BOTHOVEN

1. Introduction

Music touches the soul and helps us to relax and feel good. Music has the power of uniting people from different background and cultural heritage. In fact, it can be best described as a wonderful force that is capable of bonding people together. In Indian Music, the following seven notes form the basis for creating music:

Sa Re Ga Ma Pa Dha Ni

How about a robot singing or playing music for you?

In this technological era, robots can not only be used as a machine to reduce human work but can also be used for entertainment purpose to play music, sing or dance for you. Inspired by this idea, e-Yantra Robotics Competition (eYRC-2016) introduces “Bothoven”, a theme to experiment with robots playing music. In this theme, two robots coordinate with each other to play the notes in a given sequence.

Challenges in this theme include Audio Processing, Motion Planning and Communication. A music file will be given to teams and using Audio Processing they have to extract the notes and communicate them to the robots. The arena consists of metallic pipes of different sizes to give different frequencies of sound that are placed randomly. Both the robots will traverse the arena to play the notes in the given order by coordinating with each other.

The challenge is to complete this task in the shortest time possible and play the notes in sequence. The robots that perform the task best in accordance with the rules set for this task will be declared the WINNER of the competition.

2. Theme description

- Prior to the start of theme execution, an input audio file is given to the team. An example is shown in Figure 1.

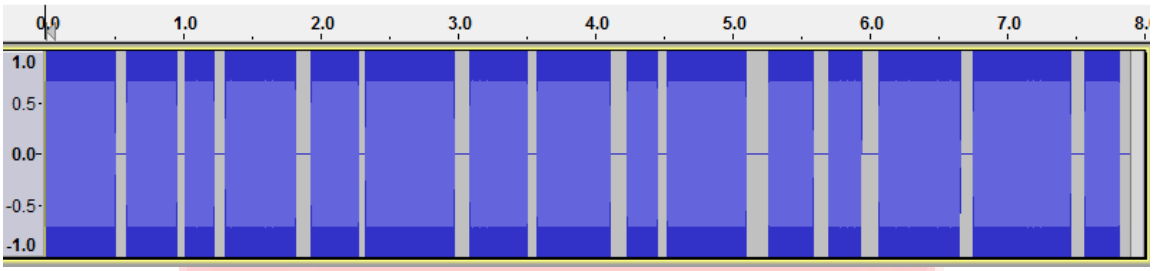

Figure 1: Example Audio File

- Audio file contains:
  - i. Notes separated by silence as shown in Figure 2. (Notes and silence can have random duration).
  - ii. A minimum of 12 and a maximum of 33 notes.
  - iii. Notes from the following:
    {(C6, D6, …., B6), (C7, D7, ….., B7), (C8, D8, ….., B8)}

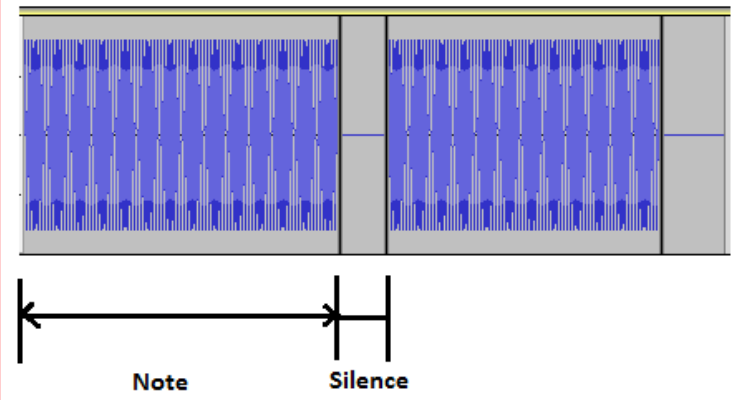

Figure 2: Part of Audio File Showing Note and Silence

- The team analyzes the given audio file on computer by using audio processing which generates the information regarding the **Notes in the file** and then communicates this information to the robot.
- The arena for this theme is shown in Figure 3, which represents a performance stage where music is played. It consists of:
  - i. 33 **Musical Note Positions (MNPs)** marked by 1, 2, …., 33.
  - ii. Black dots/squares termed as **Nodes**.
  - iii. Two Start positions marked as **Start 1** and **Start 2**.

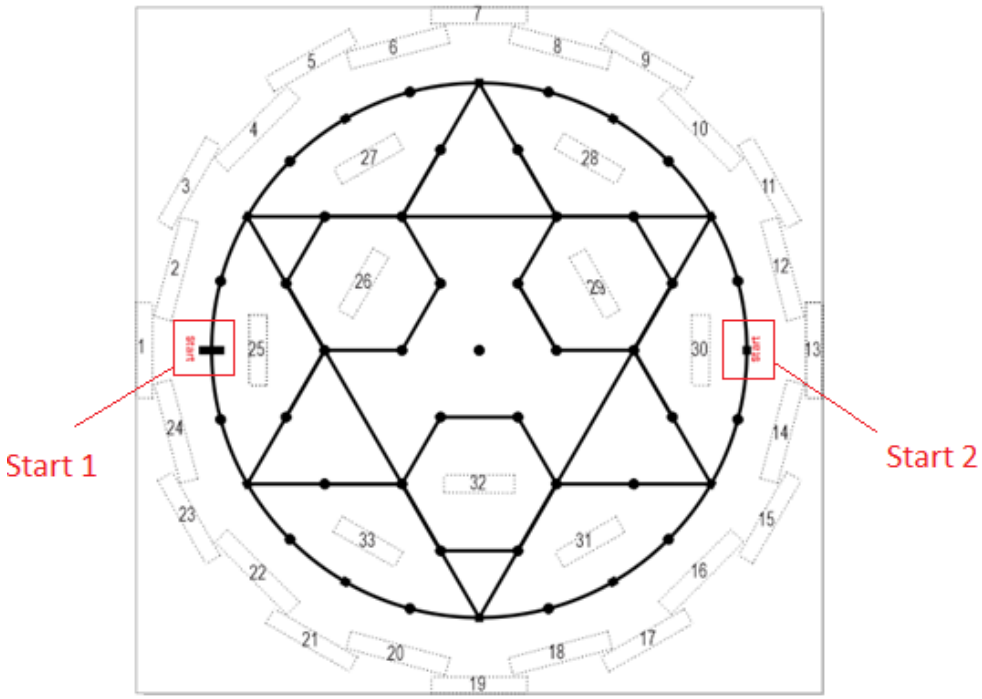

Figure 3: Arena Design

- **Notes** are represented by different sized metallic pipes to give different frequencies of sound. These **Notes** are placed on the **MNP**s. Placement of the Note is given in **Placement Table**, explained in the next section.
- **Obstacles** are represented by blocks and can be randomly placed in between two Nodes. Figure 4 shows the arena with Notes and Obstacles.

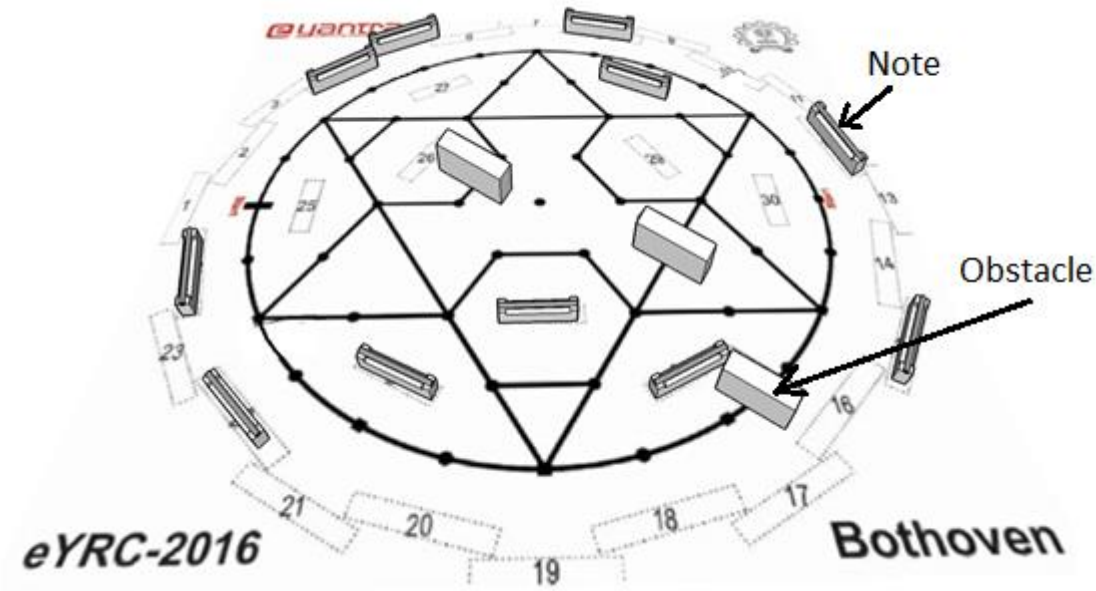

Figure 4: Arena Design with Notes and Obstacles

- This theme uses two robots which communicate with each other using zigbee communication protocol.
- The robots start from the **Start** positions (**Start 1** and **Start 2**). They coordinate with each other to play the Notes in given sequence. The Notes are played by striking on the metallic pipes.
- **FINISH** line is **NOT** marked on the arena; the robots stop when all the Notes are played and one of the robots sounds a continuous buzzer as an indication to show that task is finished.

Note: You have already completed "Audio Processing" and "Arena Navigation" in Stage 1. You may integrate these to complete the Theme.

3. Arena

The arena represents a performance stage where music is played. It consists of 33 **MNP**s, square/circular **Nodes** and two **Start** positions as shown in Figure 3.

Preparing the arena:

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

1. Printing the arena design on flex sheet.
2. Preparing and placing the Obstacles.
3. Preparing and placing the Notes.

3.1 Printing the arena design on flex sheet:

1. A pdf file containing the arena design is given to the teams. Each team prints the arena design on flex sheet according to the directions given along with the file.
2. Teams are not authorized to make any changes in the arena design. Any team making unauthorized modifications will be disqualified from the competition.

Details of Arena design (Refer to Figure 5):

- Dimension of arena is 243.84cm x 243.84cm.
- The arena consists of black lines of thickness 1 cm. Square Nodes are of dimension 3cm x 3cm. Circular Nodes are of diameter 3cm.

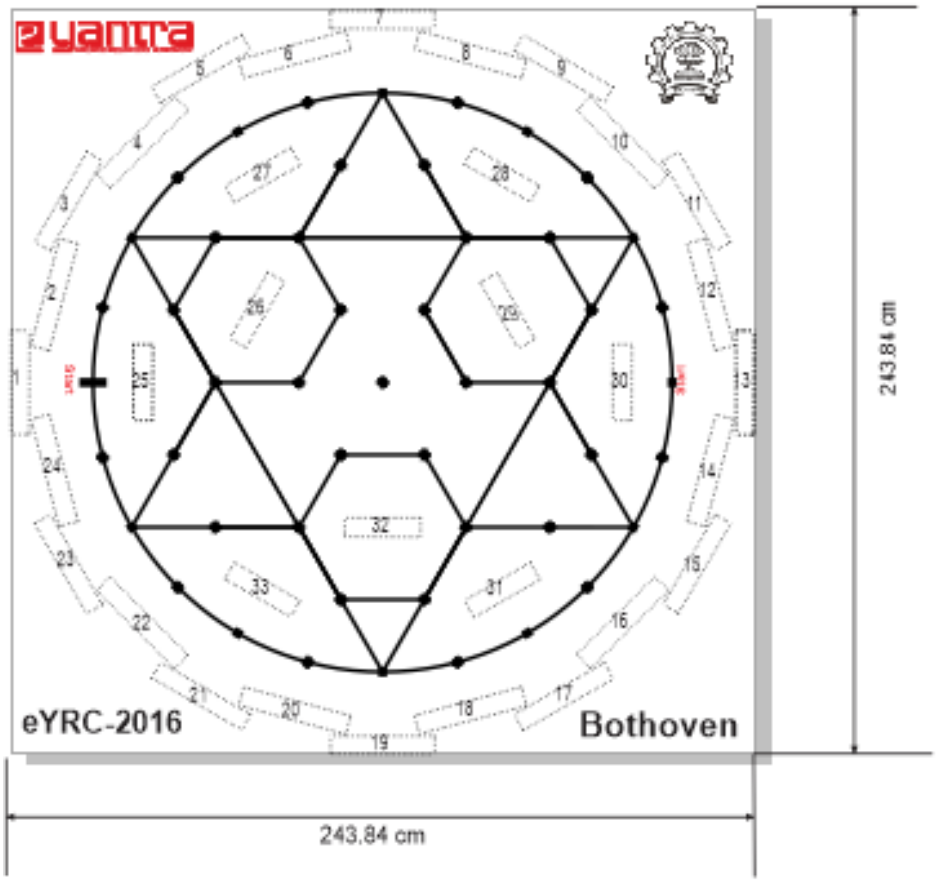

Figure 5: Arena Design

3.2 Preparing and placing the Obstacles:

Preparing the Obstacles:

Team must prepare twenty Obstacles of size 2cm x 10cm x 10cm as shown in Figure 6 using thermocol sheet/s.

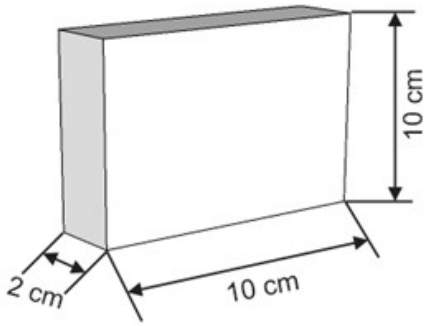

Figure 6: Obstacle Design

Placing the Obstacles:

- Placement of the Obstacles will be given to the teams as an image. Note that the image can represent any random placement of the Obstacles with the following constraints:

  1. The Obstacles will be placed in the middle of two Nodes.
  2. It will not block any MNP.

  One example Obstacle placement is shown in Figure 7.

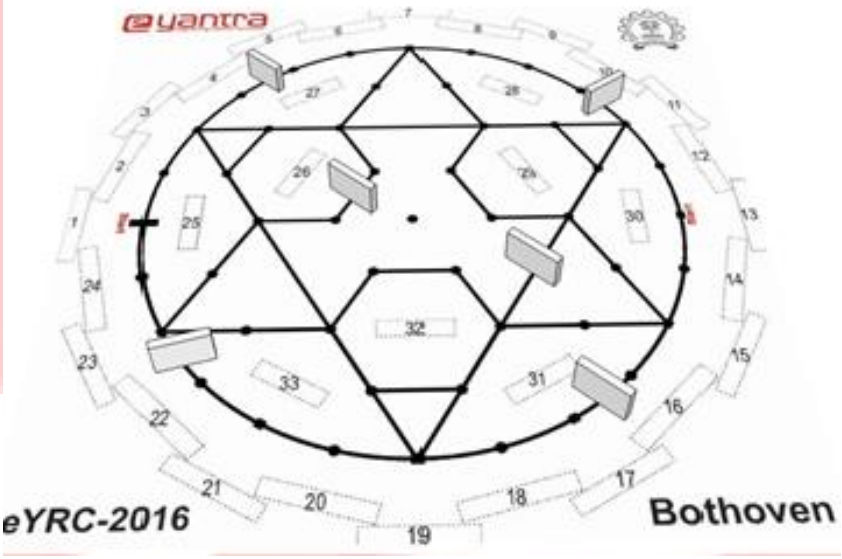

Figure 7: Arena with Obstacles

- This is an example used to illustrate the placement of Obstacles. In the competition, Obstacles will be placed randomly. **Thus, it is mandatory that you use the sensors to identify the Obstacles.**
- **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.**

3.3 Preparing and placing the Notes:

Materials required for preparing the Notes:

1. Thermocol Sheet
2. Metallic Pipes
3. Rubber bands

Preparing the Notes:

- Team prepares two sets of C6 to B8 Notes (21 Notes X 2 = 42 Notes) using metallic pipes. Metallic pipes of different sizes give different frequencies of sound.
- The characteristics of the pipes for the Notes are given in Table 1.

Table 1: Pipe Characteristics

Note	Pipe length (cm)		Note	Pipe length (cm)		Note	Pipe length (cm)
C6	33.0		C7	16.5		C8	8.5
D6	29.0		D7	14.5		D8	7.5
E6	26.0		E7	13.0		E8	6.5
F6	24.5		F7	12.5		F8	6.0
G6	22.0		G7	11.0		G8	5.5
A6	19.5		A7	10.0		A8	5.0
B6	17.5		B7	8.5		B8	4.5

- Teams first make the slot for holding the pipe using thermocol as shown in Figure 8. The length of it is equal to pipe length which depends on the Note.

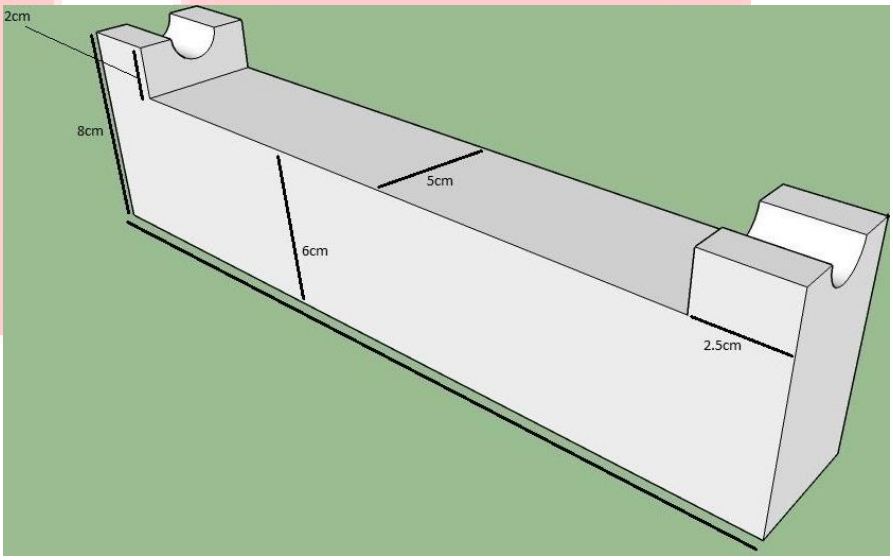

Figure 8: Slot for holding pipe

- Fix the pipe using rubber bands on both the sides. An example of creating Note C6 is shown in Figure 9. The pipe length required for C6 Note is 33cm (Refer to Table 1). In similar way you can make other Notes.

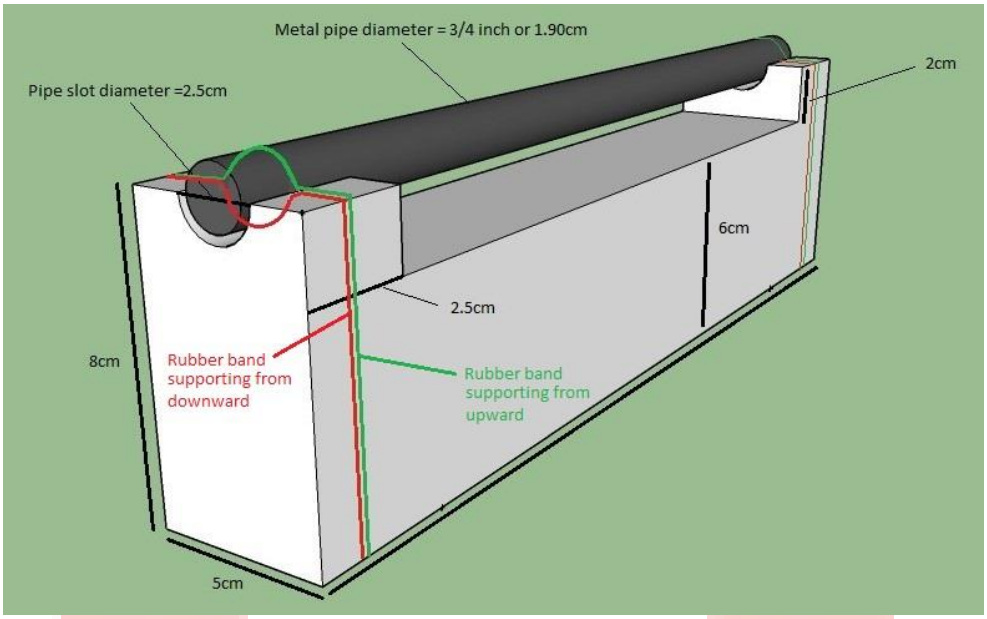

Figure 9: C6 Note

Placing the Notes on the arena:

- **Notes** are to be placed randomly on some of the **MNP**s given in the arena.
- Placement of the Notes is given in the form of **Placement table**. One example of **Placement table** is shown below:

Table 2: Placement Table

Note	MNP
C6	4
C6	8
F7	22
A7	5
B7	12
C8	31
B8	28
E6	32
F6	15
B7	33
G6	24

Suppose this table is used for placing the Notes on the arena, the arena will look like Figure 10.

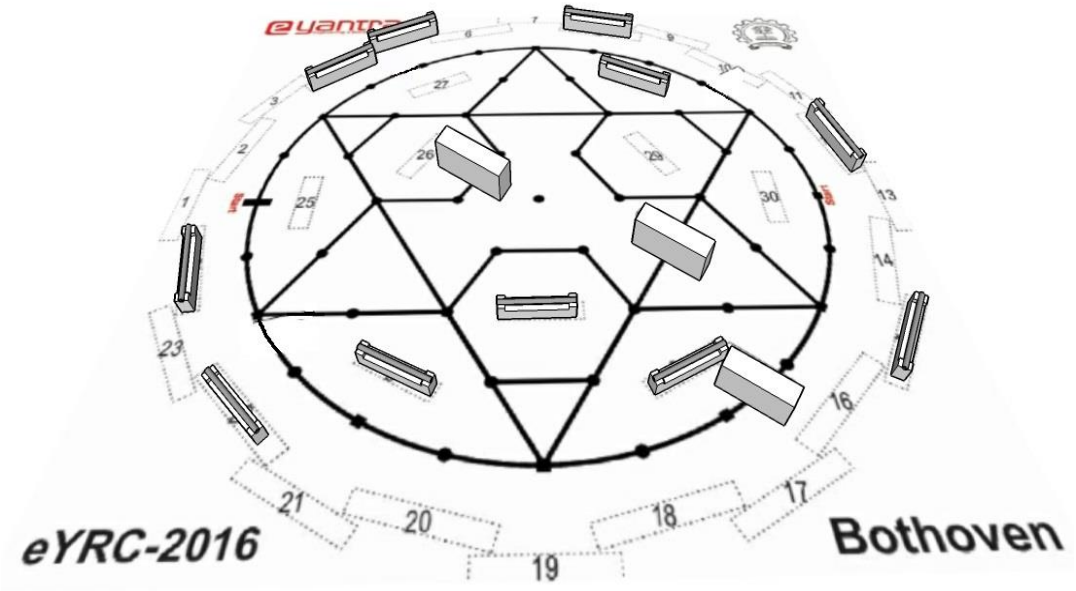

Figure 10: Arena with the Obstacles and Notes

- This is an example used to illustrate the placement of Notes. In the competition, any random placement can be given.
- Placement Table is given before a start of run.
- A maximum of 33 **Notes** can be placed on the arena.

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 10 is specific to the example considered. During the competition the Placement of Notes and Obstacles will be different.

WARNING: Please be careful while handling the flex sheet – avoid folding it like a bedsheet 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 rolled up.

4. Hardware Specifications:

4.1 Use of Firebird V:

- All participating teams must use **only** the Firebird V robot. **Only two** robots are allowed per team. One from Stage 1 (Collected from the college) and the other shipped from e-Yantra.
- Team shall not dismantle the robots.
- The robots 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 robots are 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 robots.
- Teams may connect external actuators along with their driver circuits to the Firebird V robots only on the condition that the actuators must be controlled through the robots.
- The team is not allowed to use any other sensors apart from those provided in the kit.
- The teams must use a laptop/computer capable of running Python.

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 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.
- The teams must use Python to write their code.
- Use of any non-open source libraries is not allowed and will result in disqualification.
- 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 per robot** (explained below) will be allowed in each run.
- The robots should be kept one at **Start 1** and the other at **Start 2** (teams can decide) with their castor wheels positioned on the marked lines.
- The following are the steps of the task:
    i. The input audio file and Placement table for Notes are given before the start of a run.
    ii. Robots are placed on the Start positions (Start 1 and Start 2) and turned on.
    iii. The team must use Python to identify the Notes from the Audio file.
    iv. The teams must use the **USB to serial cable** to communicate the information from the computer to one of the robots.
    v. When the communication is completed, remove the USB to serial cable.
    vi. At this point, the team can switch **ON** the robots after getting permission from the reviewer:
        a. Press the Boot key to start traversal of the robot. The second robot can be started simultaneously by using ON/OFF switch or Boot key.
        b. The **start of a run** is when any of the robots is switched on. The timer will start at the same time.
        c. Once the robots are switched on, human intervention is NOT allowed.
    vii. Robots communicate with each other using the Zigbee Wireless Protocol. The robots traverse the arena simultaneously and play the Notes by striking on the metallic pipes according to the given sequence.
    viii. After completing all the Notes, one of the robots should sound a continuous buzzer to indicate the end of the task.
- The robots must follow the sequence of Notes given in the Audio file.
- They cannot traverse the line which is blocked by Obstacle.
- For each **Note** the following apply:
    - **Correct Detection:** When a robot traverses to Note (Which is given in audio file) and waits for at least 1 second but due to striking mechanism failure it does not strike the pipe.
    - **Correct Playing:** When a robot traverses to Note (Which is given in audio file) and correctly plays the Note by striking the pipe. (Contact should be made between the pipe and the striking mechanism).
    - **Correct Sequence:** For a given audio file a detected/played Note is considered to be in sequence:
        i. If first Note, it is detected/played first.
        ii. If the Note detected/played previously to this Note matches the order of Note given in the audio file.

For example audio file contains following sequence of Notes:

C6 B8 F6 G7 E6

Table 3 illustrates how Correct Sequence is determined in the competition considering one example traversal.

Table 3: Illustration of Correct Sequence

Notes in audio file	Detected	Played	Correct Sequence	Comment
C6	-	✓	✓	First Note, it is played first
B8	X	X	X	Missed the Note
F6	-	✓	X	As robot missed the Note B8, for this Note previous Note played is C6. This is not as per the order given.
G7	✓	X	✓	Previous Note played is F6. This is as per the order given.
E6	-	✓	✓	Previous Note detected is G7. This is as per the order given.

- Buzzer sound for more than 5 seconds will be considered as continuous buzzer.
- A run ends and the timer is stopped when:
  i. The robot stops and sounds the continuous buzzer or
  ii. If the maximum time limit for completing the task is reached or
  iii. If the team needs repositioning but has used both repositioning options of that run (repositioning is explained below).
- 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 robots. 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 robots start moving on the arena, participants are not allowed to touch the robots.
- The robots are 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:

Suppose while traversing the arena one of the robots strays off the black line (Refer to Figure 11), a member of e-Yantra team who will be monitoring the task will place that robot on the previous node (node already traversed by the robot) in such a way that both the wheels of robot are parallel to the node and castor wheel is on the black line (Refer to Figure 12). This is termed as a **Reposition**. Note that the timer used for measuring the task completion time in the competition will be continuously running during a Reposition and the robot will not be switched off. **Each robot** is given **only two repositions** per run. If any one of the robots has been repositioned twice and requires a third reposition, the run will **be ended and the maximum time for the Task will be considered for that run**.

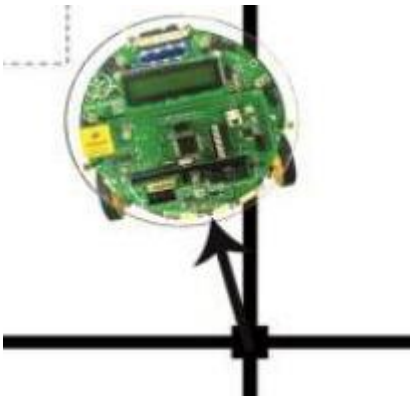

Figure 11: Robot strays off the line

Figure 12: Robot after Reposition

NOTE:

- **You will be given an audio file, Placement table and Obstacle placement 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 one of the robots is switched ON. The timer will stop as soon as the robots finish the task.
- 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) + (NCD X 20) + (NCP X 15) + (NCS X 60) – (NI X 30) + B - P

- **T** is the total time in seconds to complete the task.
- **NCD** is the number of Notes **Correctly Detected**. NCD is given when robot reaches to correct Note and waits for at least 1 second but due to striking mechanism failure it does not strike the pipe.
- **NCP** is the number of Notes that are **Correctly Played**.
- **NCS** is the number of Notes that are detected/played in **Correct Sequence**.
- **NI** is the number of Notes that are:
  i. Not given in the audio file but played by the robot.
  ii. Given in the audio file but not detected by the robot.
- **P** is a penalty where 20 (twenty) points are deducted for each reposition and for each obstacle that the robot dashes against or displaces during the run.
- **B** is a bonus of 100 points awarded, when
  i. The task is completed within 10 minutes,
  ii. All the Notes given in audio file are played (a) correctly (maximum possible NCP scored), (b) as per the given sequence (maximum possible NCS scored) and (c) NCD and NI are zero.
  iii. No penalty is incurred.