CARGO ALIGNING ROBOT

1. Introduction

Industrial development across the globe has led to mass development of warehouses for storage purposes. These warehouses store huge amounts of raw materials, and/or finished goods. If these materials and goods are not arranged properly, they can get damaged and may lead to heavy business losses. Automating the process of receiving packages and aligning them properly in a warehouse reduces manual labor and avoids damage to packages.

e-Yantra Robotics Competition 2014 aims to raise awareness about problems in warehouses by assigning a theme from this vital domain. The objective of this theme is to align packages in a warehouse such that storage and retrieval are managed efficiently.

In this theme, **Cargo Alignment,** we explore automating a basic task – aligning blocks (representing packages) in a warehouse. The robot traverses two divisions of a warehouse represented using grids, to find blocks placed at random nodes. It identifies whether a block is placed as per a specified **desired alignment**; if a block is found misaligned, it turns it in the desired direction. When all the blocks are aligned properly, it reaches the END position and sounds a buzzer.

You are free to design the mechanism for detecting the block and aligning it. The challenge is to complete this task in the shortest time possible. The robot that performs the task in the best way as per the set rules will be declared the WINNER.

2. Theme description

Make an autonomous robot that performs the following tasks:

1. The robot starts from the **START** position of the arena representing a warehouse as shown in Figure 1.
    - The arena is divided into three parts: Division 1 (**D1**), Division 2 (**D2**) and a walled path (**corridor**) connecting D1 and D2.
    - Divisions D1 and D2 consist of grids. Each division has an associated **desired alignment** that is explained in Section 3.2.
    - A block representing a package is made of two sides: one side of white color and the other of black color. Packages are placed at grid intersections as per a **placement table,** explained in the next section.
    - The corridor is shown by dotted lines along which walls will be placed. Placement of walls is explained in the next section.
    - An illustrative example is shown in Figure 1.

2. The robot starts from the START position of the arena and does the following:
    i. Traverses the grid in D1 to find blocks placed at random nodes.
    ii. If a block is found, the robot checks if it is placed as per the desired alignment. If the block is misaligned, it aligns the block in the desired direction.
    iii. After aligning all the blocks in D1, the robot follows the walls in the corridor to go to D2.
    iv. Traverses the grid in D2 and repeats step ii as above.

3. **FINISH** point is node (1, I) in D2. After aligning all the blocks in the arena the robot reaches **Finish** point and sounds a continuous buzzer as an indication to show that the task is completed.

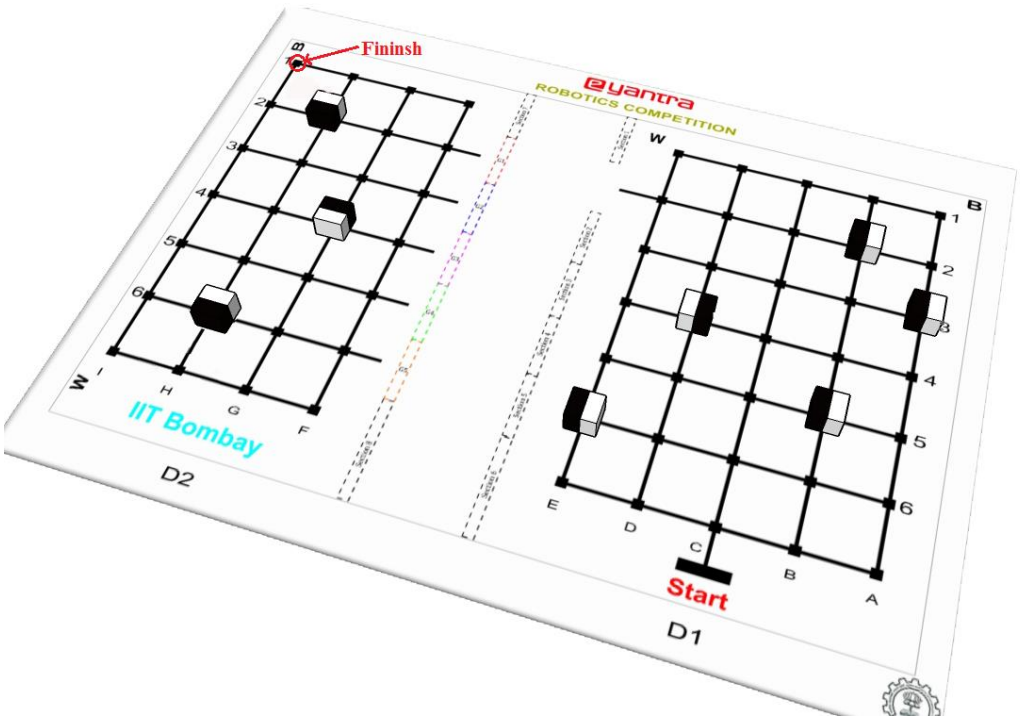


Figure 1: Arena

3. Arena

The arena represents a simplified abstraction of a warehouse. It is divided into two parts D1 and D2 with a corridor connecting them. D1 and D2 consist of grids having **nodes** at the intersections. D1 consists of 35 nodes, whereas D2 consists of 28 nodes.

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

1. Printing the arena design on the flex.
2. Preparing and placing the blocks.
3. Preparing and placing the walls.

3.1. Printing the Arena design:

The arena design is shown in Figure 2. A Corel draw (.cdr) file containing the arena design will be given to the teams. Each team prints the arena design on a flex sheet according to the directions given along with the .cdr file.

Details of Arena design (Refer to Figure 2):

- Dimension of arena is 230cm x 150cm.
- Dimension of flex sheet is 250cm x 190cm.

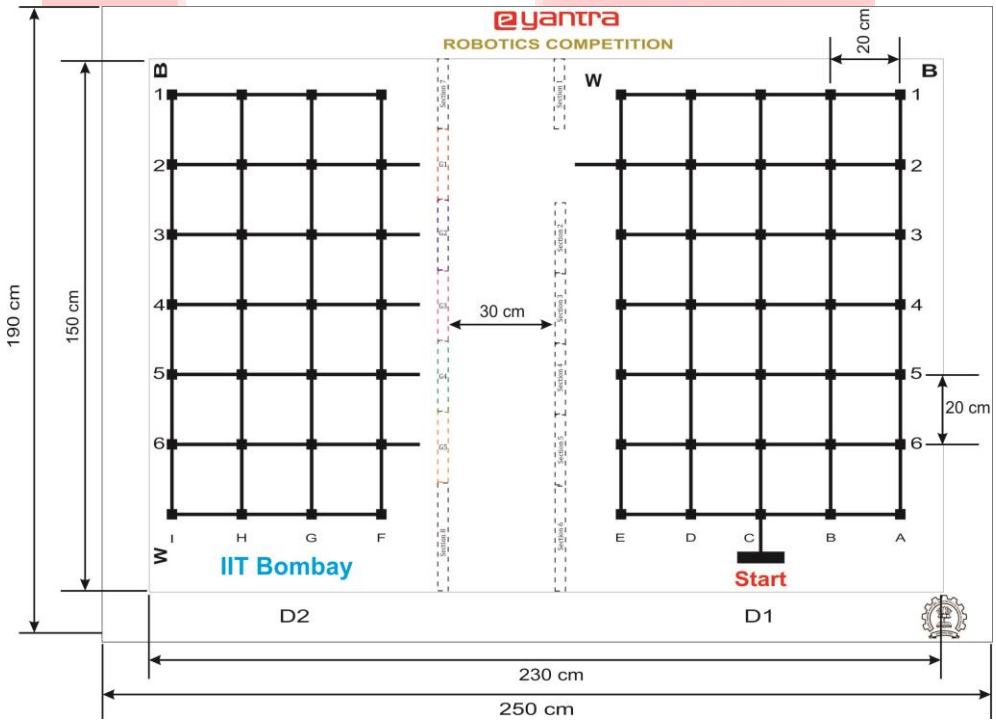


Figure 2: Flex design

- The arena consists of two grids in D1 and D2, made of black lines of thickness 1 cm. Square nodes of dimension 3cm x 3cm are provided at the intersection of two lines.

- Width of the corridor is 30cm. Details of placing the walls to create the corridor are explained in Section 3.3.
- Teams are not authorized to make any changes in the arena design. Any team making unauthorized modifications will be disqualified from the competition.

3.2. Preparing and placing the blocks:

Materials required for preparing the blocks:

- Thermocol sheets for making blocks and walls.
- Black and white colored chart paper.

Preparing blocks:

- Team prepares blocks - ten blocks of size 6cm x 6cm x 8cm with the thermocol sheet/s.
- For each block, cover half of the block with black color chart paper and the other half with white color chart paper as shown in Figure 3.

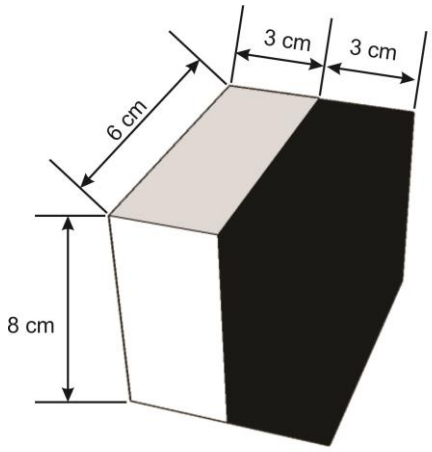


Figure 3: Block Design

Placing the blocks:

- Blocks are placed on the nodes in D1 and D2. Blocks can be in one of two **states**: **Placed Correctly (PC)** or **Placed Incorrectly (PI)**.
- A block is in the state of **PC** when the following conditions are met (Otherwise the block is in the state of **PI**):
  - In D1, note that there is **B** (for black) marked on the right side and **W** (for white) marked on the left side of the grid in the top end of the arena. These markings indicate correct placement of a block in D1; when a block is placed with its black part in the right hand side and white part in the left hand side, it is in the state of **PC**.
  - In D2, note that there is **W** (for white) marked on the lower side and **B** (for black) marked on the upper side of the grid in the left hand side of the arena. These markings indicate correct placement of a block in D2; when a block is placed with its white part in the lower side and black part in the upper side, it is in the state of **PC.**

These conditions are illustrated in Figure 4. Note that in D1, block 1 is in the state of **PC** and block 2 is in the state of **PI** whereas in D2, block 3 is in the state of **PI** and block 4 is in the state of **PC**.

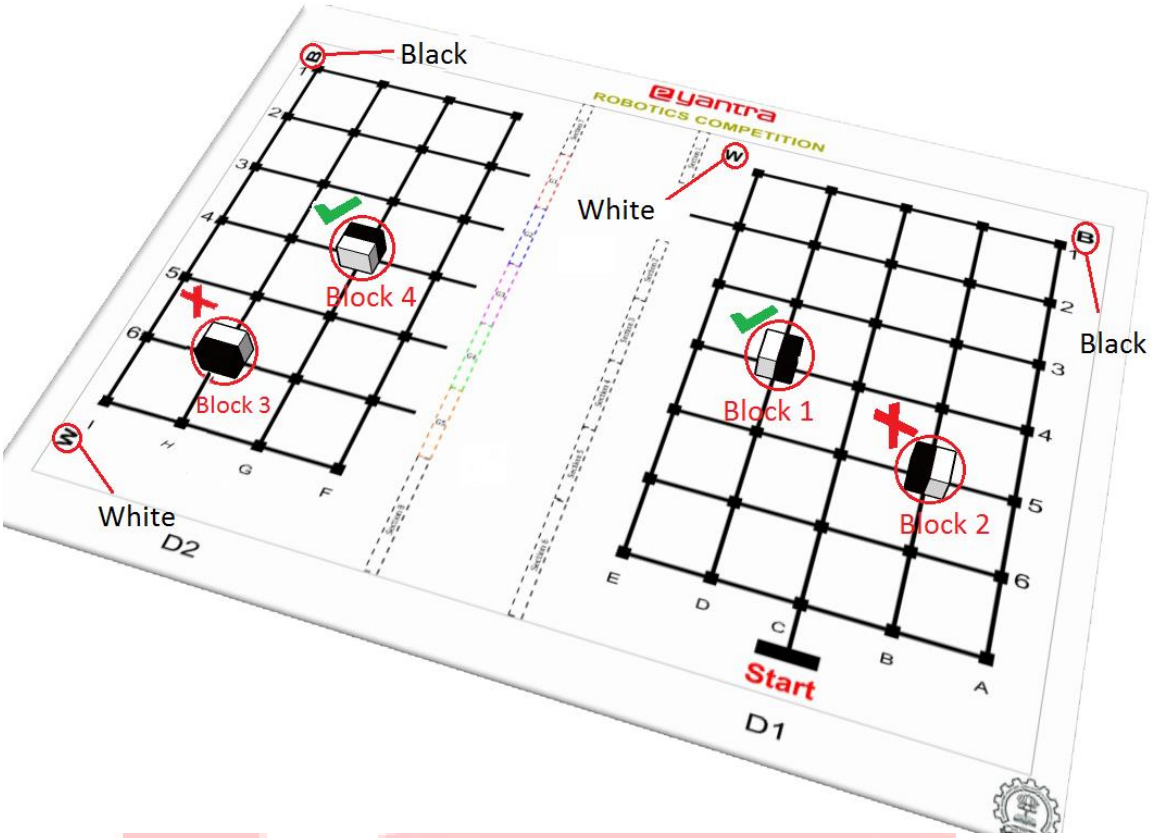


Figure 4: Block Alignments in D1 and D2

- Placement of blocks is given in a **placement table**. One example of a placement table is shown below.

Division 1 (D1)	
Node	Alignment
(2,B)	PI
(3,A)	PI
(4,D)	PC
(5,B)	PI
(6,E)	PI

Division 2 (D2)	
Node	Alignment
(2,H)	PI
(4,G)	PC
(6,H)	PI

Table 1: Placement Table

Suppose this table is used for placing the blocks on the arena, the arena will look like Figure 5.

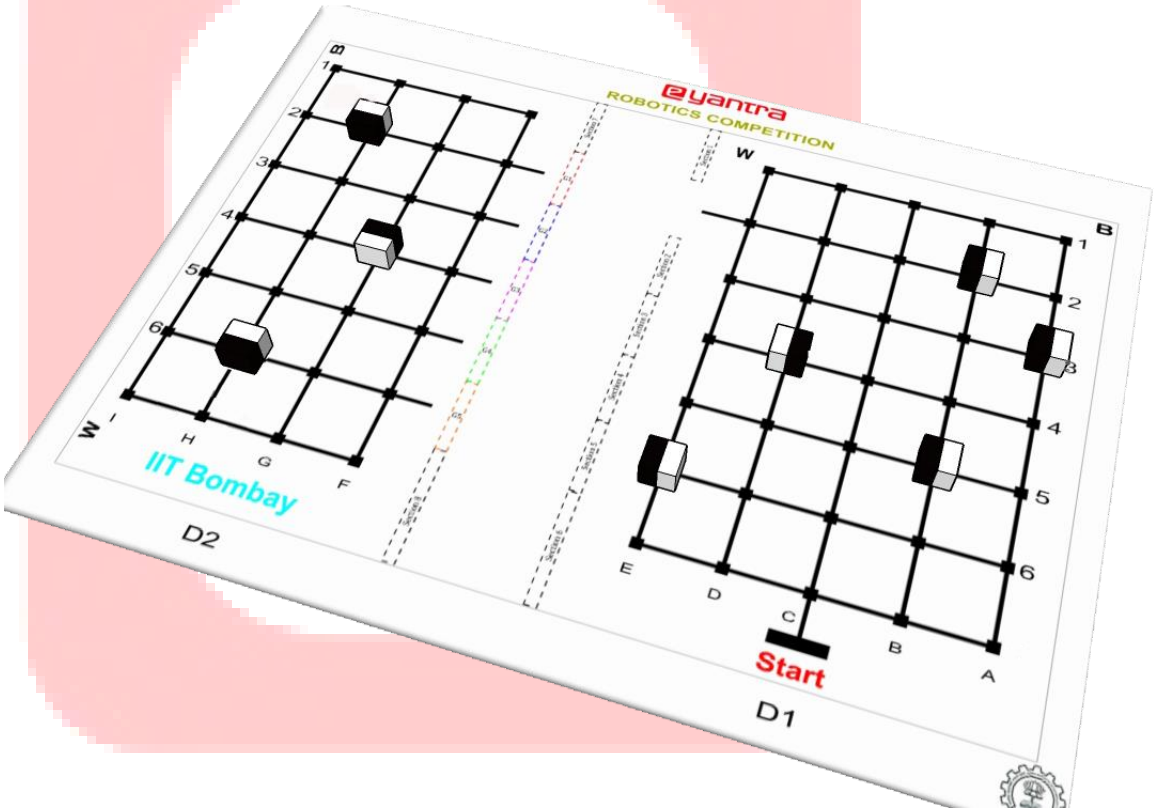


Figure 5: Example - Placement of Blocks Using Placement Table

- This is an example used to illustrate the placement of blocks. In the competition, blocks will be placed randomly on nodes. **Thus, it is mandatory that you use the sensors to identify the blocks.**
- **Accurate calibration of the sensors is key to successful implementation of a solution to this theme. You should make the sensing as robust as possible under different lighting conditions.**
- A maximum of 6 blocks will be placed in D1 and a maximum of 4 blocks will be placed in D2 during the competition.
- No blocks will be placed along column "C" in D1.

3.3.Preparing and placing the walls:

Preparing the walls:

- A walled corridor connects D1 and D2. Walls for the two sides of the corridor are made of 12 **wall sections**. Team prepares 10 wall sections of dimension 20cm x 3.5cm x 10cm referred to as **units A** and 2 wall sections of dimension 30cm x 3.5cm x 10cm referred to as **units B**.
- Wall sections need to be placed on the dotted lines marked on the arena. In the rest of this document, we will refer to the wall close to D1 as **Wall 1** and to the wall close to D2 as **Wall 2** as shown in Figure 6.

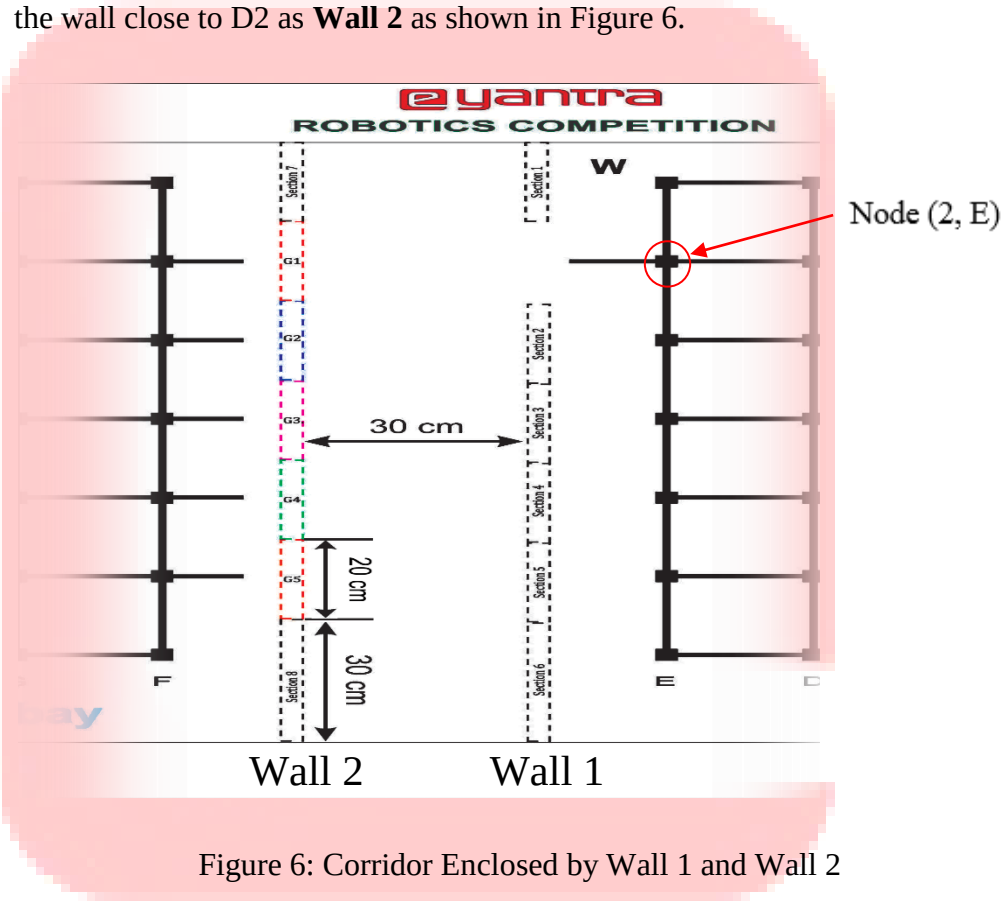


Figure 6: Corridor Enclosed by Wall 1 and Wall 2

- Exit from D1 is provided at node (2, E). This is fixed throughout the competition.
- Entry to D2 is not fixed – it will be specified just before the competition. The robot can enter D2 through one of several gates, Gates 1 – 5. The entry points and the color code associated with each of these gates are given in Table 2.
- All gates are of length 20 cm. Sections 1 – 5 and 7 are of length 20 cm and sections 6 and 8 are of length 30 cm.

Entry point	Gate number	Color
Node (2,F)	G1	Orange
Node (3,F)	G2	Blue
Node (4,F)	G3	Pink
Node (5,F)	G4	Green
Node (6,F)	G5	Red

Table 2: Entry Points and Color Codes for Gates

Placing the walls:

Wall 1:

- Place 5 **units A** on sections 1 to 5 marked on the arena.
- Place one **unit B** on section 6.
- After placing all these units for Wall 1, the arena will look like Figure 7.

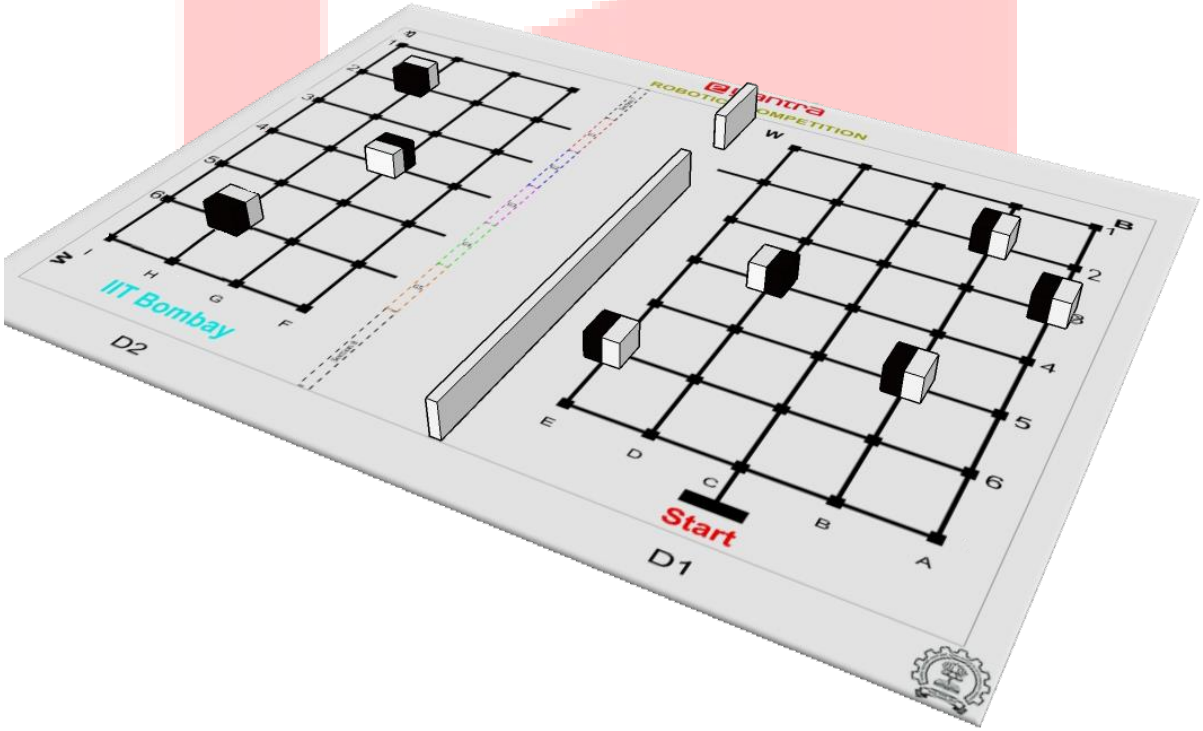


Figure 7: Placement of Wall 1

Wall 2:

- Place one **unit A** on section 7 and one **unit B** on section 8.
- Entry gate to D2 is not fixed – it will be specified just before the competition as:

  G<number>, number can take a value 1, 2, 3, 4, or 5.
- Let us consider one example; suppose entry to D2 is given as: G5.
- In this case remaining **units A** should be placed on gates 1, 2, 3, and 4.
- After placing all the units for Wall 2, the final arena will look like Figure 8.

Note: This is an example used to illustrate the placement of wall sections of Wall 2, according to the assigned entry gate to D2. In the competition, you will be given any one of the five gates G1, G2, G3, G4, or G5 as the entry gate to D2. Thus, it is mandatory that you implement an **appropriate wall following algorithm**.

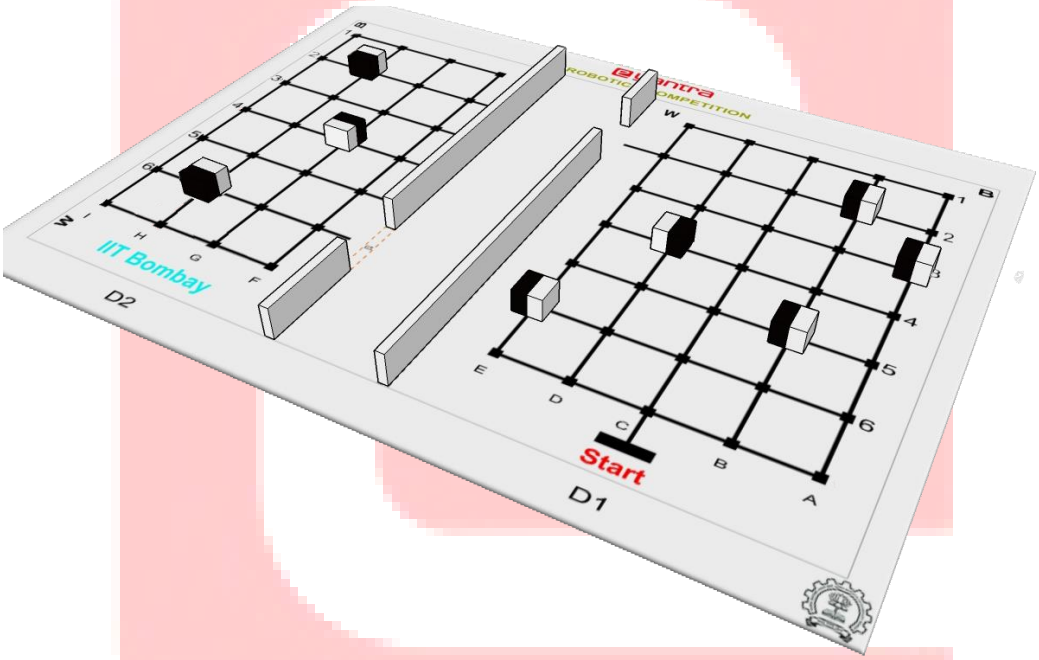


Figure 8: Arena after Placement of Walls

Now, we are ready with the arena. 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 the reviewer.**

Note: The arena shown in Figure 8 is specific to the example placement table and example entry gate considered. During the competition, the table and entry gate will be different and hence, the placement of blocks and wall sections will vary accordingly.

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. Best is to store the sheet in a rolled fashion.

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 the battery powered robot.

5. Software Specifications:

- e-Yantra has provided all teams with ATMEL STUDIO 6, a free software for programming AVR microcontroller. Participating teams are free to use any other open source Integrated Development Environment (IDE) 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.
- Robot should be kept at the **START** line with the castor wheel of the robot positioned on the line.
- Once the robot is switched on, human intervention is NOT allowed.

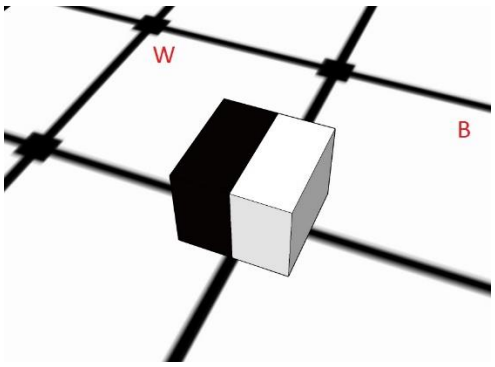
  - The robot should do the following :
    i. Start from the START position.
    ii. Traverse the grid in D1 checking for a block.
    iii. When a block is detected, check whether the block is in state **PC**.
      - If so, then sound the buzzer for 500ms.
      - Otherwise align it in the desired direction and then sound the buzzer for 500ms.

      Proper alignment of a block is explained below.
    iv. Repeat steps ii and iii until all block in D1 are detected and aligned.
    v. Sound a buzzer for 1000ms, after aligning all the block in D1.
    vi. Follow the wall to find the appropriate gate to enter D2; while entering D2 through the gate sound a buzzer for 1000ms.
    vii. Traverse the grid in D2 checking for a block.
    viii. Execute step iii; Repeat steps vii and iii until all blocks in D2 are detected and aligned.
    ix. After aligning all the block in D2, sound a buzzer for 1000ms.
    x. Traverse the grid and stop at node (1, I); sound a continuous buzzer to indicate end of task.

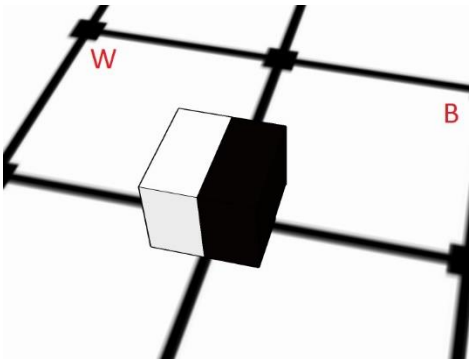
- The sequence followed by the robot to complete the task is:

  Start→Traverse and align blocks in D1→Follow Wall→Traverse and align blocks in D2→END

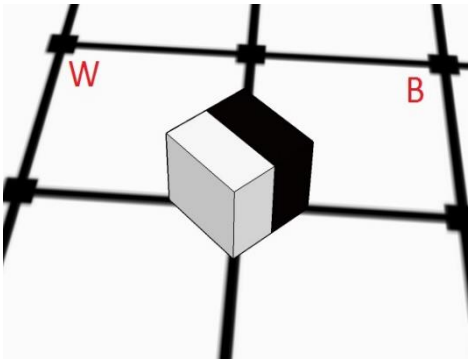
- **Proper alignment of a block:**



(a) Before Alignment

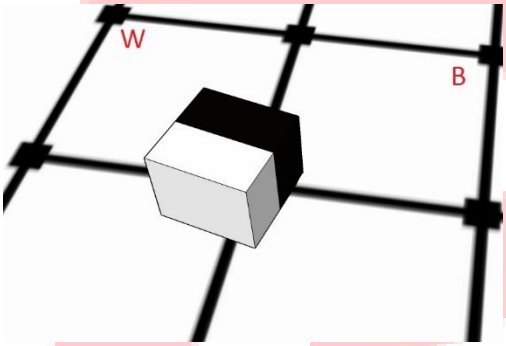


(b)

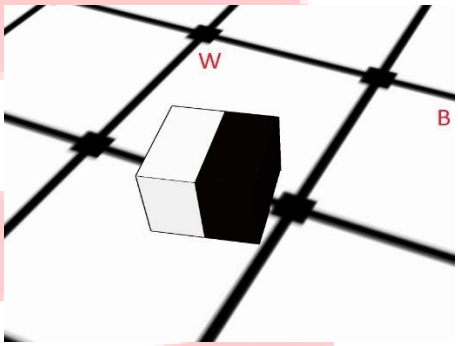


(c)

Proper Alignment



(d)



(e)

Improper Alignment

Figure 10: possible alignments in D1

- Using Figure 10 we illustrate proper alignment of a block.
  - Figure 10 (a) shows the placement of a block that needs to be aligned.
  - Figure 10 (b) shows a perfectly aligned block.
  - A block is considered correctly aligned when both the following conditions are satisfied: (i) the block is on top of the node (node is not visible) and (ii) it is aligned such that the deviation is <= 45 degrees -- as illustrated in Figure 10 (c).
  - Figure 10(d) and 10(e) illustrate two instances of incorrect alignment of the block. Teams do not get any points if blocks are not aligned properly. **The final decision is at the discretion of the e-Yantra team.**

- Buzzer sound for more than **5 seconds** will be considered as continuous buzzer.
- A run ends and the timer is stopped when:
  - The robot stops and sounds the continuous buzzer or
  - If the maximum time limit for completing the task is reached or
  - If the team needs repositioning but has used both repositioning options of that run.

- 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.

- 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.**

Repositioning of robot:

1. 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 a reposition.
2. 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.**
3. 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.
4. 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.
5. After reposition the robot has to complete the remaining task; the blocks that are previously aligned correctly will be counted in the score.

NOTE:

- **You will be given a placement table and entry gate for D2 just before the submission of Task 3: 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 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.
- The team's total score is calculated by the following formula:

Total Score = (600 - T) + (D x 20) – (ND x 20) + (A x 60) – (I x 30) - P + B

Where:

- **T** is the total time in seconds to complete the task.
- **D** is the number of blocks detected.
- **ND** is the number of blocks that are not detected.
- **A** is the number of blocks correctly aligned in the arena.
- **I** is the number of blocks that are improperly aligned.
- **P** is a penalty where 30 (thirty) points are deducted for each block or section of wall that the robot dashes against or displaces during the run.
- **B** is a bonus of 100 points awarded, if robot follows the wall to D2 and,
  - It aligns all blocks correctly,
  - Completes the task within 10 minutes, and
  - Does not incur any penalty.

ALL THE BEST…!!!