Thirsty Crow

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1. Introduction

You must know, that a crow
Felt inclin'd, when she'd dined,
For some drink, being thirsty and hot;
But puddle or pool, her fever to cool.
Within twenty miles there was not

Then said she, "Woe is me!
Surely I must soon die,"
When lo! she espied, at a distance,
A pitcher or jug, alias pipkin or mug,
Which promised the needed assistance.

"A propos" said the crow,
"Now I think I shall drink,
And I shall be there in a minute;"
But alas! for the bird, still her draught was deferr'd,
For scarcely a cup-full was in it.

"How provoking! I'm choaking!"
Said she; "but let's see!
Sure I've thought of a project to gain it;
With stones from my bill the deep jug I will fill;
Then the water will rise, till my thirst it supplies."
—She did so, and so did obtain it.

Had this two-legged thing been as stupid as many,
Though dying for drink she would not have got any;
For the good that in life one most commonly gains,
Arrives not by luck, but by using one's brains.

- Jefferys Taylor

The story of Crow and Water Pitcher is one of Aesop's Fables which everybody has heard in their childhoods.

This year, e-Yantra Robotics Competition (eYRC-2018) aims to bring this age-old fable to life using Augmented Reality with it's theme - Thirsty Crow. A robot called Crow is deployed in a field where it has to pick up pebbles from different locations in an Arena and drop them at a specific location labeled as Water Pitcher. At the same time, on a virtual screen the story comes to life with the help of AR and special markers. 3D models of Crow, Pebbles and Pitcher (created by teams) are projected on an image of the arena.

Challenges in this theme include Image Processing, Graphics Processing using OpenGL, Microcontroller Programming, Blender Model Creation and so on.

The aim of the theme is to complete the task in the shortest time possible. The team which deposits all the pebbles in the water pitcher and projects all 3D models correctly will be declared the WINNER.

2. Arena Description

A 3D representation of an arena configuration is given in Figure 1.

a) The Arena is a simplified abstraction of a drought stricken field. It is in form of a hexagonal grid consisting of 19 **Cells**

b) Each Cell has 6 circular **Nodes** (one on each corner of the **Cell**). The grid consists of 54 such **Nodes.**

c) There are 2 **Start Zones** labeled **START-1** and **START-2**. Start Zones serve as start points for the robot.

d) In the centre of each Cell, there exists a **Compass** with 3 axes which are inclined at 60º with each other. The 3 axis are named **"1-1"**, **"2-2"** and **"3-3"**.

e) In the centre of each Cell, there exists a circular region labelled the **Deposition/Pickup Zone.**

f) There exists one Robot deployed in the Arena which is called **Crow.**

g) In the arena there can be upto 5 **AR_Objects** placed in the centre of any of the Cells.

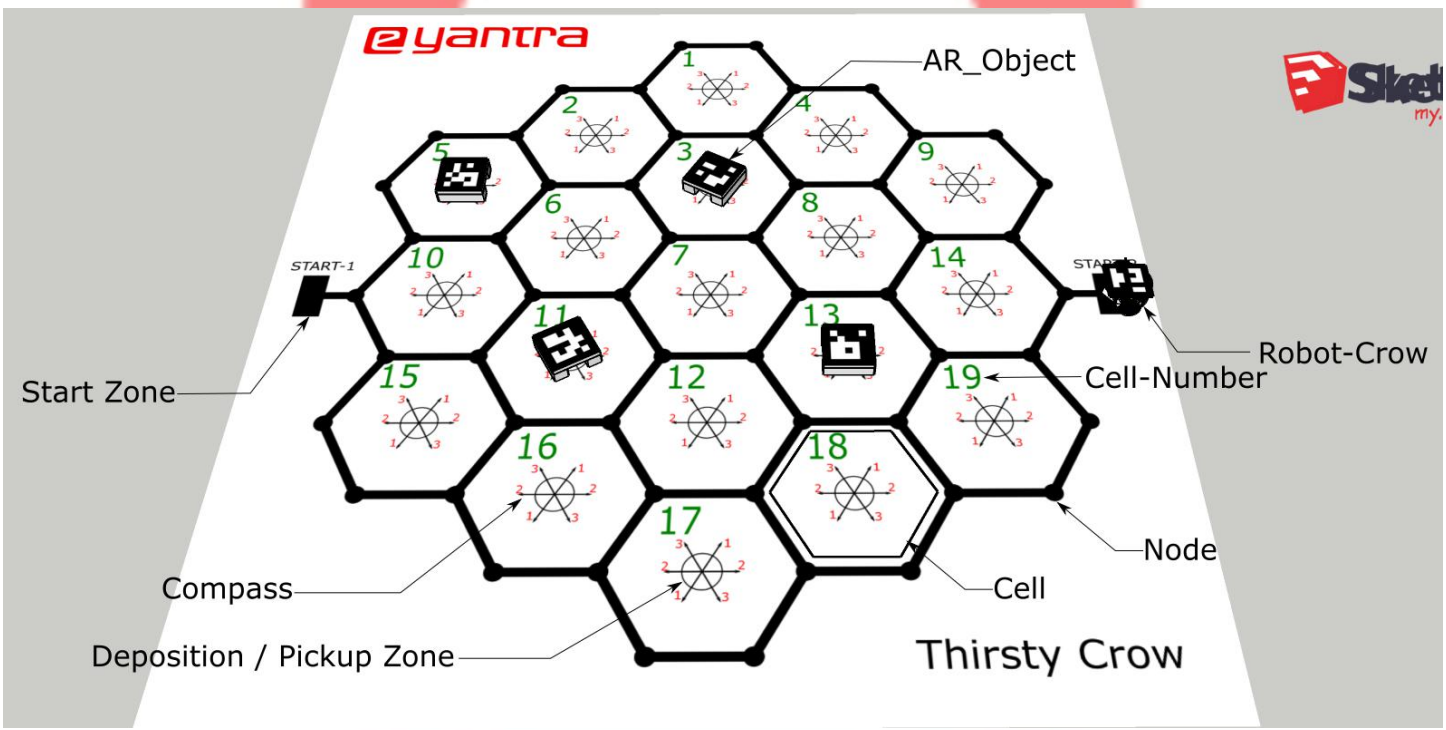


Figure 1: Arena 3D Representation

AR_Objects

Each of the Cells in the Arena may or may not contain an AR_Object. There can be upto a maximum of 5 AR_Objects in the Arena at one time. Fig 2 shows a 3D Representation of an AR_Object.

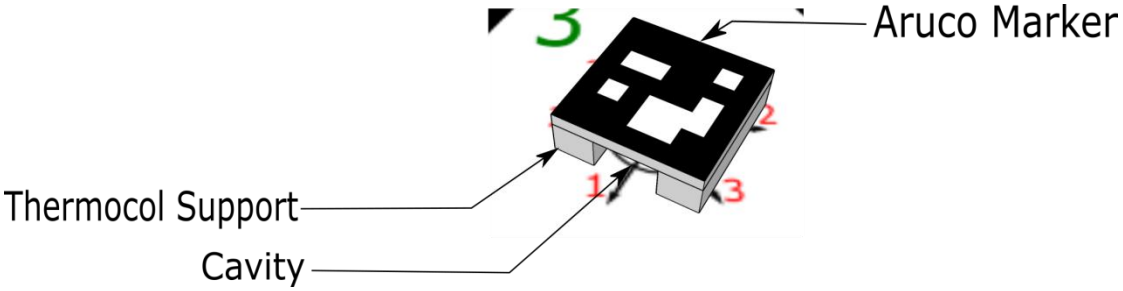


Figure 2: AR_Object 3D Representation

An AR_Object has 3 parts:

- **Aruco Marker -** It is an Aruco Marker with ID within range 0-9.
- **Thermocol Support -** There are 2 Thermocol Supports provided to raise the Aruco marker to a height of 7 cm.
- **Cavity -** Empty space below the Aruco Markers, between the two supports.

AR_Objects can be of 2 kinds:

i. **Pebble** - AR_Objects with Aruco Marker ID ranging from 1-9.
ii. **Water Pitcher** - AR_Objects with Aruco Marker ID 0.

AR_Object Orientation

AR_Objects can be aligned parallel to either one of the 3 axes ("1-1", "2-2" and "3-3") depicted on the compass. The alignment is explained in Fig 3.

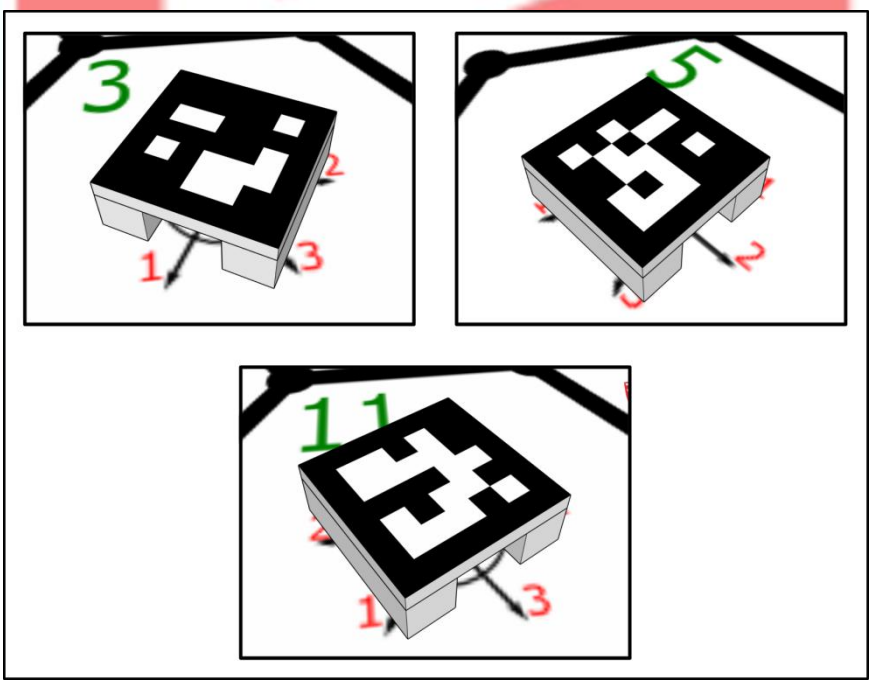


Figure 3: AR_Object Orientation

The first image in Fig 3 shows alignment along "1-1". Second image shows alignment along "2-2" and third shows alignment along "3-3".

Below each of the **Pebble AR_Object**, there are **Metallic Pebbles** (made of ferromagnetic material) placed (shown in Fig 4)

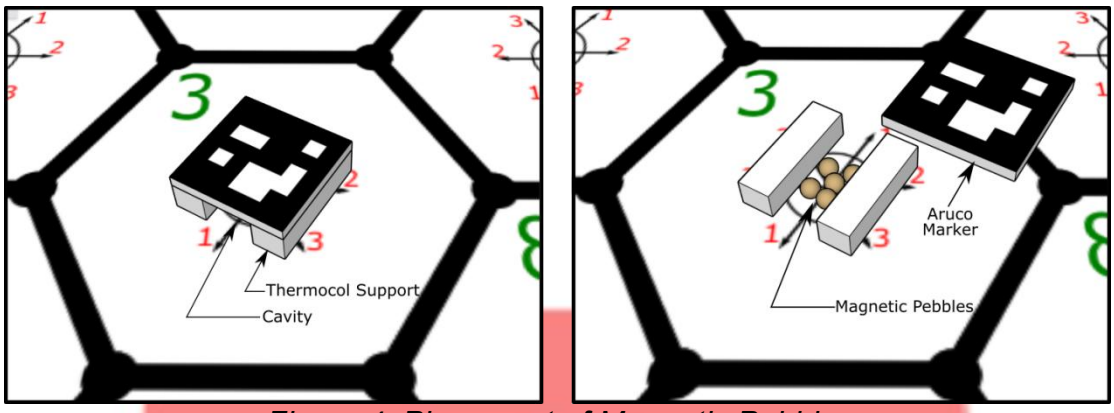


Figure 4: Placement of Magnetic Pebbles

Metallic Pebbles are of 2.5cm diameter and 4-5gm weight. There are 5 metallic pebbles placed inside the Deposition/Pickup Zone in the centre of the Cell.

Crow - Robot

In the arena there is one robot deployed called **Crow**. The Crow is equipped with an electromagnetic picking mechanism. An Aruco Marker with ID 10 is mounted on top of the robot.
Fig 5 shows a 3D representation of the robot.

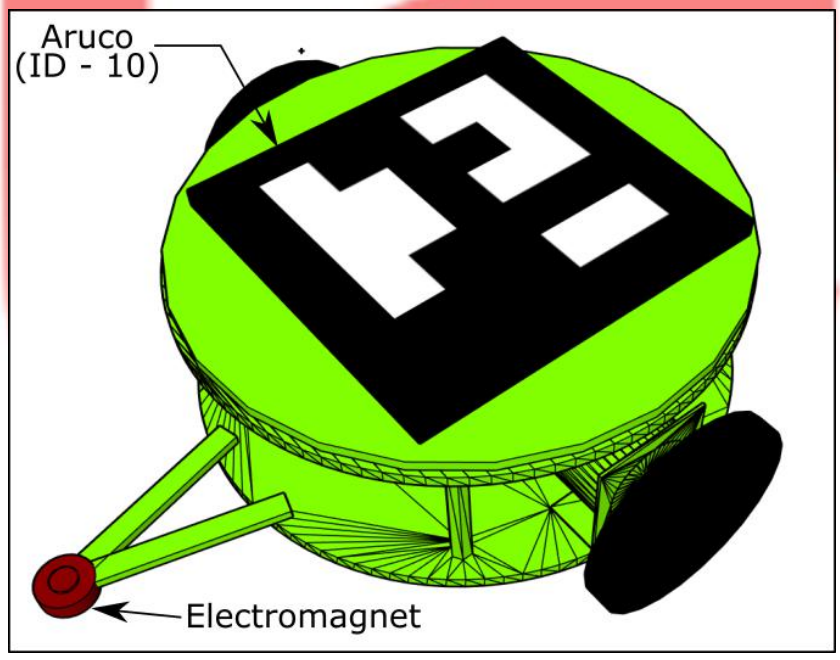


Figure 5: Crow Robot

3. Task Description

This theme is divided into broadly two parts

- Arena Traversal part
- Augmented Reality part

Arena Traversal

In this task, teams have to program the Crow-robot. In the arena there may be upto 4 Pebble AR_Objects and 1 Water Pitcher AR_Object. The AR_Objects can be oriented in any of the ways explained in the previous section.

The position (Cell Number) and orientation of all the AR_Objects are given as input to the robot.

Robot has to:

1. Start traversing arena from one of the START points given.
2. Visit each of the Pebble AR_Objects and pick up one magnetic pebble using electromagnetic pickup mechanism from the Deposition / Pickup Zone.
3. Drop the pebble in the Deposition / Pickup Zone under the Water Pitcher AR_Object.
4. After all pebbles have been deposited, robot has to sound buzzer for 5 seconds continuous until the end of the run.

Augmented Reality

Teams have to design 3D models of Pebbles, Water Pitcher and Crow in Blender. In augmented reality task, they will have to run a python script on a laptop. A webcam which is connected to the laptop, gives a sideways view of the whole arena.

Teams have to write a python script which:

1. Is run at the start of the run.
2. Identifies ID and position of AR_Objects placed in the Arena.
3. Projects 3D models of pebbles on the Pebble AR_Objects.
4. Projects 3D models of Water Pitcher/ Crow on Water Pitcher AR_Objects/ Crow.
5. 3D Models are animated to depict pickup and drop of magnetic pebbles in the arena.

3D Model Animation

In order to make the Augmented Reality experience more realistic, teams are required to animate the projection of 3D models on the arena.

- **Compulsory Animation** - Animations which are compulsorily required to be implemented by the teams in order to score points according to the scoring criteria.
  - Pebble Pick Up - When a magnetic pebble is picked up by the robot, 3D model of pebbles projected on the Pebble AR_Object should reflect the

change by showing the 3D model to be diminished.

- Pebble Drop - When pebble is dropped by the robot under the Water Pitcher AR_Object, 3D model of water pitcher should reflect the same by indicating rise in water level.

  Check this **link** for example demonstration.

- **Optional Animation** - Teams are encouraged to demonstrate their creativity in animating the 3D models of all the objects projected on screen.

Task Flow

The task flow for the theme is as follows:

1. Python script (written by teams) is started. The image of arena is projected on screen with 3D models being projected on top of AR_Objects.
2. Robot is placed (switched OFF) on either START-1 or START-2 according to configuration.
3. Once team is ready, robot is switched ON.
4. Robot traverses to each of the Pebble AR_Object locations and picks up the magnetic pebble from under the AR_Object.
5. During pebble pickup, augmented reality part should show Pebble Pickup animation.
6. After each pebble pickup, robot traverses to Water Pitcher AR_Object to deposit the magnetic pebble in the deposition/pickup zone under the AR_Object.
7. During pebble drop, augmented reality part should show Pebble Drop animation.
8. After all magnetic pebbles have been deposited under the Water Pitcher AR_Object, robot must sound the buzzer for 5 seconds to end the task.

4. Arena Preparation

Arena preparation has the following steps:

1. Printing the Flex
2. Setting up the Webcam
3. AR_Object Construction
4. Preparing the Magnetic Pebbles
5. Final Arena Setup

Printing the Flex

A Portable Document Format (.pdf) file containing the flex design was provided to teams in Task-2. Flex is to be printed according to the directions given in the Read Me file.

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 as it may be a fire hazard.

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

Dimensions of Arena are shown in Figure 6.

- Outer Dimensions of Arena are 8 feet x 7.5 feet (96 inch x 90 inch)
- Distance between the centre of 2 adjacent Nodes is 23cm
- Diameter of Node is 4cm
- Width of black line is 1.8 cm

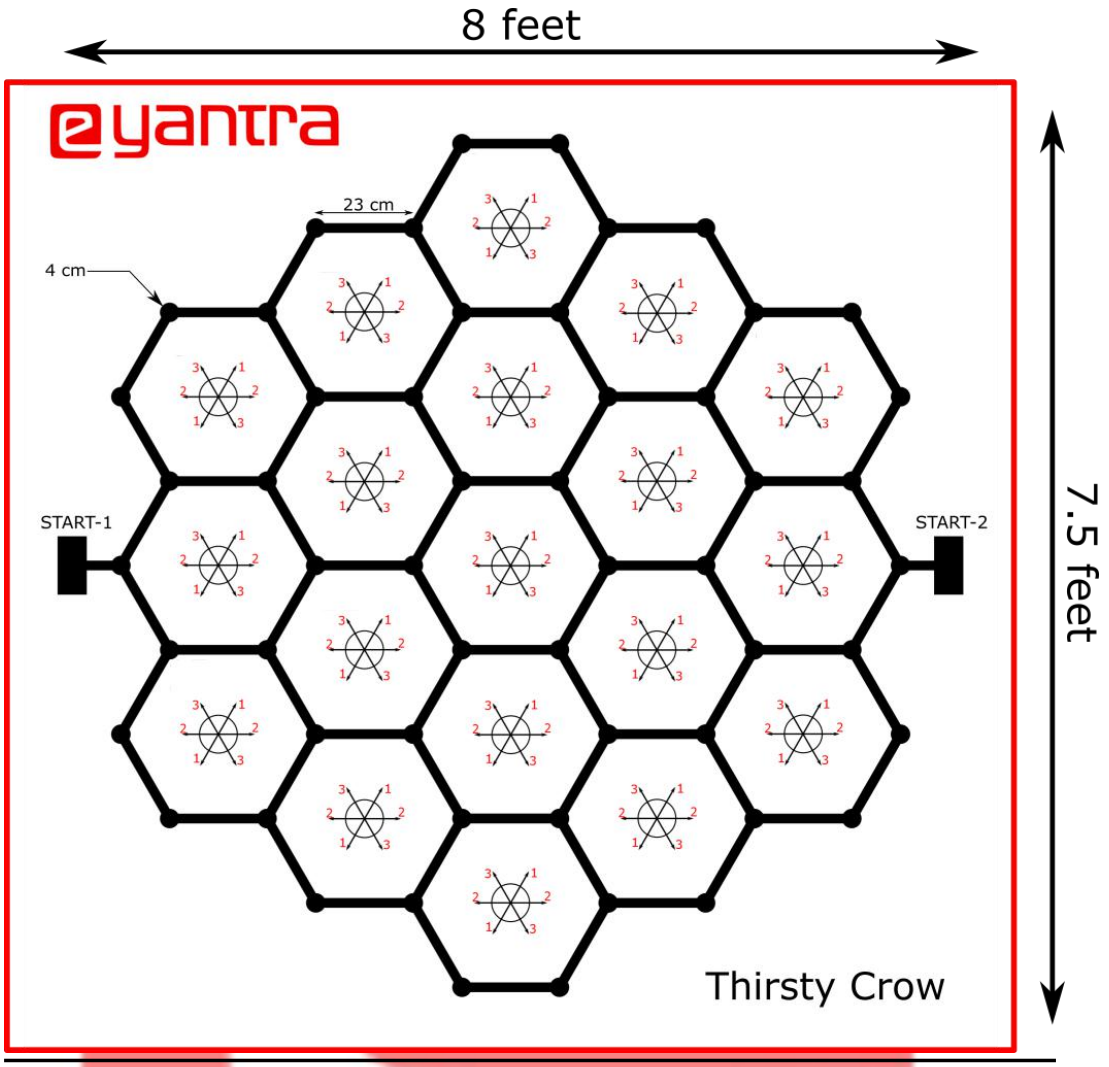


Figure 6: Flex Dimensions

Setting up the Webcam

In this theme, teams need to construct a stand for mounting the webcam.
The setup for mounting the webcam has been shown in Figure 7.

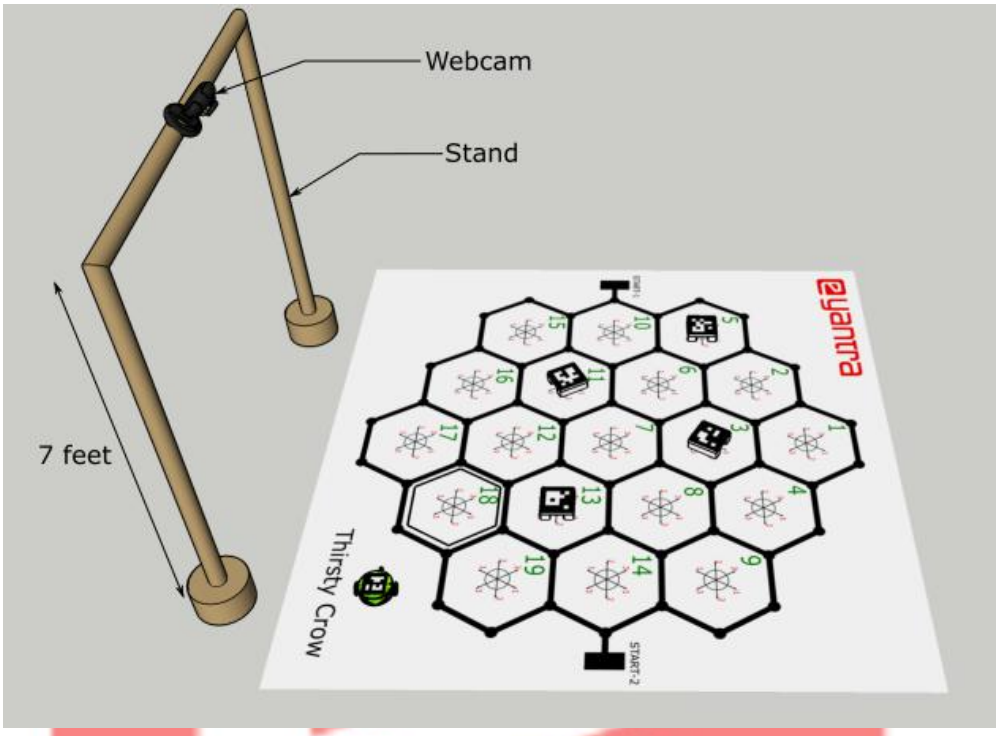


Figure 7: Webcam Setup

The height of the stand to be constructed is approximately 7 feet. It can be adjusted according to requirement.

AR_Object Construction

Total 10 AR_Objects need to be constructed for ArUco markers with ID 0-9. The dimensions of AR_Objects are given in Figure 8.

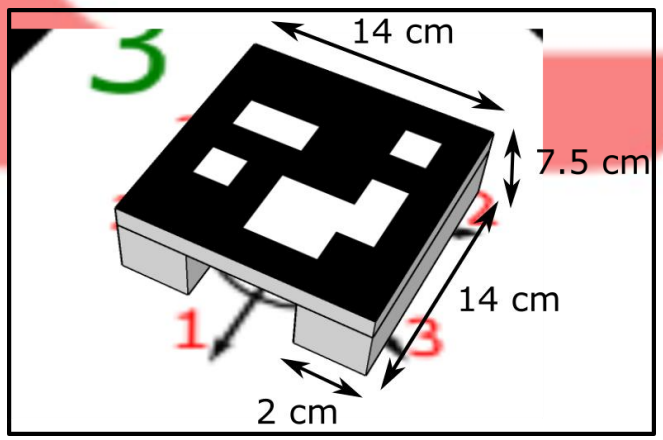


Figure 8: AR_Object Dimensions

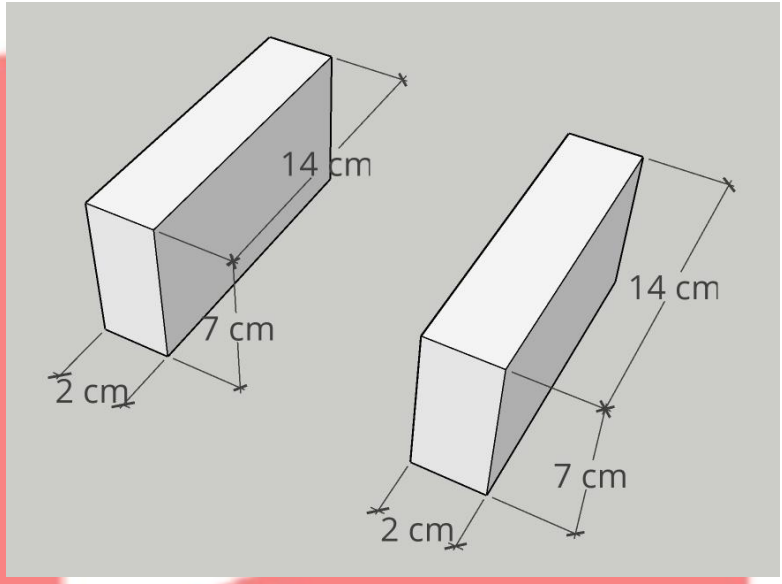
The length and breadth of ArUco marker is 14cm. The height of AR_Object is 7.5cm. The AR_Object is supported by 2 thermocol support structures each of dimensions 14 x 2 x 7.5 cm

Materials required to construct the AR_Objects:

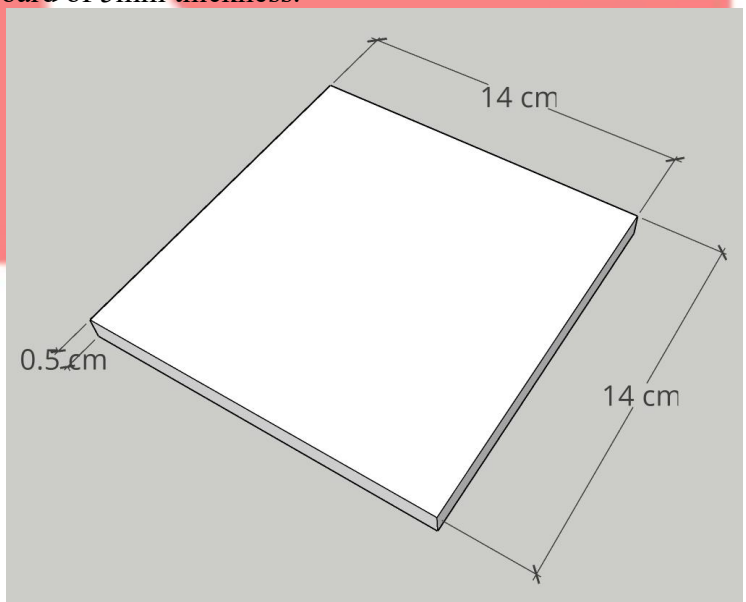
1. Thermocol Sheets
2. Sunboard
3. A4 sheets for printing the ArUco markers

Steps to be followed:

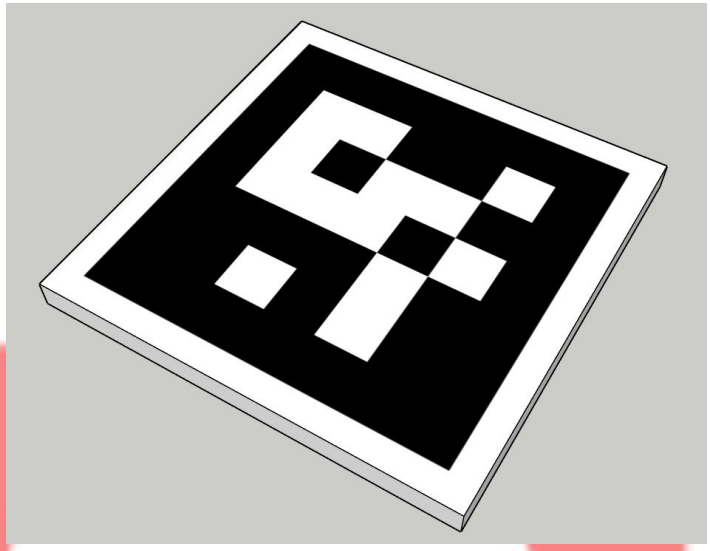
1. Cut out block of 14cm x 7cm x 2cm from thermocol sheet.



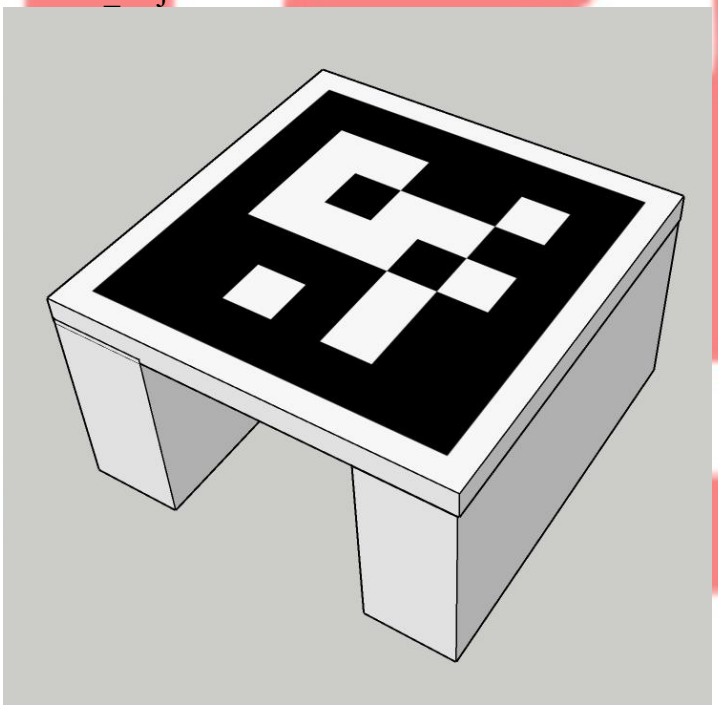
2. Cut the Sunboard into square sheet of dimensions 14cm x 14cm. Use Sunboard of 5mm thickness.



3. Paste the ArUco marker on the Sunboard using glue or double sided tape.



4. Place the ArUco marker on the 2 thermocol blocks to create the AR_Objects



Preparing the Magnetic Pebbles

Magnetic Pebbles can be prepared using steel wire of 16 gauge and aluminium foil. Take 10cm long steel wire and wrap it into a coil as shown in Figure 9(a). After that cover the coil of wire using aluminium foil as shown in Figure 9(b).
The diameter of the magnetic pebble should be 2.5cm and weight should be approx 4-5gm.

Figure 9(a)

Figure 9(b)

Figure 9: Pebbles

Final Arena Setup

A sample arena configuration is given in Table 1 and Table 2.

AR_Object Type	ArUco ID	Cell No.	Orientation Axis
Water Pitcher	0	5	2-2
Pebble	1	3	1-1
Pebble	2	11	3-3
Pebble	3	13	2-2

Table 1: AR_Object Sample Configuration

Robot- Crow	
Aruco ID	10
Position	START-2

Table 2: Robot Start Position

The Arena configuration is shown in Figure 10.

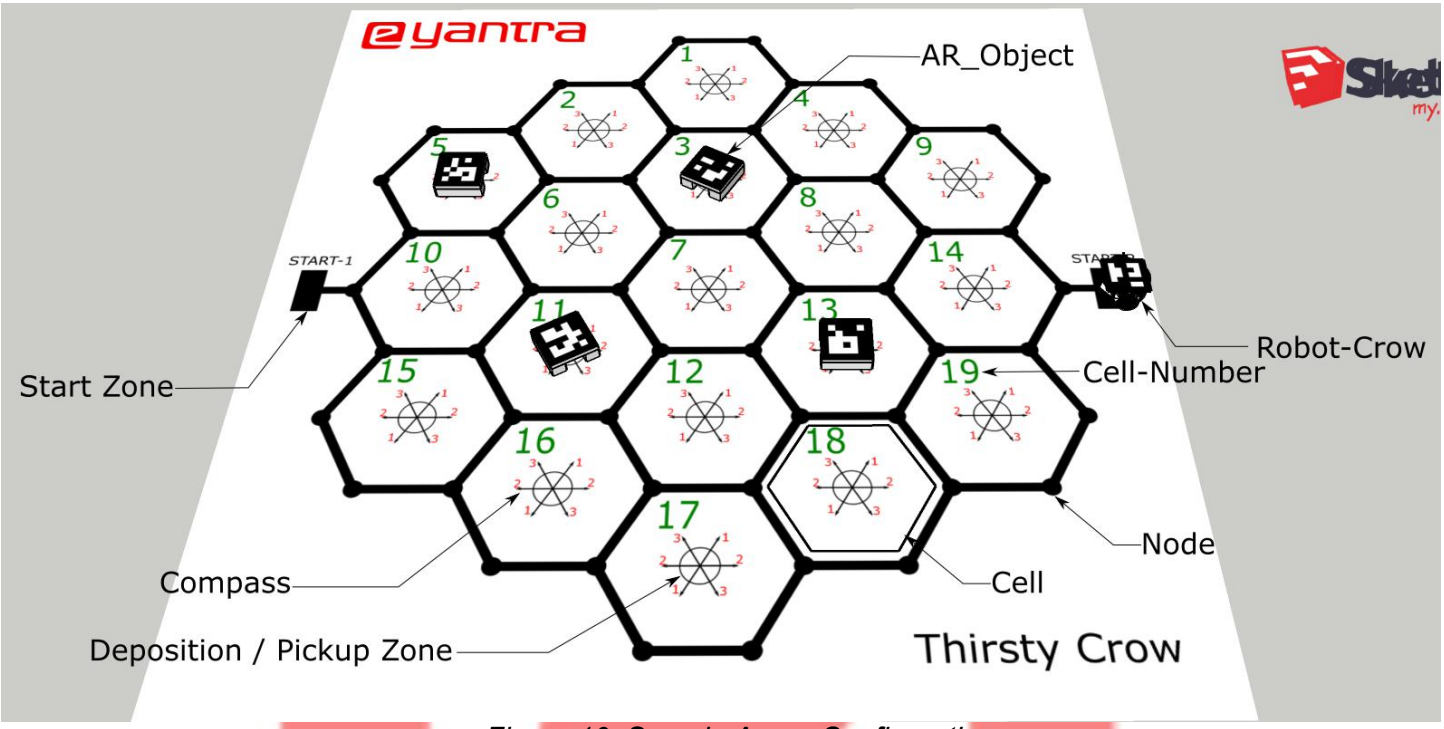


Figure 10: Sample Arena Configuration

The Arena Configuration is given in form of a dictionary as input to the python script written by the teams as given in Table 3.

CODE

`arena_config = {0: ("Water Pitcher", 5, "2-2"), 1:("Pebble", 3, "1-1"), 2:("Pebble", 11, "3-3"), 13:("Pebble", 13, "2-2")}`
 	
`Robot_start = "START-1"`

Table 3: Code to initialise configuration in python script

Note : Arena shown in Figure 10 is just for illustration. Placement of AR_Objects and starting position of robot may vary.

5. Hardware Specifications

a) Use of Components

- All the participating teams must only use the components that were sent to them in the kit. Only one set of components given in kit are allowed per team.
- You can use additional actuator with the permission of e-Yantra Team.
- The robot should be completely autonomous. The team is not allowed to use any wireless remote or any other commuincation protocol for manual control of the robot.

- Teams are allowed to use any kind of raw material to build the chassis of the robot as well as the electromagnet mechanism.
- Teams cannot use any readymade mechanism for the electromagnetic pickup mechanism.

b) Power Supply

- The robot can be powered through Li-Ion battery power supply. Only the batteries that have been provided with the kit may be used.
- Teams cannot use any other power source to power the robot.

Note: No other expansion or microcontroller based board may be attached to the ATMEGA2560.

6. Software Specifications

- e-Yantra has provided all the teams with ATMEL STUDIO 6, a free software for programming AVR microcontrollers. Participating teams are free to use any other open source IDE to program AVR microcontroller.
- For Python programming, participants may use the default Python IDE (IDLE). They are free to use any other IDE as per their requirements.

7. Theme Rules

1) Maximum time allotted to complete the task is 5 min. A maximum of two runs will be given to a team (the better score of the two runs will be considered as the team's score). A maximum of 2 Re-Positions (explained below) will be given for each run.
2) Team must use XBee modules to communicate between the robot and the laptop running the python script.
3) Ten minutes before start of run, teams are given the arena configuration and are required to enter the position of AR_Objects and robot in the python code.
4) At the start of the run, the robot is switched OFF and kept at either START-1 or START-2 according to configuration. Once this setup is completed. Python script execution is started and then the robot is switched ON. **Timer is started only when robot is switched ON.**
5) Once the run starts, human intervention is not allowed. Any human intervention during the run is considered a re-position.
6) A run ends and timer is stopped if the time limit of 5 min for completing the task is exhausted or when the following conditions are satisfied:
   a) All of the pebbles have been picked up from the Pebble AR_Objects and dropped at the Water Pitcher AR_Object.
   b) Robot has sounded the buzzer for 5 seconds indicating the end of Task.
7) Task will be considered incomplete and time will be considered maximum if atleast one pebble hasn't been successfully deposited and buzzer hasn't been sounded or if they have exhausted all their repositions.

8) Second run starts once again by resetting the score, timer and arena. The score of both runs is recorded and the best score of the two runs is considered as the team's score.
9) For the second run, teams are not allowed to make any software changes. Hardware changes are allowed.
10) Participants are not allowed to keep anything inside the Arena other than the robot.
11) The robot is only allowed to pick up a single magnetic pebble at a time.
12) The time measured by reviewer is final and will be used for scoring the teams.
13) Time measured by any participant by any means is not acceptable for scoring.
14) The robot is not allowed to make any marks while traversing the Arena. Any robot found damaging the Arena will be immediately stopped; re-position will be allowed as per rules. The final decision is at the discretion of the e-Yantra team.
15) A pebble is said to be successfully picked up if the following conditions are satisfied:
    a) Magnetic pebble is picked up using electromagnetic pickup mechanism from below the Pebble AR_Object
    b) AR animation is shown during pebble pickup
16) A pebble is said to be successfully dropped if the following conditions are satisfied:
    a) Magnetic pebble is dropped below the Water Pitcher AR_Object
    b) AR animation is shown during pebble drop.

8. Re-Position Rules

- While traversing the Arena, if the robot strays off the black line, a member of the e-Yantra team will place the 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 line and the white line sensors are above the Node. This is termed as **Re-position**.
- During Re-position, the timer will not stop and robot will not be switched off.
- Teams are allowed a maximum of 2 Re-positions. The run ends and timer is stopped if the robot requires a Re-position after 2 Re-positions have already been exhausted.
- 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.

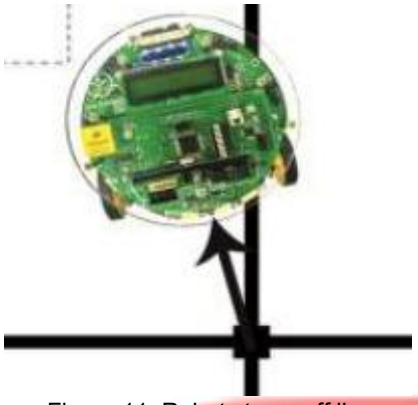


Figure 11: Robot strays off line

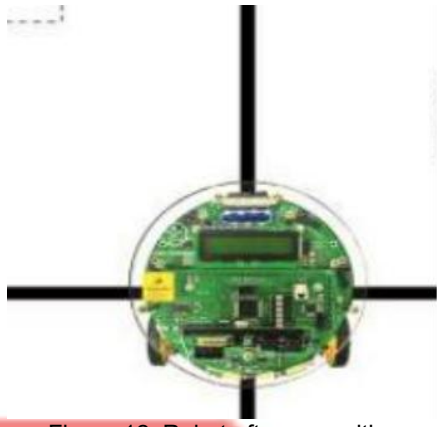


Figure 12: Robot after re-position

9. Judging and Scoring Criteria

- Best score of the two runs for a team will be considered as final score of the team.
- The team's total score is calculated using the formula:

Total Score = (300-T) + CPP*100 + CPD*100 + CARP*50 + CARA*100 - P*30 + DB + B

- **Time - Total time (in seconds) to complete the task.**
- **CPP - Correct Pebble Pickup**
  If robot picks up magnetic pebble from under the Pebble AR_Object correctly using the electromagnetic pickup mechanism.
- **CPD - Correct Pebble Drop.**
  If robot drops magnetic pebble under the Water Pitcher AR_Object correctly.
- **CARP - Correct AR Projection**
  At the start of the run, if all AR_Objects are successfully and correctly detected and 3D models of Water Pitcher and Pebble are projected properly on the AR_Objects, then it counts as Correct AR Projection.
- **CARA - Correct AR Animation**
  When magnetic pebble is picked up and dropped, 3D model of object should show corresponding animation of pebble pickup and drop. This will count as correct AR Animation.
- **P - Penalty**
  Penalty is incurred in the following cases:
  i. Touching or Colliding with AR_Objects placed on the Arena.
  ii. Going off the Arena.
  iii. If Re-Position is taken by team.
- **DB - Design Bonus**
  Design bonus is given by judges and will be awarded to teams for

showcasing their creativity in designing the 3D Models in Blender and implementing AR animation during the commencement of their run. Design Bonus is given out of 100 points.

- **B - Bonus**

  Bonus of 100 points is awarded to a team if they complete the task perfectly i.e
  - All magnetic pebbles are picked up and dropped correctly.
  - All AR_projections and animations have been displayed correctly.
  - There are no penalties incurred during the traversal.
  - Task is completed within 5 minutes.

ALL THE BEST !!