

## WAREHOUSE MANAGING ROBOT

### I. INTRODUCTION

Warehouse management system is vital in storage and movement of goods. On-line purchasing has gained tremendous popularity among people of all generations and this entails receiving orders, packaging, transportation, storage and shipment. Goods are packaged in cartons of defined sizes -- received, stored and shipped from a warehouse. Given that storage is vital in the supply chain, optimizing storage space through proper placement of packages such that movement of packages is minimized, is the key. Automating the process of receiving the packages, placing them in correct locations in the warehouse reduces manual labor and avoids damage to the packages.

Keeping with the importance of this subject, in e-Yantra Robotics Competition 2014 (eYRC-2014), one of the themes chosen is warehouse management. In this theme, we focus on automating the task of placing the packages in designated locations in the warehouse.

The theme design represents a simplified warehouse having 12 **pick-up points** where packages arrive. We use different colored blocks to represent three **types** of packages. There are five **deposition zones**, each designated for deposition of a particular type of package. The robot has to visit each pick-up point and if there is a package pick up the package. The robot detects the color of the package using a color sensor provided and places it in the appropriate deposition zone.

In this competition, you are free to design the mechanism for picking and placing the packages in the appropriate zones. The challenge is to complete this task in the shortest time possible. The robot that performs the task best in accordance with the rules set for this task will be declared the **WINNER** of the competition.

## 2. THEME DESCRIPTION

Make an autonomous robot that performs the following tasks:

1. The robot starts from **START** position of the arena representing a warehouse (Refer to Figure 1).
  - Thermocol blocks are used to represent packages. Three colors Red (R), Blue (B), or Green (G) are used to represent different **types** of packages.
  - There are twelve **pick-up points** in the warehouse where packages are placed on arrival to the warehouse. Each pick-up point can contain: (i) **No package** – when the pick-up point is empty (ii) **Valid package** – when a package of one of the colors – Red (R), Blue (B), or Green (G) – is at the pick-up point or (iii) **Invalid package** – when a Black package is at the pick-up point which should not be picked up. Number of valid packages to be picked up from the pick-up points can vary from 3 to 7.
  - There are five **Deposition Zones** numbered 1 to 5. Each deposition zone has an associated color – only packages of that color can be deposited in that deposition zone. A **deposition table** (explained in Section 6: Theme rules) provides the information on the designated color for each deposition zone. For example, if deposition zones 1 and 2 are designated as R, only red packages can be deposited in these deposition zones. Each deposition zone can take a maximum of 2 packages only.
2. The robot traverses the path around the warehouse and does the following:
  - Checks pick-up point for a package.
  - If the package is **Invalid**, sounds a buzzer and moves on.
  - If the package is **Valid**, does the following:
    - Indicates the color of the package by turning on the appropriate color in the RGB Light Emitting Diode (LED) provided with the kit.
    - Picks up the package and deposits it in the appropriate deposition zone.
  - Robot repeats the above protocol till it picks up and deposits all the valid packages on the arena.
  - After depositing the last package at the appropriate zone, the robot sounds the buzzer continuously.
  - Sound of the continuous buzzer indicates END of task.

## 3. ARENA

The arena for this theme is a simplified abstraction of a warehouse. There are 12 pick-up points marked on the arena. Packages of different types represented by blocks of colors Red, Blue, or Green will be placed on these pick-up points. A pick-up point may or may not contain a package. For example, with reference to Figure 1, there are 2 red blocks, 3 blue blocks, and 2 Green blocks placed on the pick-up points. There are three black blocks that are invalid packages and two pick-up points are empty. The deposition zones are indicated by 1, 2, 3, 4, and 5 in the arena. The black line on the arena is the line along which the robot will navigate its path.

The complete arena with the above mentioned details for this theme is depicted in Figure 1.

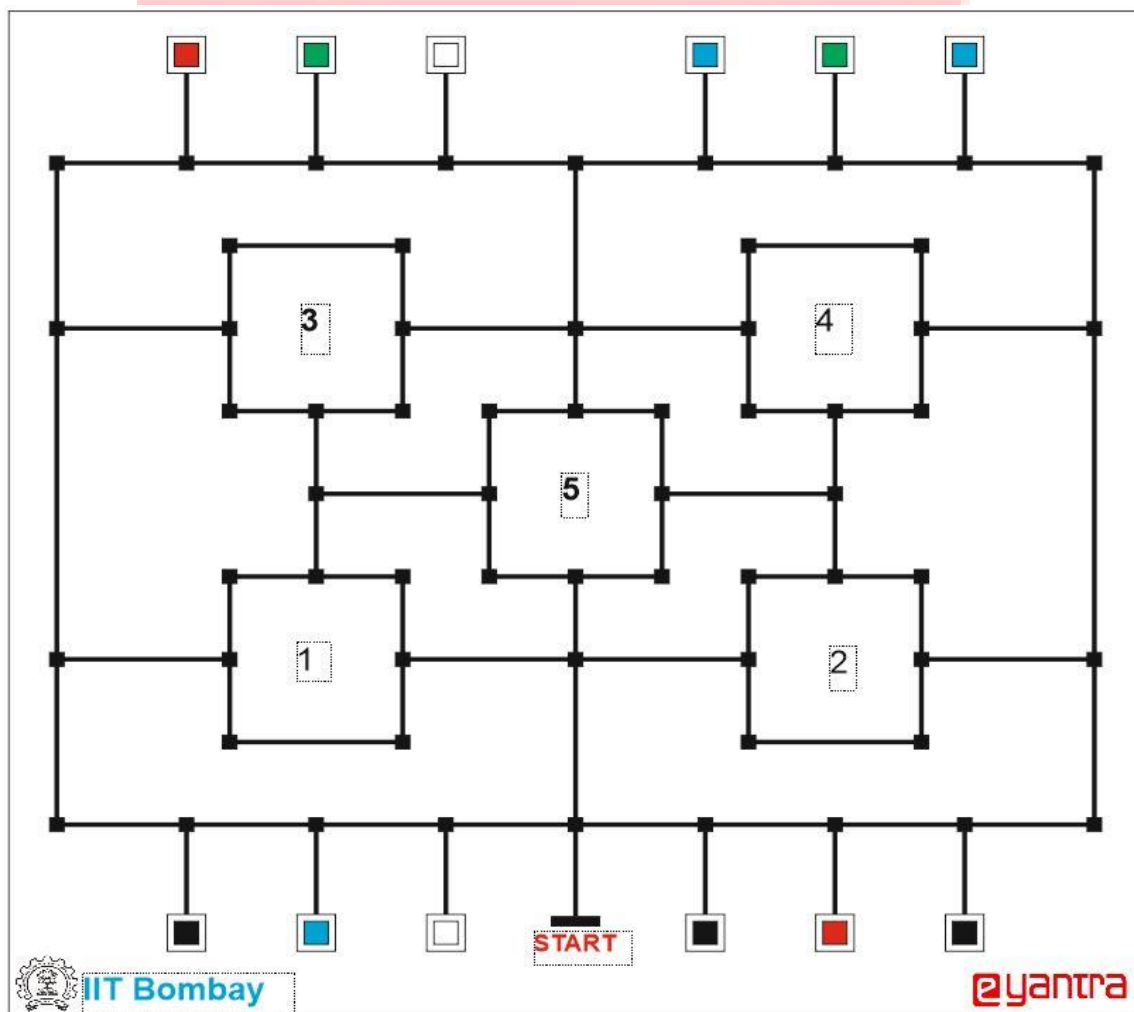


Figure 1: Arena

**Arena preparation:**

Each team prepares the arena. Preparing the arena consists of three major steps.

1. Printing the design on a flex sheet.
2. Preparing the blocks.
3. Placing the blocks on the flex sheet.

Details of these steps are given below:

**3.1. Printing the design on a flex sheet:**

- The arena design is as shown in Figure 2.
- A Corel Draw (.cdr) file containing the flex design will be provided to the teams along with .pdf for reference. Each team shall print the arena layout design according to the instructions provided in the .cdr file.

**Details of arena design:**

- Dimension of arena is 216 cm x 199 cm.
- Dimension of the flex sheet is 236 cm x 220 cm. A margin of 10 cm is provided on all the sides to allow for sticking the flex sheet on the ground (Refer to Figure 2).
- START line is marked on the flex sheet. This is the point from where the robot starts its task.
- FINISH line is NOT marked on the sheet as when the robot places the last package at the appropriate deposition zone, it sounds the continuous buzzer indicating that the task is complete.
- The arena consists of a grid made of black lines of 1 cm thickness. Square nodes of dimension 3 cm x 3 cm are provided at the intersection of two or more black lines.

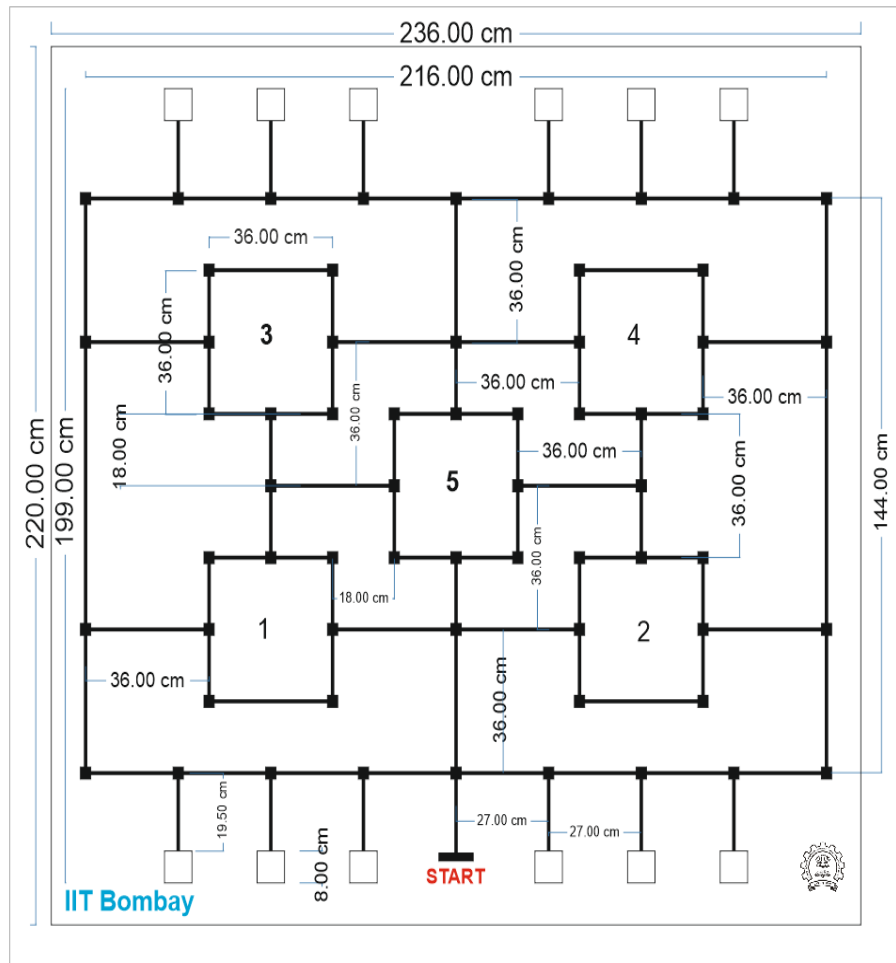


Figure 2: Flex Design

- There are five deposition zones numbered 1, 2, 3, 4 and 5. This numbering will remain same throughout the competition.
- The size of each deposition zone is 36 cm x 36 cm.
- Teams are not allowed to make any change in the arena design. Any team making any modification whatsoever will be disqualified from the competition.

## 3.2. Preparing the blocks:

Materials required for preparing the blocks:

- Thermocol sheet for making the blocks.
- Red, Blue, Green and Black color chart paper for covering the blocks.
- Sample chart paper of all these colors are provided in your kit. Teams may need to purchase additional chart paper for preparing the blocks. Even minor variation in the shades of chart paper can cause error in detection of these colors. Hence, we recommend that you take the sample chart paper and exactly match these when you buy additional chart paper.
- NOTE: Accurate calibration of the sensors is key for successful implementation of a solution to this theme. You should make the sensing as robust as possible under different lighting conditions. Also take care in the fabrication of the blocks since the proper sizing, positioning and positional stability of the blocks might make the difference between failure and success. All the colors given as samples have been tested for detection by the sensors provided with the robot.

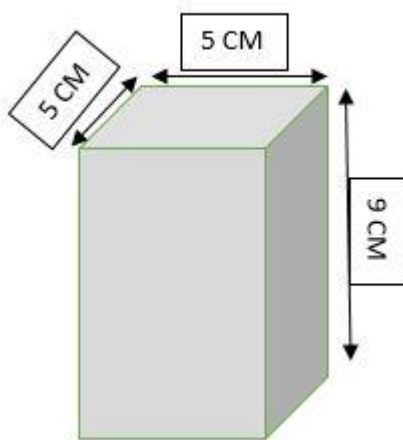


Figure 3A: Dimension of the Blocks

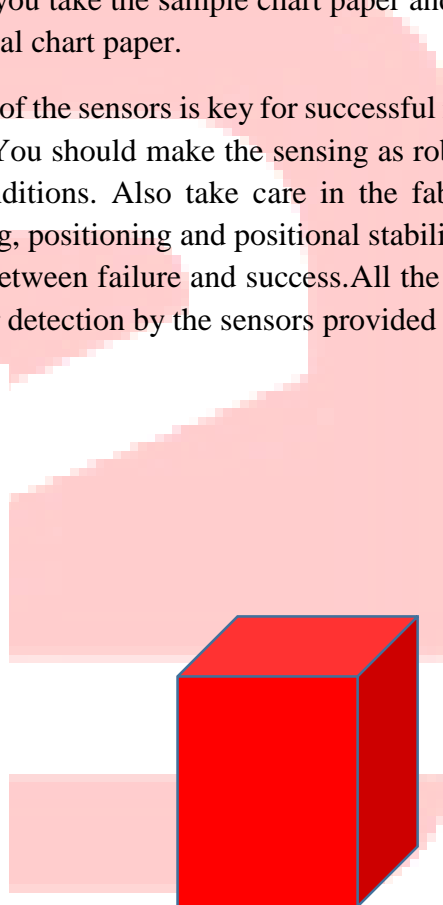


Figure 3B: A Red Colored block

- Team prepares 20 blocks using Thermocol sheets.
- Dimension of each block is 5cm x 5cm x 9cm as shown in Figure 3A. (If the Thermocol sheets of required dimensions are not available then the teams may cut or join the available sheets on their own)
- Team prepares 5 blocks each of Red, Blue, Green and Black by covering the blocks with the respective colored chart paper. A red block is shown as an example in Figure 3B.

### 3.3. Placing the blocks on the arena:

- Blocks are to be placed on the 12 pick-up points.
- Placement of the blocks will be given to the team as an image just before the deadline for video submission. Note that the image can represent any random placement of the blocks.
- As explained in our *theme description*, blocks of color Red, Blue and Green are valid packages while a black colored block is an invalid package. In the competition, only 3 to 7 valid packages and up to 5 invalid packages will be placed at the pick-up points.
- We provide an example in Figure 4. If the team gets this image for placement of the blocks, they will place the colored blocks as shown in this figure and proceed with the task.

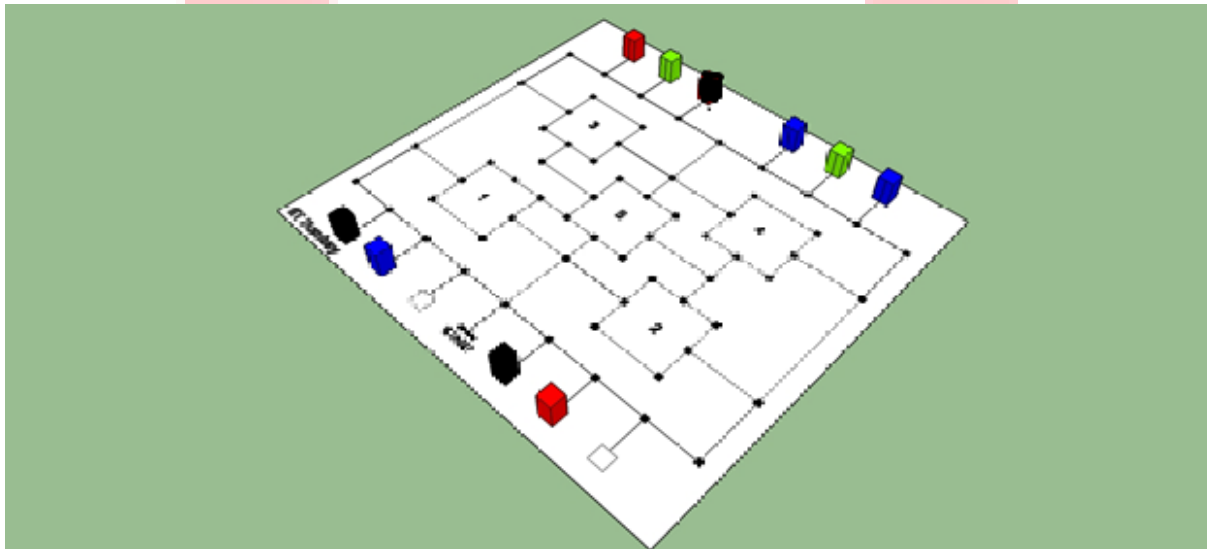


Figure 4: An Example of Placement of Blocks on the Arena

Now we are ready with the arena. Please maintain the arena in good condition. If the arena is found damaged or in a condition that makes evaluation process difficult, e-Yantra has the right to disqualify the team. The final decision is at the discretion of e-Yantra.

**WARNING:** Please be careful while handling the flex sheet – avoid folding it at any stage as folding will result in creases which in turn will impair the movement of the robot. 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.

## 4. HARDWARE SPECIFICATIONS

### **4.1 Use of Firebird V:**

- All participating teams must use **only** the Firebird V robot sent to them in the kit. **Only one** robot given in the kit is allowed per team.
- Team shall not dismantle the robot
- The robot should be **completely autonomous**. The team is not allowed to use any wireless remote or any other communication protocol or devices such as a camera while the robot is performing the task.

### **4.2 Use of additional components not provided in the kit:**

- No other microcontroller-based board shall be attached to the Firebird-V robot.
- Teams may connect external actuators along with their driver circuits to the Firebird V robot only on the condition that the actuators must be controlled through the Firebird V robot.
- The team is not allowed to use any other sensors apart from those provided in the kit.

### **4.3 Power Supply:**

- The robot can be charged through battery or auxiliary power supply. These are shipped with the robot.
- The team cannot use any other power source for powering the robot.
- The team can use auxiliary power during practice but the final demonstration should only be made using only battery powered robot.

## 5. SOFTWARE SPECIFICATIONS

- e-Yantra has provided all teams with ATMELO STUDIO 6 – a free software programming AVR microcontroller. Participating teams are free to use any other open source Integrated Development Environment for programming AVR microcontroller.
- As per e-Yantra policy, all your code and documents are open-source and maybe published on the e-Yantra website.



## 6. Theme Rules

- The maximum time allotted 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 repositions** (explained below) will be allowed in each run.
- The team should switch **ON** the robot when told to do so by reviewer. This is the start of a **run**. The timer will start at the same time.
- A **deposition table** that defines the designated color for each deposition zone will be given 10 minutes before start of a run.
- Note that each deposition zone has an associated color – only packages of that color can be deposited in that deposition zone. A maximum of 2 packages can be placed in each deposition zone.
- The format for the deposition table is as follows:
  - i. First column represents type of package identified by the color of the block.
  - ii. Second column represents the number of packages of a given type.
  - iii. Third column provides the number/s of the designated deposition zone/s for each type of package.

### Example:

An example of a deposition table is provided in Figure 5:

Type of Package	Number of Package/s	Designated Deposition Zones
Red (R)	2	1,5
Blue (B)	3	2,4
Green (G)	2	3

Figure 5: Example of a Deposition Table

Let us consider the sample arena in Figure 5. Consider the deposition table given in Figure 5. Since the maximum capacity of each deposition zone is two, various possibilities for depositing the blocks arise, based on the path and deposition zones that the teams select.

Two possible scenarios after completing the task are given in Figure 6A and Figure 6B. In both scenarios, green blocks are deposited in deposition zone 3, as there is no other deposition zone allocated for green. But for red blocks there are options for either depositing both blocks in deposition zone 1 or deposition zone 5 or one in deposition zone 1 and the other in deposition zone 5. Similar options exist for blue blocks – two blocks can be deposited in deposition zone 4 and one in deposition zone 2 or two in deposition zone 2 and one in deposition zone 4.

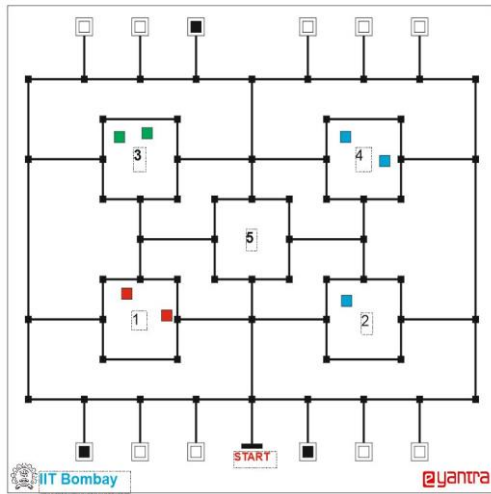


Figure 6A: Arena after completion of Task (Possibility-1)

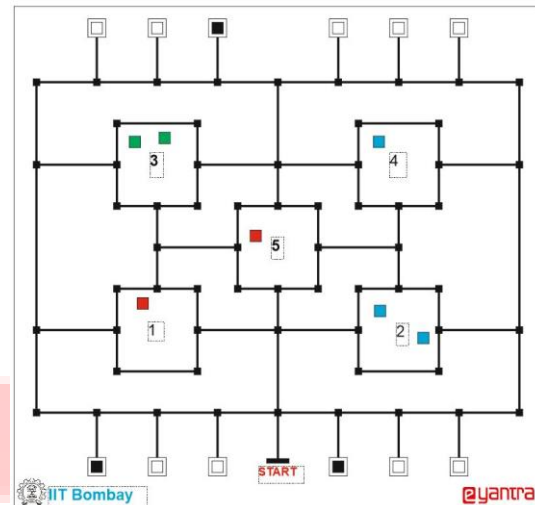


Figure 6B: Arena After completion of Task (Possibility-2)

- Teams are given 10 minutes to initialize their robot with the given deposition table. After this time, the robot is kept at START position to start the run.

### Note:

- The robot can pick up and deposit a block in any order.
- It should indicate the detection of color of a block by turning on the appropriate color in the RGB Light Emitting Diode (LED) provided with the kit.
- Important:** The RGB LED should be placed such that it is visible for judging without any difficulty.
- When a black block is detected, it should sound a buzzer of one second.
- All blocks should be placed inside the appropriate deposition zone/s. As shown in Figure 7, blocks which protrude beyond the borders of the deposition zones are not considered as deposited.
- Participants are not allowed to keep anything inside the arena other than the robot.
- The time measured by the reviewer will be final and will be used for scoring the teams.
- Time measured by any participant by any other means is not acceptable for scoring.
- Once the robot starts moving on the arena, participants are not allowed to touch the robot.
- The robot is not allowed to make any marks while traversing the arena. Any robot found damaging the arena will be immediately stopped; repositioning will be allowed as per the rules. The final decision is at the discretion of the e-Yantra team.

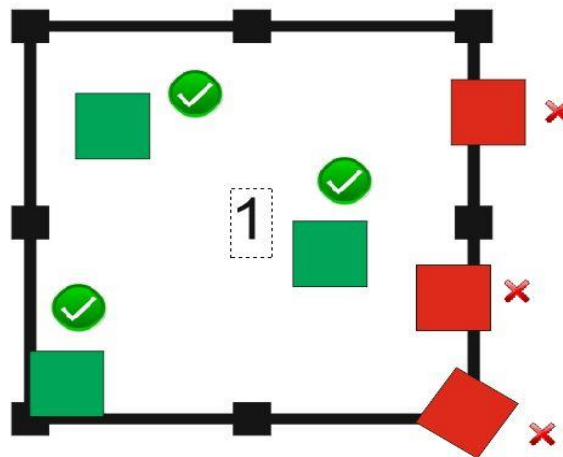


Figure 7: Placing the Packages in a Deposition Zone

- The team has to use same colors given in the kit.
- The robot must be started with only one switch. The starting procedure of the robot should be simple and should not involve giving robot any manual force or impulse in any direction.
- Robot should be kept at the START line with the castor wheel of the robot positioned on the line.
- When the robot malfunctions during a run it can be repositioned. In this case the robot is kept at the START position without resetting the timer.
- A maximum of two repositions are allowed in each run.
- A run ends and the timer is stopped when:
  - The robot stops and sounds continuous buzzer or
  - If the maximum time limit for completing the task is reached or
  - If the team needs repositioning but has used both options.
- Buzzer sound for more than 5 seconds will be considered as end of task.
- Second run will start once again whilst resetting the score, timer and arena. The score of both runs will be recorded and best of two runs will be considered as the team's score.
- **Special Case: If the number of blocks of a particular color exceeds the capacity of deposition zone/s designated for that color then the robot has to skip that package and continue with the remaining task; this will be considered as the correct action for scoring even though a valid package remains un-deposited.**

Example:

Consider the Deposition Table in the Figure 8 given below:

Type of Package	Number of Package/s	Designated Deposition Zones
Red (R)	2	1,5
Blue (B)	2	2,4
Green (G)	3	3

Figure 8: Example of a Deposition Table (Special Case)

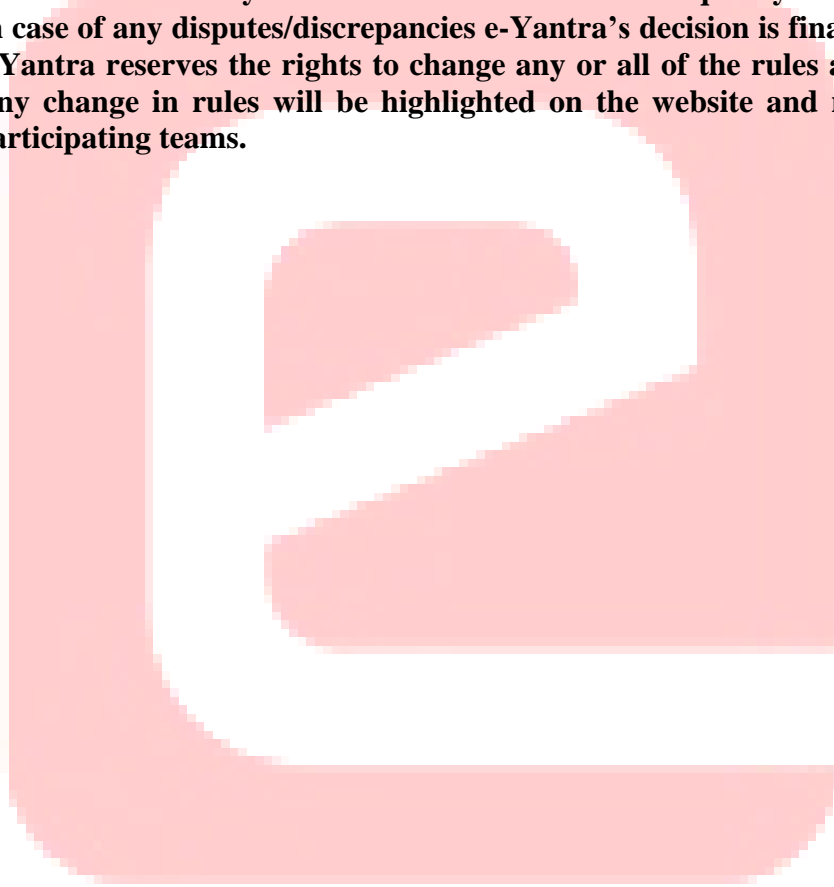
From the deposition table given in Figure 8, the deposition zone designated for the green package is deposition zone 3. The number of packages to be deposited is three. Since the maximum capacity of each zone is two, team has to deposit any two package and skip the third one.

### Repositioning of Robot

- Robot repositioning is done under following circumstances:
  - If robot is found to be displacing any block or damaging the arena then it will be kept at the **START** position.
  - If the robot gets stuck in the arena or goes off the arena, teams can ask for the reposition.
- For a reposition, the robot should be in Power Off mode, and turned on again at the **START** position, upon signal from the reviewer. **During a reposition, the timer will not be set back to zero.**
- Each team is allowed a maximum of two repositions in each run. All repositions require the approval of the reviewer; the team will be disqualified if the robot is handled within the arena without approval.
- During repositions, a participant must not feed any information to the robot. A participant may not alter a robot in a manner that alters its weight. The reviewer's decision is final.
- Note that during reposition, any block that is not deposited at the appropriate deposition zone, (any block dropped during traversal) will be placed back in its original position on the appropriate node.
- After reposition the robot has to complete the remaining task; the blocks that are previously deposited correctly will be counted in the score.

**Note:**

- You will be given: (i) An image for placement of the blocks and (ii) a deposition table, just before the submission of Task 3: Video submission along with instructions for completing 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 rules as it deems 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 robot is switched ON. 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 as the final score of the team.
- Teams will be eligible for scoring only if they deposit minimum of three blocks (correct/incorrect deposition).
- The total score will be calculated by the following formula:

$$\text{Total Score} = (600 - T) + (D * 20) + (C * 50) - (W * 20) + B - (P * 20)$$

- ❖ T is total time in seconds taken to complete the task.
- ❖ D is the number of packages detected correctly.
- ❖ C is the total number of packages that are deposited correctly in the appropriate deposition zone as specified in the deposition table.
- ❖ W is the number of blocks deposited incorrectly. Deposition of a block is considered incorrect in the following cases:
  - ✓ When a block of a different color is deposited in a deposition zone designated for a given color; for example, if deposition zone 1 is designated as R, and a green block is deposited in it.
  - ✓ If number of packages exceeds two in any deposition zone.
  - ✓ If the number of packages deposited after completing the task is less than the number of packages to be actually deposited; for example if four packages are to be deposited and only three packages are deposited then one package will be considered as incorrect.
- **Bonus Points (B)**

Forty (40) Bonus points will be awarded, if the robot:

  - ✓ Places all the packages correctly.
  - ✓ Completes the task within 10 minutes.
- **Penalty(P)**
  - ✓ Twenty (20) points will be deducted if the arena is damaged.
  - ✓ Twenty (20) points will be deducted if any black package gets displaced from its position.

Note: If a black package is picked up and deposited in a deposition zone it will be considered invalid -- incurring a deduction of 20 points for incorrect package in addition to a penalty of 20 points. But, if a black package is just displaced from its position, there will be a penalty of 20 points only.

**ALL THE BEST .....!!!!!!!**