e-Yantra Robotics Competition (eYRC 2019-20)

Task 3.1 – Supply Bot Questionnaire

Team ID - SB#64

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Scope and Preparing the Arena

Q1. a. State the scope of the theme assigned to you.
(5)
< Teams should briefly explain in their own words the theme assigned. What in your opinion is the purpose of such an application?
Answer format: Text, Word - limit: 100 words>

The theme is about disaster management(flood relief). Theme arena is abstracted view of real world which has state, capital, districts, villages, lakes, roads and forests. Robot has to move along whiteline(highway). Camera which is placed above, emulates satellite in real world, is used to detect relief aids, track robot using Aruco, instead of extracting features. Purpose of building this prototype is that we will have the ability to make a complete robot by using technologies like computer vision, machine learning which would be really helpful in during disaster times and help people within short time.

b. Upload the Final Arena Images. **(20)**

< Prepare the arena according to the steps given in Section 3: Arena, of the Rulebook. Please follow the arena configuration shown in "Figure 1: Basic Elements of the Arena" of the rulebook.

Configuration for Capital and Relief Aid are similar to that mentioned in the Test_Setup_Read_Me.pdf document in the Task 3.2 folder and as given in the table below:

Node Type	Node Number
Capital	1
Medical Aid	3
Food Supply	6

Take a single photo of the completed arena such that the entire arena along with arena components such as Capital, Relief Aids, e-Yantra logo, primary cities, and all basic elements of the Arena etc., are clearly visible in the photo.

Answer Format:The image file should be pasted in the space provided for it in this document here below [the image should be (maximum) of 256x256 in jpg format]:

Building Modules

Q2. Identify the major components required for designing the robotic system for the theme assigned to you. (5)

< Teams should classify the components into various categories: mechanical systems, electronic systems etc. and mention how these units will be used in the theme. You may draw diagrams/figures to illustrate your answer.

Answer format: Bulleted form

1. Component 1
2. Component 2
3. Component ….etc. >

Mechanical systems:

a. Wheels : Pair of wheels along with castor wheel are used for robot movement.

b. Chassis : Which includes a bottom plate, top plate which form the body of the robot.

c. Geared DC motors : DC motors drive wheels of the robot, these are powered using 11.1V 2200mAh battery. DC motor is also used for hitting mechanism.

d. Mechanical structure for hitting : Which consists of a DC motor and a square plate for hitting.

Electronic systems:

a. Motor Driver : If we directly connect the DC motors to the output of the Arduino Uno board, it may not provide sufficient current (40-80 mA) to drive the DC Motors. Thus Motor Driver acts as a bridge between the DC motors and arduino uno board as current amplifier to provide sufficient current for DC motors.

b. 11.1V 2200mAh Battery Pack : Provides power supply to components.

c. Buzzer : Buzzer module is used for making beeps(sounds).

d. Arduino Uno : It is a microcontroller board based on the ATmega328P, the microcontroller is programmed using Embedded C in Atmel Studio.

e. USB Camera : USB camera acts as a satellite which is placed above the arena 8 to 10 feet takes live video of arena and does coin detection and other detection using image processing algorithm.

f. Jumper wires : These are used for making the interconnections.

g. Whiteline sensor : This is essential for the robot traversal along the white highway path.

h. XBEE modules : These are used to achieve wireless communication between robot and system(laptop).

i. STK programmer : For loading the program from system to microcontroller chip.

j. Potentiometer : It is a variable resistor. It is used to adjust the brightness of white line sensor's LED.

Power Management

Q3. a. Explain the power management system required for a robot in general and for the theme assigned to you in particular.
(5)

< Teams should mention the power requirement of their system with current rating and voltage requirement. You can mention the number of batteries you think your system actually needs to use in your system with necessary justification. You can also draw some diagrams/figures to illustrate your answer.
Please provide the answer in your own words.
Answer format: Text, Word-limit: 100 words>

Power consumption of real robot consists of providing energy to it's sensor system, motion system and control system. When it comes to our robot, energy is required for

Component	Operating voltage	Current
Whiteline sensor	5V	around 60mA-120mA
DC motors	12V	around 30mA-4A
Buzzer	3.3V-5V	around 5mA-15mA
XBEE modules	3.3V	around 33mA
Arduino UNO	5V	around 20mA-50mA

So totally one require around 2.10A to 4.50A of current, as single battery can supply around 2.2A-4.4A(max) of current for one-hour, so single battery is sufficient to power all the components of the robot.

b. Can there be a single power supply for your robot? - Yes/No/Don't know. Please elaborate/justify your answer choice.

(5)

< Support your answer.

Answer format: Text, Word - limit: 200 words >

Yes, we can use single power source for the system for robot operations.
white-line sensor operates at 5V, requires around 60mA-120mA of current.
DC motors which operate at 12V, require around 30mA-900mA of current.
Buzzer which operate at 3.3V-5V, requires around 5mA-15mA of current.
XBEE modules which operate at 3.3V, requires around 33mA of current and Arduino which operate at 5V, requires around 20mA-50mA of current. So totally one require around 2.10A to 4.50A of current, as single battery can supply around 2.2A-4.4A(max) of current for one-hour, so single battery is sufficient to power all the components of the robot.

Design Analysis

Q4. Teams have to design a robot which traverses an arena following a given path and simulate dispatching required Relief Aid.

a. How will your robot traverse the state represented by the Arena given in the rulebook?

(5)

< Explain your path planning technique(s). Clearly specifying the hardware components, inputs and outputs for your technique. You can explain multiple techniques.
Word-limit: 300 words. >

The robot traverses the arena by sensing the white line using a 3 channel white line sensor. The actuators used are DC motors and castor wheel.

Input : 3 channel sensor values.

Output : Left or Right or Straight movement.

White line path planning algorithm :

- If the left, center and right sensor readings represents black, white and black respectively then, both motors will be running and bot moves in straight direction.
- If all the sensor values represents white and if the city has relief aid (those details are described in the solution of Q5 a.) then the bot stops.
- If left, center and right sensor readings represents white, black and black respectively then the bot turns left ie) left motor will be turned off.
- If left, center and right sensor readings represents white, white and black respectively then the bot turns left ie) left motor will be turned off.
- If left, center and right sensor readings represents black, black and white respectively then the bot turns right ie) right motor will be turned off.
- If left, center and right sensor readings represents black, white and white respectively then the bot turns right ie) right motor will be turned off.

During implementation potentiometer values will be adjusted to differentiate black and white readings. Since the fast movement of bot affects the accuracy of circular motion ie) the motion of bot won't be an accurate circle, the speed of the motors will be adjusted to get a good circular motion.

Hardware Components :

1. 3 Channel White line sensor.
2. DC motors.
3. L298 Motor driver.
4. Arduino UNO.

b. If you were to implement this theme in the real world scenario, what would be the actuators you will employ? Explain their purpose.
(3)

< Justify your answer by stating the advantage/s of the chosen actuator/s over others. Actuators that will be required for movement, planting mechanism, etc.
Answer format: Text, Word - limit: 200 words>

Actuator is a component of machine which is responsible for movement. Different actuators which may be used in making the real world robot are Hydraulic, pneumatic, electric, linear, series elastic and pneumatic air muscle actuators.

a . Hydraulic actuators :

A hydraulic actuator consists of cylinder or fluid motor that uses hydraulic power to facilitate mechanical operation.

b. Pneumatic actuators :

A pneumatic actuator converts energy formed by vacuum or compressed air at high pressure into either linear or rotary motion.

c. Electric actuators :

An electric actuator may provide the actuation force/torque in one of several ways such as electromechanical, electro hydraulic or hydraulic accumulator.

d.Air muscles:

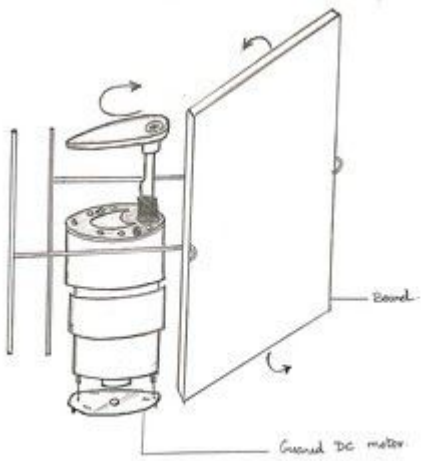
Pneumatic artificial muscles, also known as air muscles. So if we implement our theme in the real world, it is better to use the combination of hydraulic, electrical, Pneumatic artificial muscles(**PAM**) because Hydraulic and electric actuators can be made to act in a compliant manner through the use of relatively complex feedback control strategies. PAM's are very lightweight because their main element is a thin membrane. This allows them to be directly connected to the structure they power, which is an advantage when considering the replacement of a defective muscle.

c. What kind of mechanism will you design to ensure dispatch of Relief Aid? (10)

<Explain your mechanism. You can put hand-made drawings/software based designs, as well (maximum 2 images/drawings of size 256x256)>

The mechanical structure for hitting is shown in the figure below. The mechanical structure consists of a geared DC motor and a small square board. The square board and DC motor are attached to the robot. The shaft of the DC motor is attached with a blade. So when the DC motor rotates, the blade will hit the board one time per rotation. This will make the board to flap when the motor rotates continuously, which will hit the coin.

Friction between the coin and surface(arena) plays a significant role for accurate landing of the aids. So for dispatching the aids to center white zone the robot should be trained on various surfaces. So what we will do is, first we will calculate the distance between center of white circle (inner one) and center of coin and try hitting the coin on different surfaces keeping that destination distance as same as the distance between center of coin and center of inner white circle so that hitting mechanism works on any surface(as different materials are used for making the same arena). The learned force will be used to hit the first coin in the arena. Suppose that in the worst case the coin landed somewhere else instead of inner white region or orange region, then we will see where the coin landed using camera, then we will adjust the force accordingly so that the coin lands on inner white region or orange region. So in this way the robot learns the required force to hit so that the coin lands on the inner white region or orange region perfectly. So for the purpose of hitting we are going to use one more extra **geared DC motor**. Force will be adjusted by changing the RPM of DC motor ie) if the RPM is low then the force will be less, similarly if the RPM is high then the force will be more. So in subsequent hits the mistake will be corrected.



Environment Sensing

Q5. a. Explain how you will use the given USB camera to decide the course of traversal. **(5)**

< Team should explain in detail how they will use the mounted USB camera to sense the environment associated with the theme. Explain the role of Camera in providing important feedback during the Run.
Answer format: Text, Word - limit: 300 words>

First detection of aruco marker, numbering of cities and detecting relief aids with location is done by camera.The planning of path for dispatching is described below.

Input : Numbered cities, location of aids and aruco marker.

Output : An array of length 6 or 4(if capital is affected).

eg.) [‘a’,‘2’,‘c’,‘3’,‘a’,‘4’]
a - Anticlockwise.
c - Clockwise.

Note : Counter variable is used to count the number of cities the bot traverses. Counter is set to zero initially and after each dispatch.

Number of cities the bot traverses is counted ie) if all three readings of sensor represents white then counter is incremented.

So the command according to above example is :

- Move anticlockwise and stop when the counter value is 2 and dispatch.
- Move clockwise and stop when the counter value is 3 and dispatch.
- Move anticlockwise and stop when the counter value is 4 and dispatch.

In case if capital is affected then array size is 4 ie)capital will be served first.

Algorithm :

Our path planning is based on the angle ie) if the angle between two relief aid and center white circle is less, then the coins are close and vice versa. Similarly, if the angle between aruco marker(bot), coin and center is less, then the robot is close to the relief aid and vice versa. So the algorithm will first calculate the path for red coin or capital(if affected).

Next, from current position, the next closest aid will be detected based on angle and will be appended (direction and city count) to array and so on. So an array of size 6 will be generated if capital is not affected else 4. This will be sent via XBee.

Camera feedback is used for force planning after each dispatch(described in Q7 solution).

b. What other sensors will the team use to aid their robot to complete its task successfully? (5)

< Answer format: Bulleted form

1. Sensor 1
2. Sensor 2
3. Sensor 3 ….etc. >

In the case of our robot, no other extra sensor is required for completion of the task, expect the given white-line sensor for path following along white highway, but if we implement this in the real world, one require various sensors like

1. Light sensors like photoresistor for detecting light.
2. Sound sensor for speech and voice recognition.
3. Proximity sensors like ultrasonic sensors for detecting the objects nearby.
4. Acceleration sensor for measuring the acceleration and tilt.
5. Gyroscope for maintaining the stability.
6. Motion sensor for detecting motion of live object.
7. Navigation or positional sensors like GPS and digital compass etc which are used to approximate the position of the robot.

Testing your knowledge (Theme Analysis and Rulebook-related)

Q6. a. If a team has a condition such as that shown in figure 1 below compute the possible bonus, penalty if any and the maximum marks the team can score. Elaborate on bonuses or penalty if any - why it will be applicable? Also elaborate the conditions in which the team will score a maximum in this situation (5)

Figure 1: Overlay Example

< Analyse the formula provided in the rulebook and explain how it will affect the score.
Answer format: Text/Bulleted form >

Note: disregard the unequal shape of the coins, there are 2 green and 1 red coins in the Arena

The team will get 2 coin bonus(CB) if the robot has hit Red coin(medical aid) first, otherwise team will get 1 coin bonus(CB) and two green coins, will NOT get any additional points or bonus but these 2 green coins will get points for NH for correct hitting and CD for correct city detection,similarly red coin will also get both NH and CD,team will get run bonus i.e B because penalty has NOT occurred. According to the rule book total score is

(TT - RT) + (NH*100) + (CD*30) - (P*40) + (CB*75) + B

So here,
NH = 3
CD = 3
P = 0 as NO penalty has occurred (best possible case).
CB = 2 assuming that red coin (medical aid) is hit first.
B = 0 as all the coins didn't land in village or white zone.
And total time **TT** = 480 seconds.
So upon substitution we get
Total score = 1020 - RT

So, the total score of a team will depend on the running time i.e) RT of the algorithm which the team writes which involves :

a.) Image processing part i.e) for correct detection of coins which typically might take approx. around **15 seconds**.

b.) Deciding the course of traversal using USB camera and sending the signal from XBEE attached to laptop to XBEE attached to robot which typically may take running time around **10 seconds** (for all XBEE communication).

c.) Path planning part i.e) bot traversing along whiteline and dispatching the coins which typically might take **14 seconds** (for first green coin), **28 seconds** (for next green coin), assuming that the robot is placed at the city where red coin is placed which is the best case possible, and total **3 seconds** of beep sound after servicing cities (beeping twice before

servicing any city time is very small and can be neglected), **5 seconds** of long beep after servicing all cities.

RT = 15 + 10 + 14 + 28 + 3 + 5 = 75

So the total score is **1020 - RT = 1020 - 75 = 945**, total maximum score of the team in the given situation is **945**.

b. Name the different elements in the Arena.

(3)

<Answer format: Bulleted form
1:
2:
3:…etc. >

1. State.
2. Capital.
3. Districts of state.
4. Cities within the district.
5.Villages of district.
6. 2 way intrastate highway.
7. Lake.
8.Forest area.
9. Dead zones.
10. Relief aids such as medical aids and food aids placed on the arena.

c. If there are all 3 Food Supply (Green Color) Markers placed on the Arena, how many CBs can you have maximum for a run?
(3)
< Answer format: Text
Word-limit: 200 words >

If three food supplies i.e) green coins are placed on the arena, team can get a maximum of 3 coin bonus (CB) , if all the three hits by the robot lands in the inner white circle.

d. What are the different conditions that indicate the end of a run?
(3)
< Explain in your own words. Answer format: Bulleted form, word-limit: 300 words
Condition 1:
Condition 2:
Condition 3:…etc. >

Condition 1 :
If the robot is NOT able to completely dispatch the relief aids to the village in the stipulated amount of time given by eyanta which is 480 seconds .

Condition 2 :
A long beep of 5 seconds which indicates that robot has completely dispatched the relief aids to villages.

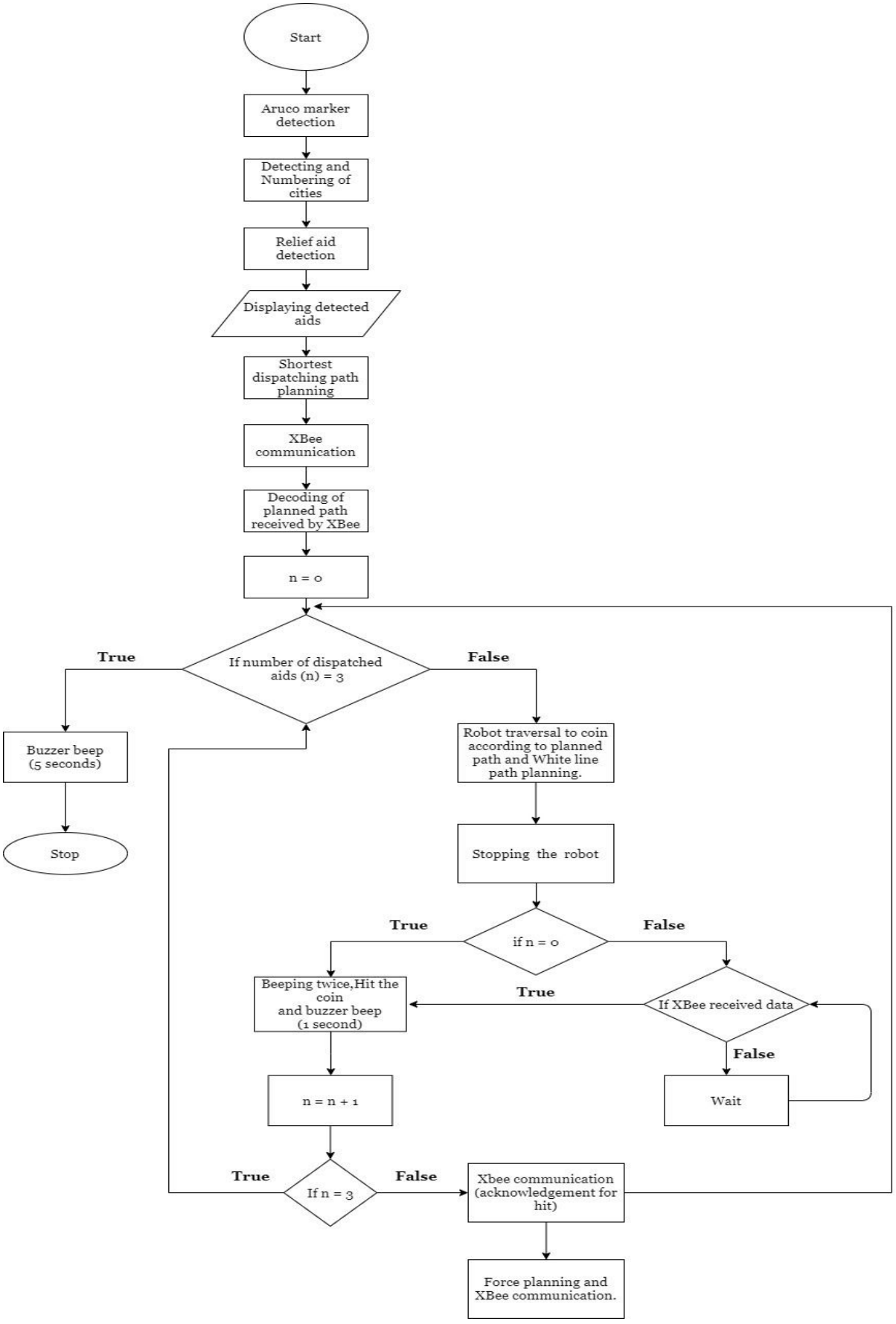
Condition 3 :
In the run if the robot goes off the whiteline and thus requesting for the restart again.

Condition 4 :
If the team has already exhausted its available restart, and requires another restart; in this case time will be considered maximum (480 seconds).

Algorithm Analysis

Q7. Draw a flowchart illustrating the algorithm you propose to use for theme implementation.
(10)

< The flowchart should elaborate on every possible function that you will be using for completing all the tasks in the assigned theme. Follow the standard pictorial representation used to draw the flowchart.
Answer format: Text, Word-limit: 1000 words >


Start
Aruco marker detection
Detecting and Numbering of cities
Relief aid detection
Displaying detected aids
Shortest dispatching path planning
XBee communication
Decoding of planned path received by XBee
n = 0
If number of dispatched aids (n) = 3
True
False
Buzzer beep (5 seconds)
Stop
Robot traversal to coin according to planned path and White line path planning.
Stopping the robot
if n = 0
True
False
Beeping twice,Hit the coin and buzzer beep (1 second)
If XBee received data
True
False
n = n + 1
Wait
If n = 3
True
False
Xbee communication (acknowledgement for hit)
Force planning and XBee communication.

1. **Start :** Script starts running.

2. **Aruco marker detection :** Detecting aruco marker in the arena and that city is considered as capital. [Python]

3. **Detecting and numbering of cities :** Detecting the cities and numbering them in the clockwise direction from capital. [Python]

4. **Relief aid detection** : Detecting relief aid which are present in the inner black ring of arena.[Python]

5. **Displaying detected aids :** Displaying detected relief aids in python IDLE's console.

6. **Shortest dispatch path planning :** After detecting relief aids the shortest path to dispatch the relief aids will be planned and shortest path to all the three aids will be planned at once as discussed in question **5 a.)** .

7. **XBee communication :** The planned path is sent to the bot. The XBee module in the bot will receive the message.

8. **Decoding of planned path received by XBee :** Decoding the path ie) 'a' in the array refers to anticlockwise and 'c' refers to clockwise.[Embedded C]

9. **n = 0 :** Here n is a variable for counting the number of dispatched relief aid. So initially n is initialized to zero.

10. **If number of dispatched aids (n) = 3 :** Since n is initialized to zero above this will be false in the beginning.

11. **Robot traversal to coin according to planned path and white line path planning :** Now the bot will traverse to the first coin which is planned ie) first two entries in array eg) 'a', 4. Here 'a' refers that the bot should move in anticlockwise direction. Here the movement of the bot along the white line is discussed in Q4 a.). Another separate counter variable will be initialized to keep track of the number of cities the bot crosses. That counter is initialized with zero. If all the three reading of white line sensor represents white then the counter variable is incremented. So according to the above example, if the counter value is 4, then the bot will stop at that city.[Embedded C]

12. **Stopping the robot :** Robot stops when it reaches the corresponding destination as mentioned above.

13. **If n=0 :** In the initial phase n will be zero since no relief aid has been dispatched. Hence the program flow goes to the left branch.

14. Beeping buzzer twice and Hitting of coin and buzzer beep(1 second) : So here the buzzer beeps twice and the bot will hit the coin with certain force. Since friction matters, this force is decided by testing the bot in various surface and the value of force is decided(experimental value). So the first relief aid is dispatched with this force.
[Embedded C]

15. n = n + 1 : After dispatching a relief aid n is incremented.

16. If n = 3 : Since only the first coin is dispatched this will be false.

17. XBee communication(Acknowledgement for hit) : After hitting each coin acknowledgement is sent to XBee which is connected to the laptop. First dispatch aid is dispatched by using the force which is obtained by a lot of experiments on different surfaces. So after receiving the acknowledgement the camera detects the coins again to check whether the relief aid is dispatched to the center zone.Else the error is calculated(distance between coin and center white zone).

Sending acknowledgement - Embedded C.
Computing error (distance) - Python.

18. Force Planning and XBee communication : By using the error (distance) the value of force by which the coin is hit is updated ie) if the relief aid landed in midway itself (it didn't reach the white zone) in this case the force will be increased such that the coin will be dispatched little far in the next dispatch. If the coin crosses the white zone then the force should be reduced in the next dispatch such that the coin reaches the center white zone.After computing updated force it's sent to bot by XBee communication.

Note : After hitting a coin the bot sends acknowledgement and will start moving to the next relief aid according to the planned path. So force planning and bot movement occurs parallely.

Next the control goes to **9 ie) if number of dispatched relief aid = 3.** Since only one aid is dispatched this will be false and the bot starts moving to the next affected city.

Force planning - Python.
Sending updated force value - Python.

19. If XBee received data : As mentioned above if the bot received the updated force value (the force planning is done and the updated force value is sent to the robot) in the midway of traversal, then the control goes to **14** ie) Beeping twice and hitting of coin and beep of 1 second else it waits until it receives the updated force value.

Note : If the coin lands on white zone then the force value used in the beginning is considered as correct and the same is sent as updated force value.

So after receiving the updated force the buzzer beeps twice, hitting will be done and again buzzer beeps for 1 second. This is the second coin hit and n is incremented to 2. After this again the value of n is checked which is false. XBee will send the acknowledgement again and the force planning is done for the second coin. Parallely the bot moves to the third relief aid(according to planned path). After receiving the updated force value, hitting is done with required beeps. Then n is incremented to 3.

Now the condition n = 3 is checked and it's true. Now the control goes to **9** and the result is true.

20. Buzzer beeps (5 second) : Buzzer beeps for 5 seconds which indicates the end of run. [Embedded C]

21. Stop : Program terminates.

So in this way the bot works to dispatch the relief aid. Here the bot learns the force value in the consequent hits.

Challenges

Q8. What are the major challenges that you can anticipate in addressing this theme and how do you propose to tackle them?

(8)

< Answer format: Bulleted form
1. Challenge 1
2. Challenge 2
3. Challenge 3, etc. >

a. First challenge : To be able to design a light weight robot with some good innovative design which has both mechanical stability and durability.

Our approach to tackle it : We will try out different ways so that we can come upon with some good innovative design, experimentation is the key to get a good design.

b. Second challenge : To come with the mechanical structure for hitting which involves dispatching the relief aids to their corresponding villages.

Our approach to tackle it : This process is done by choosing initial force obtained by doing a lot experimentation i.e) training on various surfaces for hitting and coin is hit with some random force (obtained from experimentation), and adjust the force until the coin reaches the center, this process is done different surfaces (on other surfaces we will keep the destination distance same as the distance between center of inner white circle and center of coin), by this

way the robot learns the force to hit so that the relief aid exactly lands on the orange part or white part of arena without being struck at dead zones.

c. Third challenge : Writing a generalised image processing algorithm for the detection of the coins(relief aids) which works in all lighting conditions.

Our approach to tackle it : Here we will use the advanced contour techniques and morphological properties of image to get the region of interest from entire arena and do color detection.

d. Fourth challenge : Algorithm for accurately following the whiteline.

Our approach to tackle it : Speed of DC motors will be adjusted to get that circular motion.