Gate Array) that controls its sensors, actuators and pick-place mechanism.

Major challenges and learnings in this theme include **building** the *Soil Monitoring Bot* from scratch using an FPGA. This FPGA based robot will be able to traverse the arena, sense the environment and pick and place the necessary supplies from the supply unit to the field. It will also use **wired and wireless communication techniques**. This theme will help teams build a sophisticated architecture using **Verilog HDL** and unveil the powerful parallel processing capabilities of **FPGAs**.

The team that builds the *Soil Monitoring Bot* that best performs the task in accordance with the rules will be declared the WINNER.

ALL THE BEST! Happy Learning !!

Reference:
[1]
https://www.nature.com/scitable/knowledge/library/soil-the-foundation-of-agriculture-84224268/

2.   Theme Description:

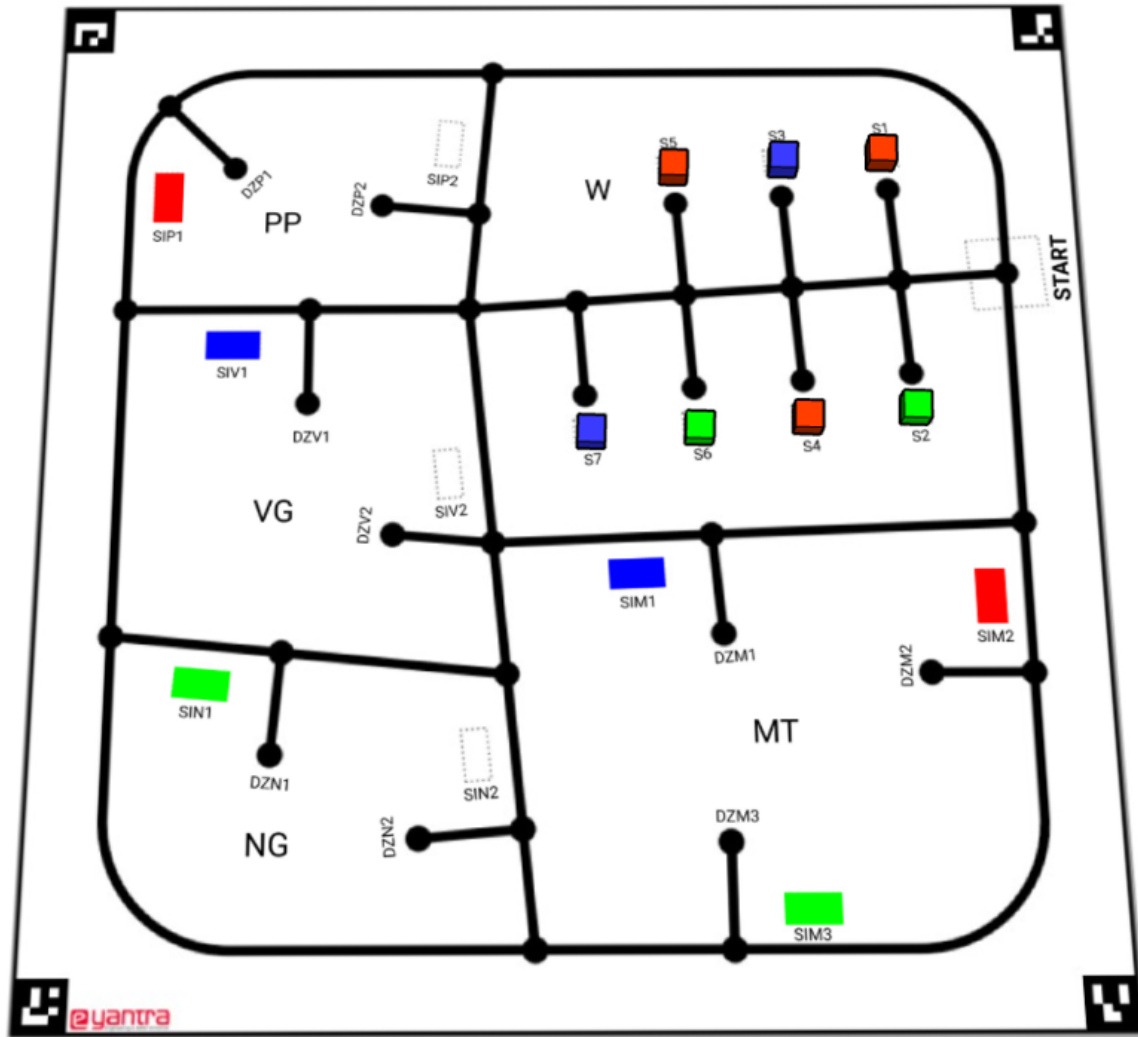The arena represents farmlands in an agricultural field. The arena and its components are as shown in figure 1.

Figure 1: Arena and its components

With reference to Figure 1, we have defined the following:

Start: The starting point of the path of Soil Monitoring Bot (SM) is defined as the "**Start**".

Farmlands (F): The agricultural land has a total of 4 farmlands. These are:

1) Paddy Plains **(PP)**
2) Vegetable Garden (**VG**)
3) Nutty Grounds (**NG**)
4) Maize Terrains (**MT**)

PP, VG, NG and MT contain Status Indicators (SI), defined below:

Status Indicators (SI): These are the colored rectangles placed along the path close to a node in the different Farmlands. Color of Status Indicator (SI) indicates the issue/requirement for Soil in the Farmland as per Table 1. Soil Indicators associated with Paddy Plains (PP) (top left of the arena in figure 1) are identified as SIP1 and SIP2 as shown. Similarly, other Soil Indicators are identified as *SIV1, SIV2 for Vegetable Garden (VG); SIN1, SIN2 for Nutty Ground(NG) and SIM1, SIM2 and SIM3 for Maize Terrains (MT).*

Table 1: SI, Supply, Supply Colors and Message mapping

SI Color	Supply	Supply Color	Message
Red	Pesticides (P)	Red	P
Green	Nutrients (N)	Green	N
Blue	Water (W)	Blue	W

Note: The other elements in the table are explained in further points

Warehouse (W): Warehouse is the section in the agricultural field where all the required Supplies are stored.

Supplies (S): Based on the issue identified through SI, SM Bot has to provide Supplies (S) to the Farmland. A particular Supply is associated with a particular Status Indicator as per Table 1. These Supplies are represented by cubes of corresponding colours which need to be picked from the Warehouse (W) and deposited in the respective Farmland. On the Arena, these Supplies are identified as *S1, S2,...,S7* (Warehouse section).

Supply Position Message (SPM): At the time of the run, the information on the placement of various Supplies in the Warehouse is provided through the SPM. This information is provided to SM Bot at the start of the run (as an input message).

For the current configuration, S1 has Red, S2 has Green and so on. Thus the SPM for current configuration is: "**SPM-Red-Green-Blue-Red-Red-Green-Blue-#**". If a specific Supply Position is empty, it mentions "Null" for that position.

SI Identification: SM Bot is equipped with 3 RGB LEDs. SM uses a color sensor to identify Status Indicator color. As soon as SM Bot identifies a Status Indicator - it turns ON the

appropriate LED colour and sends a corresponding **Identification message** to the system as given in Table 1.

SI Identification Message: As soon as SM Bot identifies a Status Indicator, it transmits a message to the system (user laptop/computer) via Zigbee as per Table 1. The message format for SI identification is:

"SI-SI_Name-Message-#"

> *For example:*

> *If Blue SI is identified at SIV1 in Vegetable Garden (VG), the message is "SI-SIV1-W-#"*

> *If Green SI is identified at SIM3 in Maize Terrains (MT), the message is "SI-SIM3-N-#"*

Deposition Zone (DZ): SM Bot has to pick Supplies from the Warehouse and deposit in the Farmland at the Deposition Zones (DZ). For example, the Deposition Zones DZP1 and DZP2 are associated with SIP1 and SIP2.

Similarly, DZV1, DZV2, DZN1, DZN2, DZM1, DZM2 and DZM3 are associated with SIV1, SIV2, SIN1, SIN2, SIM1, SIM2 and SIM3 respectively. SM Bot has to deposit the Supplies as per the associated SI and DZ.

Supply Pick Message (SPiM): As SM Bot picks a Supply for a particular Deposition Zone (DZ) in a Farmland, it transmits a message to the system (user laptop/computer) via Zigbee as per Table 1. The message format for Supply Pick is:

"S-P-SIName-Message-#"

> *For example:*

> *If Blue S is picked for DZV1, the message is "S-P-DZV1-W-#"*

> *If Green S is picked for DZM3, the message is "S-P-DZM3-N-#"*

Supply Deposition Message (SDM): As SM Bot deposits a Supply at a particular Deposition Zone (DZ) in a Farmland, it turns OFF the corresponding LED (LED that was turned ON upon SI Identification). It also transmits a message to the system (user laptop/computer) via Zigbee as per Table 1. The message format for Supply Deposition is:

"S-D-SI_Name-Message-#"

> *For example:*

If Blue S is deposited at DZV1, the message is "S-D-DZV1-W-#"

If Green S is deposited at DZM3, the message is "S-D-DZM3-N-#"

Theme Play for the SM Bot is as follows:

- SM Bot is placed at the START on the arena in Warehouse (W).

- SM Bot has to traverse the arena via the Path connecting different Farmlands.

- At each Farmland (F), SM Bot identifies if there is/are any Status Indicator (SI).

- As soon as SM Bot identifies SI, it turns ON the LED depending on SI color and sends a SI Identification Message to the system (user laptop/computer) via Zigbee.

- SM Bot can then go to other Farmlands to identify more SI, or it can go to Warehouse (W) for Supplies (S) (this depends on the team's algorithm).

- SM Bot then picks the Supplies from the Warehouse (W) and sends the Supply Pick Message.

- At the Deposition Zone, as SM Bot deposits a Supply, it turns OFF the corresponding LED and sends the Supply Deposition Message.

- After requirements in all the Farmlands are addressed, SM turns "white light" ON and OFF for all the LEDs with a delay of 1 second and marks the end of run.

3. Arena:

Each team has to prepare the Arena as per the following steps:

3.1. Printing the arena design on flex sheet

3.2. Constructing Supply blocks and Status Indicators

3.1. Printing the arena design on flex sheet:

Flex Design is shown in Figure 2. A Portable Document Format (.pdf) file containing the flex design is provided to the teams in Task 3. Each team prints the flex design according to the directions given in Task 3.

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 SM Bot 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 -- as it may be a fire hazard. Please maintain the Arena in 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.**
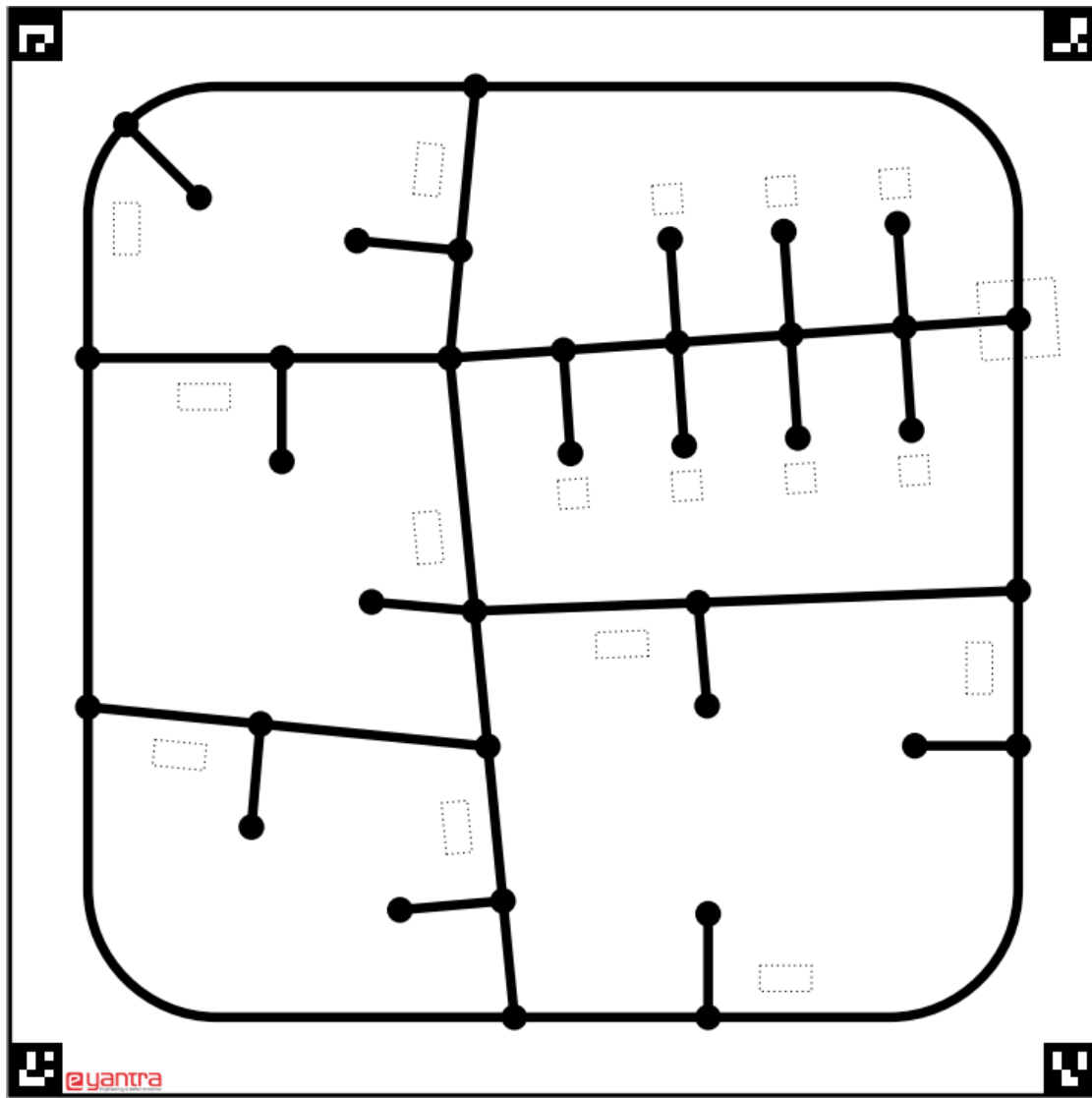

Figure 2: Arena Flex Design (7 x 7 sqft)

Table 2: Dimensions of various elements in the arena :

Element	Dimensions
Black lines (Path)	0.75 in (width)
Nodes (N)	2 in (diameter)
Color patch	4 in x 2 in
Supply block outline	2.25 in x 2.25 in

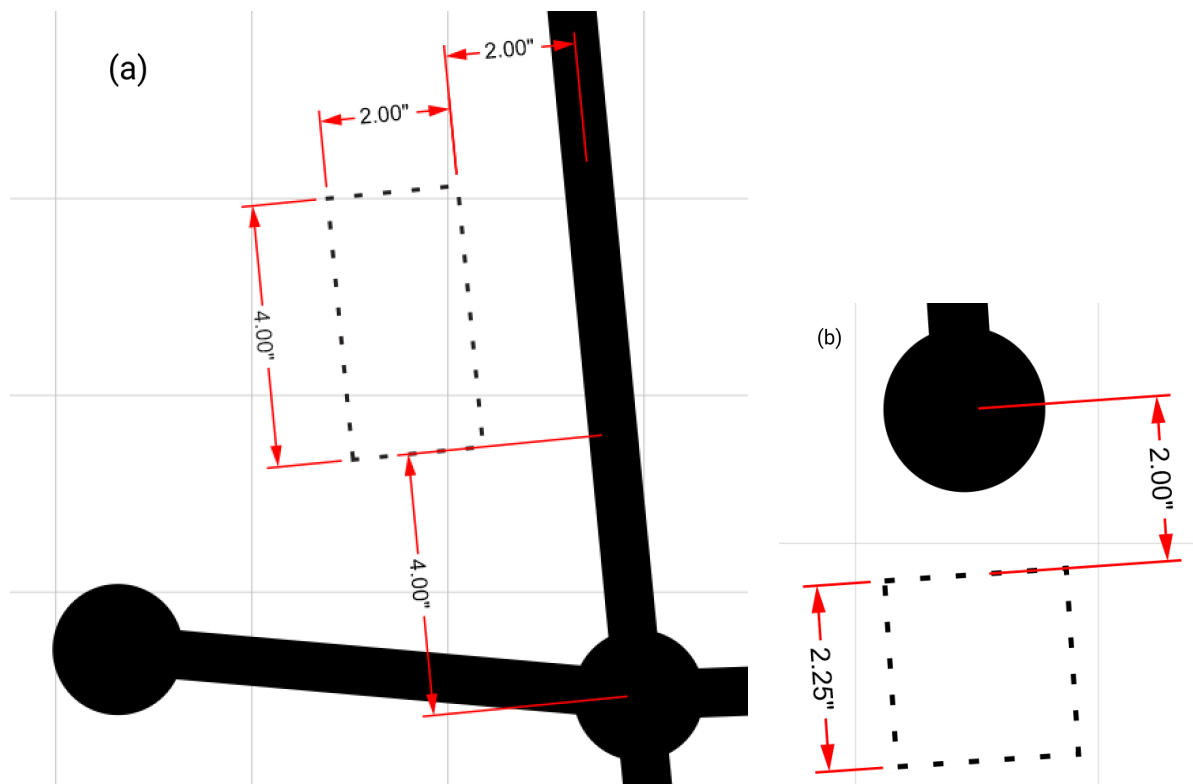Refer Figure 3 below for detailed dimensions for Supply Indicator and Supply block placement.

Figure 3: Dimensions for Status Indicator (a) and Supply Placement (b)

3.2. Constructing Supply blocks and Status Indicators

- Teams are provided 10 thermocol cubes of the dimension 2 x 2 x 2 cu. inch. in the hardware kit sent by e-Yantra.
- In these blocks, teams should attach some ferromagnetic material on one side of each block. It should ideally cover one entire face of the cube. Do not use magnets.
- Ferromagnetic materials (such as iron) are attracted to magnets which can be purchased from Hardware stores.
- Below are some of the examples of ferromagnetic material
    - Metal Washer
    - Metal Flat Bracket
    - Glass Bottle Caps of soft drinks, etc.
  NOTE:

- ○ Teams can use other materials but it is extremely important that they are very well attracted to magnets and light in weight.
- ○ These blocks will be picked and placed by the Bot using an electromagnet hence the above point is emphasized.
- After completing the above steps wrap 2 blocks with RED colour sheet, 2 blocks with GREEN colour sheet & 2 blocks with BLUE colour sheet. So you will have 6 coloured blocks and the remaining blocks can be used as backup in case of accidental damage.
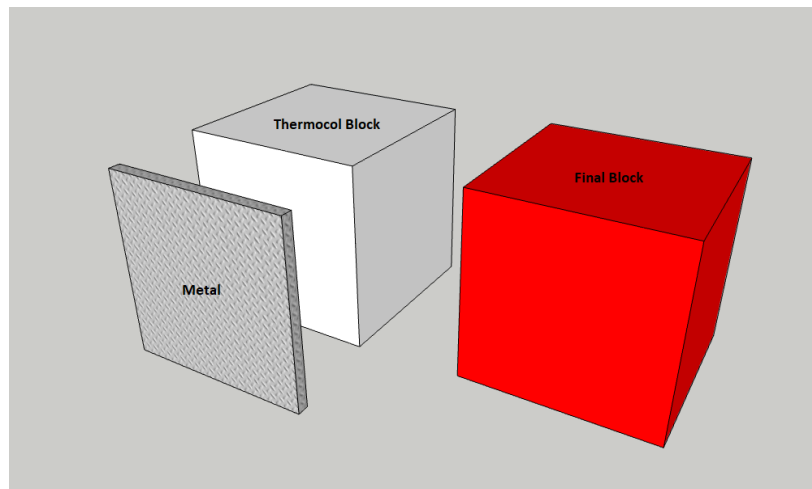- Refer below image for better understanding:

Figure 4: Constructing Supply blocks

- The colour patches for Status Indicators are given by e-Yantra in Task 3. Teams have to print these colour patches on A4 size paper, cut them and place them on the arena as per Table 3.

  Note: Teams may use masking tape (or any other adhesive to stick patches on the arena). We advise you to refrain from using Fevicol or other strong adhesives for better life of the flex as you might need to constantly replace patches while testing your algorithm.

Table 3: Status Indicator and Supply Placement Table

SI Placement			Supply Placement	
Farmland	**Status Indicator (SI)**	**SI Color**	**Supply (S)**	**S Color**
PP	SIP1	Red	S1	Red
PP	SIP2	--	S2	Green

VG	SIV1	Blue	S3	Blue
VG	SIV2	--	S4	Red
NG	SIN1	Green	S5	Red
NG	SIN2	--	S6	Green
MT	SIM1	Blue	S7	Blue
MT	SIM2	Red		
MT	SIM3	Green		

Once the team prepares the arena as instructed, the arena would look as shown in Figure 5.
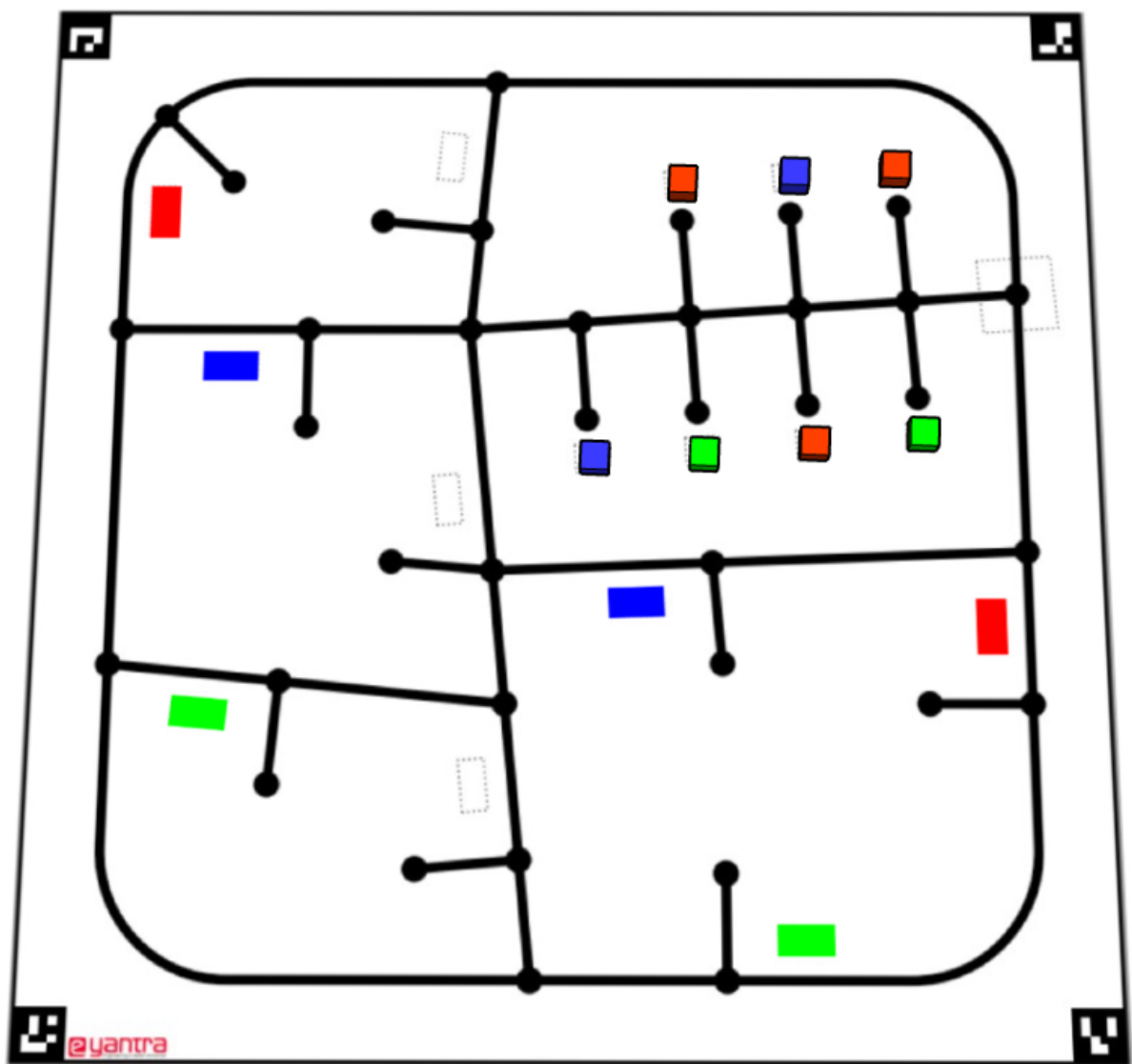

Figure 5: Sample Arena

Note: The arena shown in Figure 5 is specific to the example configuration discussed. For the final task, the arena setup will be different as per the Status Indicator and Supply Placement Table.

4.   Hardware Specifications:

4.1.   Use of De0-Nano board :

No other development board shall be used other than the provided De0-Nano FPGA development board.

4.2.   Use of other components provided in the kit :

The team is not allowed to use any other sensors and/or actuators apart from those provided in the kit.

4.3.   Use of components NOT provided in the kit:

The team can use any material to build the SM bot strictly of the size within **15x15x15 cm^3**. The color sensor and electromagnet assembly can protrude out of these limits but it is recommended to design a compact robot.

Recommended materials for chassis: Sunboard, Plywood, Acrylic sheet, MDF.

4.4.   Power supply :

The team must only use the provided battery for powering the entire SM bot. Use of secondary sources of power such as power banks is strictly restricted.

4.5.   Pick and Place mechanism :

The team must attach the given electromagnet on the robot to perform the 'pick and place' action. Use of other mechanisms is strictly prohibited.

Warning: If above rules are not followed, e-Yantra has the right to disqualify the team. The final decision is at the discretion of e-Yantra.

5.   Software Specifications:

5.1.   e-Yantra has provided all teams with Quartus Prime Lite 19.1, a free software for programming the De0-Nano board.

5.2.   Use of any other software for compilation and programming of the De0-Nano board is strictly restricted and may result in disqualification.

5.3.   The teams must use **Verilog HDL** only.

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

5.5. If you are maintaining your code and project repo online, **ensure you keep them private and confidential**. **Any intentional or unintentional sharing of code, solution, task, etc. can lead to disqualification.**

6. Theme Rules:

6.1. Theme Run and Human Interventions (Repositions and Restarts):

6.1.1. We define **Theme Run** as the actions of SM Bot on the arena during the start and stop of the timer.

6.1.2. The maximum time for each run is 600 seconds.

6.1.3. Each team will get a maximum of two runs during the finals.

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

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

6.1.6. **Human Intervention:** If SM Bot strays away from the path, teams can request a Human Intervention, that is, a **Reposition** or a **Restart** as described below.

For each Run, a maximum of 2 approved Human Interventions can be taken.

(Reposition-Reposition, Reposition-Restart, Restart-Reposition or

Restart-Restart).

a) **Resposition:** Suppose SM Bot strays away from the path, an e-Yantra team member will place it just ahead of the previous Node which was traversed properly, on the request of the team and approval of the e-Yantra reviewers. This is called Resposition (Refer Figure 6):
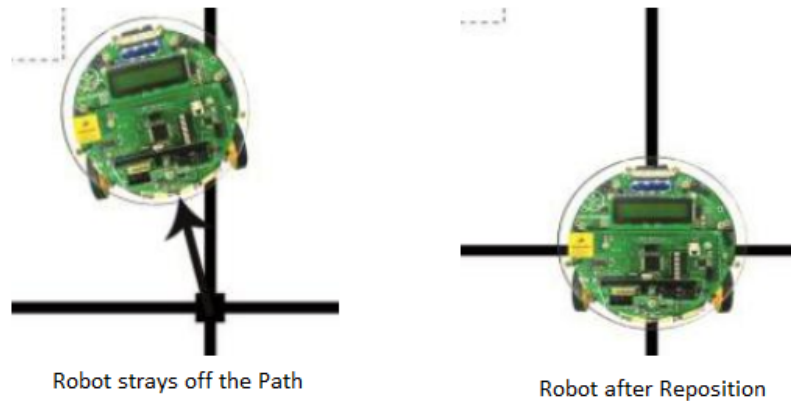
Robot strays off the Path   Robot after Reposition

Figure 6: Repositioning

   ○ During Reposition, the timer will NOT stop and SM Bot will NOT be switched off.

   b) **Restart:** During the finals, suppose SM Bot strays away from the path, teams will be allowed to **Restart** the SM Bot; SM Bot will be placed back on the "Start" and it can be restarted (re-run the code).

   ○ Restart can only be done by e-Yantra team members on the request of the participant and approval of the e-Yantra reviewers.

   ○ Restart gives the teams a second chance to start the same run from the beginning. However, in this case, the timer will keep running, only the score is reset (except, a Human Intervention Penalty is applied as discussed in Section 7). If a Restart is used, the maximum score of before or after the Restart will be used for that run.

6.1.7.   During the run, any unapproved Human Intervention of the team on the Arena will be treated as Reposition.

6.1.8.   Each Human Intervention will attract a Human Intervention Penalty (discussed in Section 7).

6.2.   Start and End of Run:

6.2.1.   Teams will be provided with Supply Position Message (SPM) 10 minutes before the Run to provide it as an input information to SM Bot.

6.2.2.   Before the start of a Run, SM Bot should be placed at the "START" position in the arena (as stated in section 2).

6.2.3. During the finals, the team should start the execution of code when told to do so by the e-Yantra reviewer.

6.2.4. As soon as the execution of code begins, the timer will start. This is the start of a Run.

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

- ○ SM Bot continuously turns ON and OFF "white light" for all the LEDs with a delay of 1 second.
- ○ The maximum time limit (600 seconds) for completing the task is reached.
- ○ A third Human Intervention is made or required.

6.3. For and During the Run:

6.3.1. For a given theme Run, there can be a maximum of 7 Status Indicators (SI) and 7 Supplies (S) on the Arena.

6.3.2. SI Identification: As stated earlier in section 2, as soon as SM Bot identifies a Status Indicator (SI), it turns ON one of the LEDs depending on SI color as per Table 1. For a SI identified in a Farmland, SM Bot has to turn ON the LED before crossing the subsequent Node.

For example, if SM Bot is approaching the SI as shown in Figure 7, it has to turn on the Blue LED before crossing the subsequent Node for SI Identification.
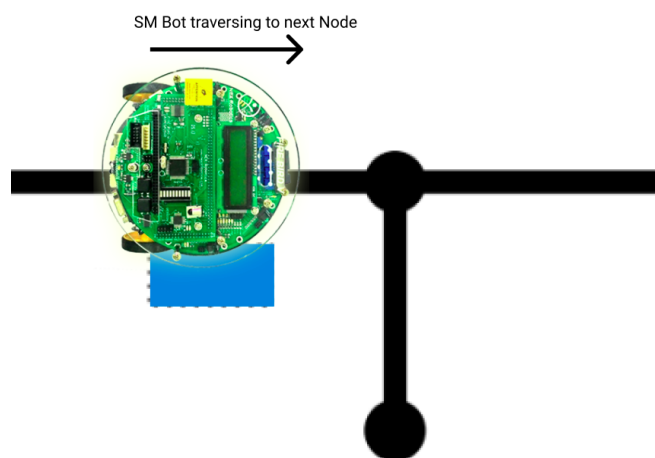

Figure 7: SI Identification

6.3.3. SM Bot displays SI Identification messages as discussed in Section 2. This message has to be transmitted using UART through Zigbee to the laptop and be displayed on the command prompt. SM Bot has to send the SI Identification Message before crossing the subsequent Node.

6.3.4. SM Bot keeps the LED ON until it deposits the corresponding Supply. Only after it deposits Supply, it turns OFF the corresponding LED indicating Supply is deposited. SM Bot has to turn OFF the LED at the associated Deposition Zone only, before traversing further.

6.3.5. Supply pick: At Warehouse, as soon as SM Bot picks up the Supply block, it transmits the Supply Pick Message (SPiM) as discussed in Section 2. SM Bot has to send the Supply Pick Message before crossing the subsequent Node. For a Supply pick to be considered as valid, SM Bot must carry the Supply out of the Warehouse, that is, it must traverse the Nodes in the Figure 8 below.
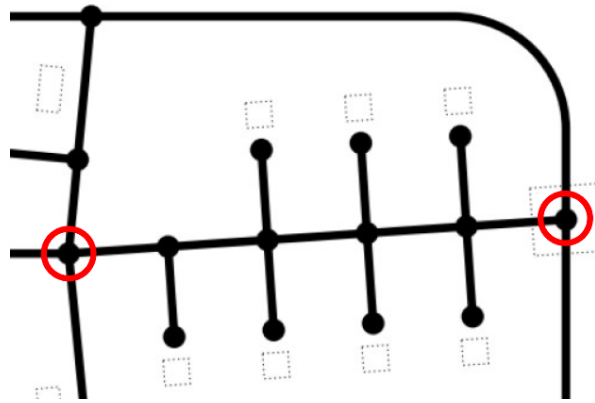

Figure 8: Valid Supply pick Nodes

6.3.6. Supply deposition: As SM Bot deposits a Supply at a Deposition Zone (DZ), it turns OFF the corresponding LED and sends the Supply Deposition Message (SDM) as discussed in Section 2. SM Bot sends the Supply Deposition Message before crossing the subsequent Node.

6.3.7. At a given point in time during the Run, SM Bot can have a maximum of 3 undeposited Supplies. That is, if SM Bot has identified 3 Status Indicators and has not yet picked and deposited any Supply, it must go to Warehouse and pick and deposit atleast one Supply before checking for other Status Indicators.

6.3.8. Penalty: A penalty is incurred (as described in Section 7) when SM Bot hits any block that it does not intend to pick.

6.4. General Theme Handling:

6.4.1. Participants are not allowed to enter the Arena (or stand on flex sheet) while the Run is in progress.

6.4.2. Participants are not allowed to keep anything inside the Arena other than SM Bot.

6.4.3. The time measured by the e-Yantra reviewer is final and will be used for scoring the Teams. Time measured by any participant or team by any other means is not acceptable for scoring.

6.4.4. SM is not allowed to make any marks on the arena, while traversing. If SM is found damaging the Arena, it will be immediately stopped; Human Intervention will be allowed as per the rules.

6.4.5. **In case of any disputes regarding rules, the final decision is at the discretion of the e-Yantra reviewers / judges.**

7. Judging and Scoring System

- Better score of the two runs for a team will be considered the final score of the team.
- The team's total score is calculated by the following formula:

Total Score = 600 - 0.25*T + 9*SIC + 21*SIM + 21*SPiM + 36*SP + 9*SDC + 21*CSDM + 36*SD - 30*HIP - 30*P+ 150*B

Note: For a Run to be valid, the team has to get at least one SIC, SIM, SPiM, SP, SDC, CSDM and SD. Only in that case the above formula is applied. Else, the team receives a '0' for that Run.

The various elements in the formula are explained below:

- ❖ **T:** Total time is the time taken in seconds to complete the task or end of run
- ❖ **SIC:** Number of SI correctly identified and indicated through turning ON respective LED
- ❖ **SIM:** Number of SI correctly identified and indicated through respective Message
- ❖ **SPiM:** Number of Supplies picked correctly and indicated through respective Message
- ❖ **SP:** Number of Supplies picked correctly (SM Bot traversal out of Warehouse)
- ❖ **SDC:** Number of Supplies deposited correctly and indicated through turning OFF respective LED
- ❖ **CSDM:** Number of Supplies deposited correctly and indicated through respective Message

- ❖ **SD:** Number of Supplies deposited correctly (physically on the arena) at corresponding DZ. Only if the team receives SD for a deposition, it is eligible to receive SDC and CSDM.
- ❖ **HIP:** HIP is a penalty where 30 (thirty) points are deducted when a team opts for Human Intervention (Restart or Reposition)
- ❖ **P:** P is a penalty where 30 (thirty) points deducted when SM Bot hits any block that it does not intend to pick
- ❖ **B:** B is a bonus of 150 points awarded, when all the following conditions are satisfied:
  - ➢ All the SI on the arena are correctly identified
  - ➢ All the requirements of various Farmlands are correctly served
  - ➢ No Penalty (HIP & P) is incurred

Note: In case of any disputes/discrepancies, e-Yantra decision is final and binding. e-Yantra reserves the right 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.

ALL THE BEST!