CS684 Project Prototype Report

Project Title: Collaborative cleaning project
Project Team number: 11
Team members (Name and roll numbers):

Name	Roll No.	Email
Ashutosh Patel	09305003	ashupatel@cse.iitb.ac.in
Chinmay Vaishampayan	09305918	chinmay@cse.iitb.ac.in
Jitendra Sahu	09305059	jeet@cse.iitb.ac.in

1. Introduction

Mobile robots are getting special attention now-a-days in everyday use. Especially cleaning robot applications are at hand today and tend to become a mass market, for example Roomba introduced in 2002 by IRobot has gain considerable popularity in consumer home market. Here we try to implement our own collaborative cleaning robots which will reduce time to clean. The cleaning algorithm used here can be useful for doing operations in farms, open grounds. The entire project is not only based in cleaning but also uses coverage and positioning algorithms.

1.1 Problem statement

Collaborative cleaning robot is meant for cleaning a rectangular space using multiple robots thus reducing the time required. There will be a master robot which control slave robots and directs them to clean in specific non-overlapping areas. It can be used in various environments like rooms, grounds, farms etc.

It will mainly include positioning, coverage and communication. Positioning and coverage will be involve using beacons i.e. 4 poles at each corner of rectangular space. Communication will be done using Zigbee.

1.2 Requirements Specification

Functionalities of robot are:

- Master robot senses for 4 poles and calculates the length/width of rectangular space.
- Divides the space in equal parts. Number of parts will be decided on the basis of number of robots available and area of space to be cleaned.

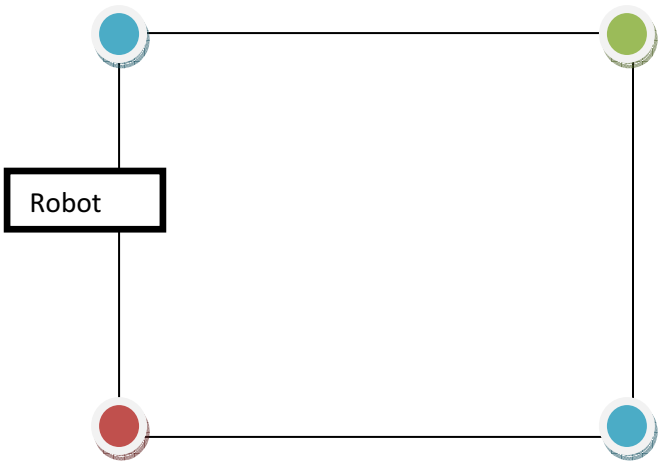
- Communicates the area to robots using zigbee.
- Robots then clean allotted area in spiral fashion.

1.3 System Design

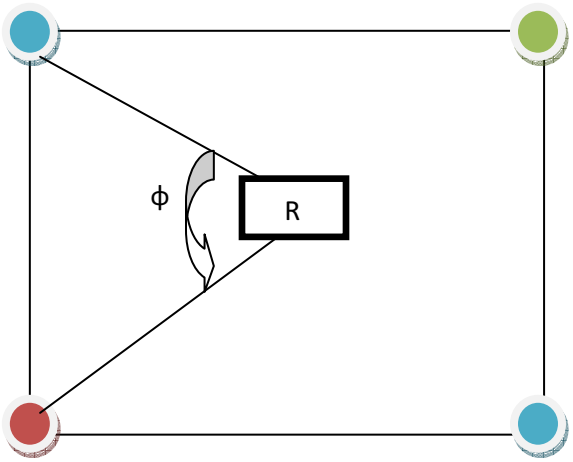
Algorithms:

Algorithms that are used in collaborative cleaning robots are : 1) Area identification and 2) Coverage

1. **Positioning**



The main task of first robot is to position itself with respect to poles placed at each corner of the rectangle. With the help of camera it takes images of the coloured poles and identifies which coloured poles are at what places.It then with the help of sharp IR sensors gets the knowledge of its distance from the other poles.



The robot then with the help of triangle formed(two colored poles and robot at the vertices of triangle)finds the distance between two poles and similarly finds the distance between other poles also and thus gets the knowledge of the whole rectangle.

For a triangle with length of sides *a*, *b*, *c* and angles of α, β, γ respectively, given two known lengths of a triangle *a* and *b*, and the angle between the two known sides γ (or the angle opposite to the unknown side *c*), to calculate the third side *c*, the following formula can be used:

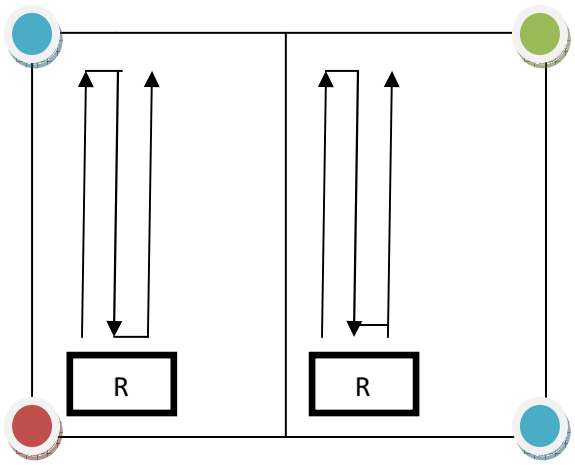
$$\begin{aligned} c^2 &= a^2 + b^2 - 2ab\cos(\gamma) \\ b^2 &= a^2 + c^2 - 2ac\cos(\beta) \\ a^2 &= b^2 + c^2 - 2bc\cos(\alpha) \end{aligned}$$

The law of sines, or sine rule states that the ratio of the length of a side to the sine of its corresponding opposite angle is constant, that is

$$\frac{a}{\sin\alpha} = \frac{b}{\sin\beta} = \frac{c}{\sin\gamma}.$$

Thus the robot finds the position of it in the rectangle.

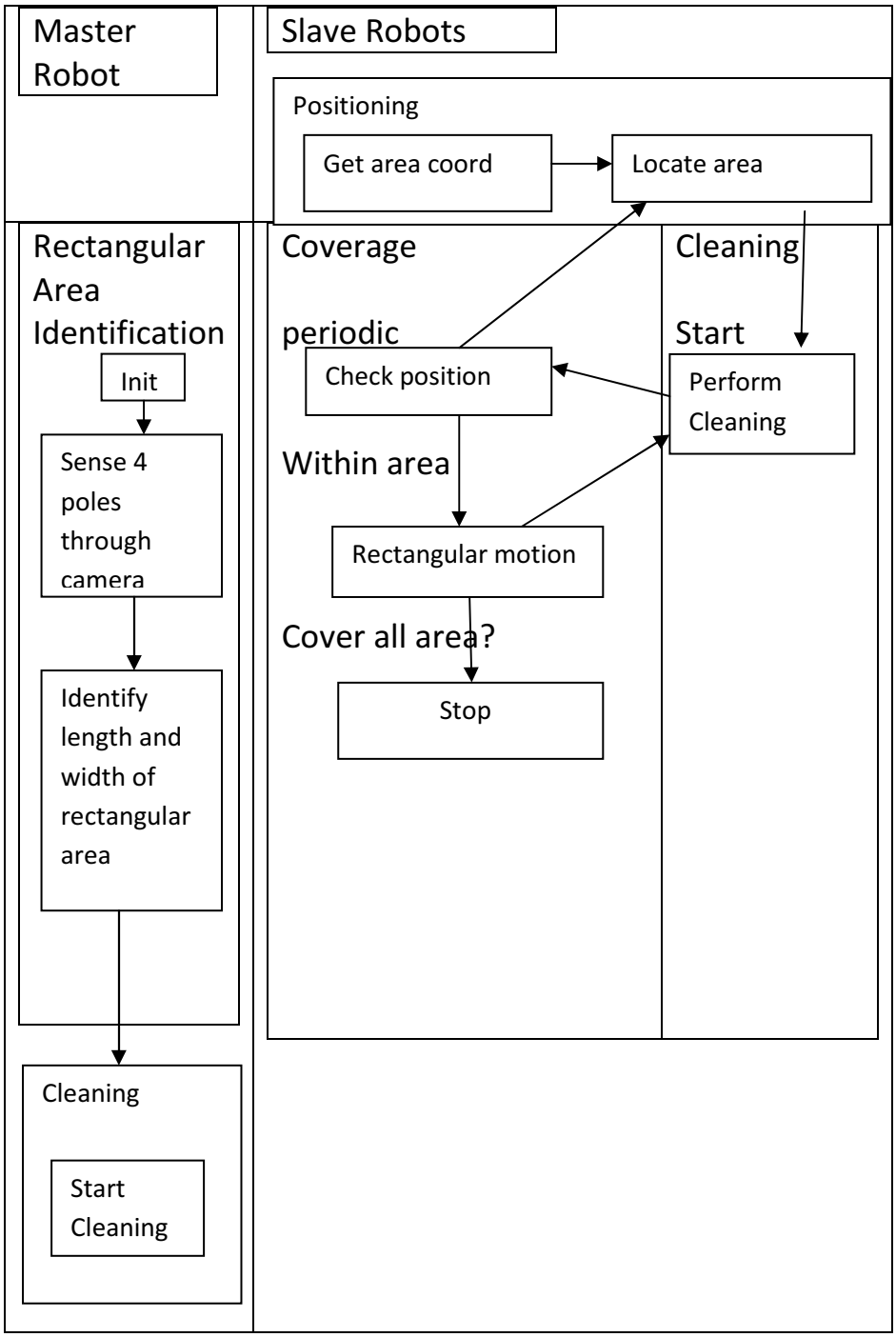
2. Coverage



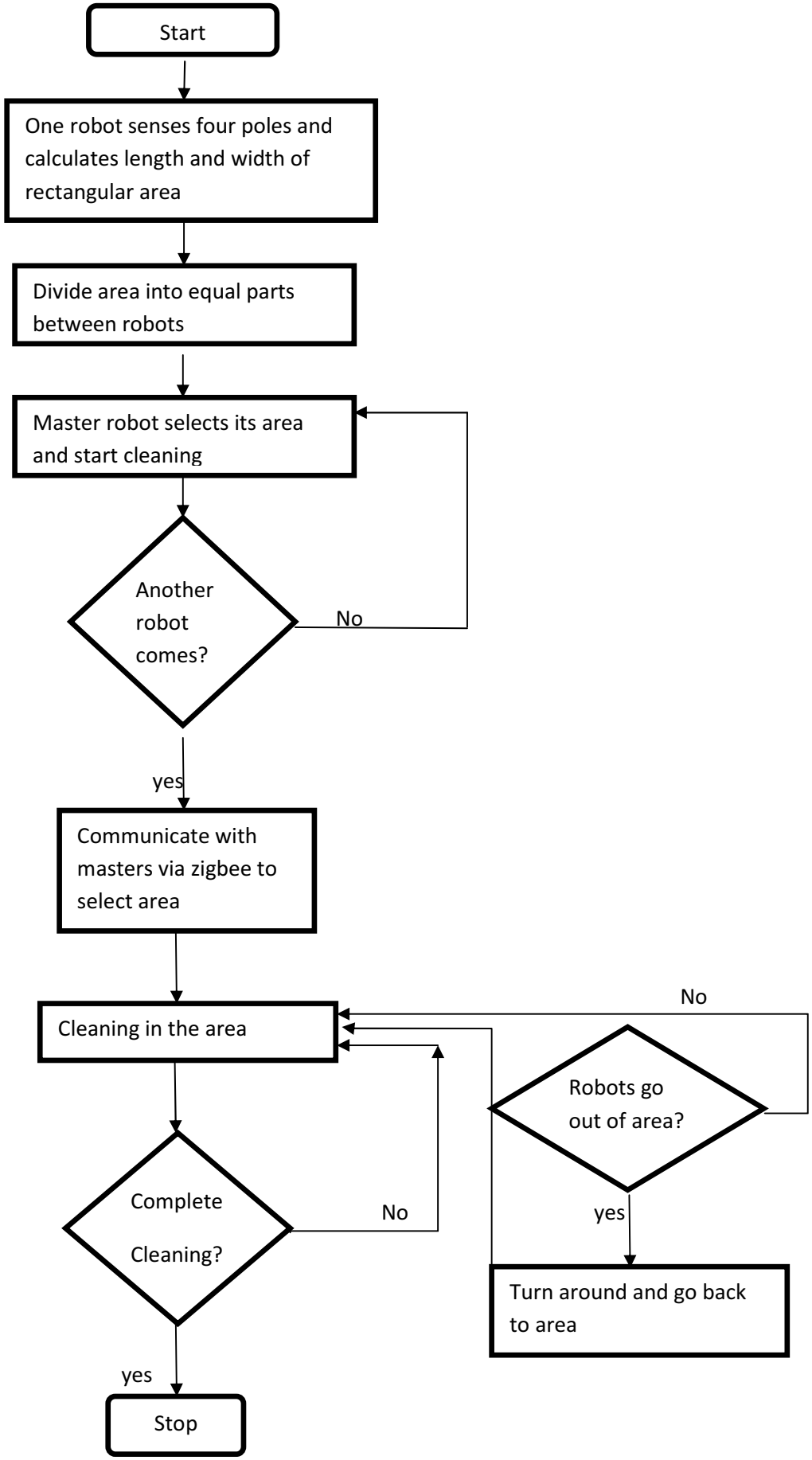
Robot after finding the its position and having the knowledge of the rectangle divides the area into parts depending upon the total robots employed for the cleaning of the area which in our case is two.After dividing the area into quadrants,it assigns the each quadrant to other robots for cleaning.New robots who enters into reactangular area also position itself with the help of algorithm described above and goes into its prescribed part of the rectangle which the first robot instruct it through data sent by zigbee communication.

Since robot has got the knowledge of the area which it has to clean,it just sweeps through the area step by step and at the same time checking whether it does not goes into other robot's territory. It does this by checking it position by algorithm described earlier.

State chart:


Master Robot
Slave Robots
Positioning
Get area coord
Locate area
Rectangular Area Identification
Init
Sense 4 poles through camera
Identify length and width of rectangular area
Coverage
periodic
Check position
Within area
Rectangular motion
Cover all area?
Stop
Cleaning
Start
Perform Cleaning
Cleaning
Start Cleaning

Flowchart:


Start
One robot senses four poles and calculates length and width of rectangular area
Divide area into equal parts between robots
Master robot selects its area and start cleaning
Another robot comes?
No
yes
Communicate with masters via zigbee to select area
Cleaning in the area
No
Robots go out of area?
Complete Cleaning?
No
yes
Turn around and go back to area
yes
Stop

1.4 Assumptions and limitations

- **Area is assumed to be rectangular:** The cleaning area that robots clean is assumed to be a rectangular area.
- **Use different color poles to identify area:** At each corner of the cleaning area poles of different colors are installed for the positioning of robots.
- **Zigbee communication:** Zigbee communication is broadcast communication protocol. Due to broadcast in nature particular robot can not be addressed
- **Interval Sensing** : After some interval it senses location using camera for better positioning

1.5 Setup and any extensions implemented on the robot

1. AVR Studio 4
2. Matlab 7.7.0.471(R2008b)

1.5 Additional hardware used

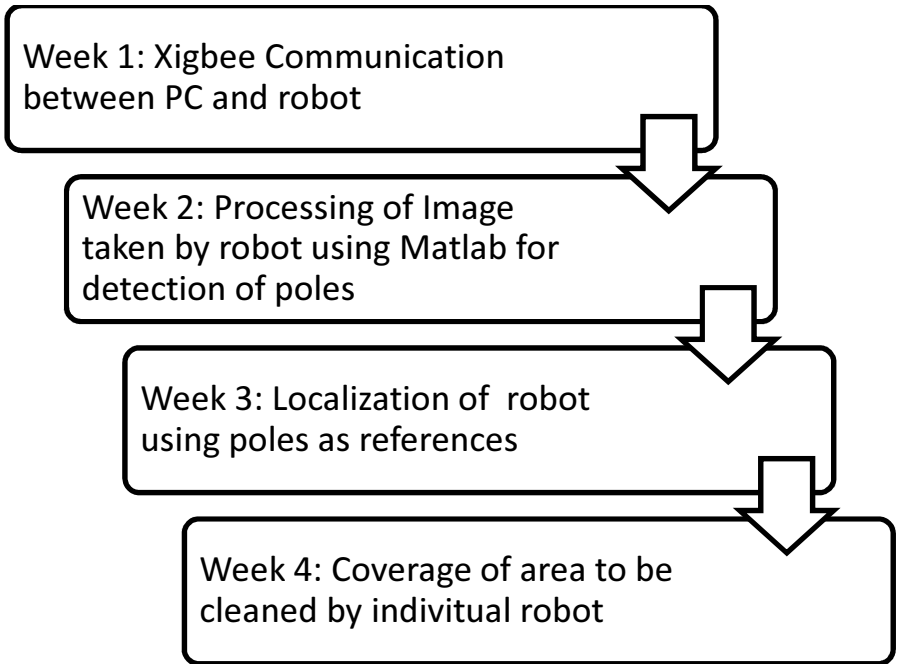
- **Camera** - To take image and further to process it for the detection of poles.
- **Servo Motor** - To detect poles when a robot enters into the area and to position itself
- **Sharp sensor** –To detect the distance of a robot from the poles.
- **Zigbee** – To communicate with other slave robots.
- Camera should be mounted on servo motor, and make sure “90 degree” of servo motor should be in front of robot.

1.7 Any other important aspect/issues, specific to your project

Zigbee is broadcast communication protocol so to make it unicast we need to hard code addresses of slave robots.

2. Present Status

2.1 Time Line



2.2 Delays and Other Issues

Reasons for delay :

- MTP stage 1 of two partners (Ashutosh and Jitendra)
- illness of one partner which costs 15 days (Chinmay)

Overcome issues:

- Using redundant work
- By taking turns to complete work

2.3 Critical steps in your projects:

- Coverage – The robot should cover the area which has been assigned to it and should not cross into area assigned to other robots.
- Positioning – Robot should position itself into his area with respect to other robots
- Accuracy of servo motor – For image detection the accuracy of servo motor is important
- Sharp sensor limitation – Sharp sensor cannot sense beyond 80cm.
- Color detection – Robot should indentify the actual colors of the poles and nothing else.

2.4Work division

Work	Members Involved
Zigbee Communication **- PC – Bot communication** **- MATLAB – Bot Communication**	**Jitendra, Chinmay, Ashutosh**
Positioning **- Detection of poles** **- Calculation of Rectangular Area** **- Calibration**	**Chinmay, Ashutosh**
Coverage and Testing **- Calibration** **- Rectangular motion**	**Chinmay, Jitendra**
Documentation	**Ashutosh , Jitendra**
Presentation	**Ashutosh, Jitendra**

2.5 Project Time

1. Understanding initial work like serial communication, positioning(workshop) - 1 man day
2. Implementation of basic zigbee communication and motion – 4 man days
3. Matlab understanding and image processing – 8 man days
4. Positioning and coverage implementation – 7 man days
5. Remaining things like Documentation, Report – 3 man days

Total time: 23 man days

3. Final Roadmap of Project

3.1 The roadmap to completion – with milestones + deliverables

Filename	Contains
Code.tar.gz	SourceCode of programs to be burnt on Robot. Contains documentation of the code as well.
Code.tar.gz	Contains Matlab files.
Documents.tar.gz	Contains Project related doc files.

4. Innovation, Creativity and Reusability Index of your Project

4.1 Innovations in project

- Collaboration cleaning : project involves collaborative cleaning so using this project we can save lots of time and project also enables to perform tasks in parallel environment.
- Make broadcast addressing into unicast addressing : The interface attached with the firebird robot is zigbee. Zigbee is broadcast communication protocol. The project uses broadcast medium and convert it into unicast medium

4.2 How you have enhanced reusability in project

- The entire project is built with the modules. Modules can be reused in the future project. Eg. Localization module used in project can be used to localize area like farms, open grounds etc.
- **Modules can be reused in the future project.**
    - Calibrate
    - Detect poles
    - MATLAB-Bot communication
    - Rectangular motion area coverage

5. Help us in improving the process

5.1 What you think can be improved in terms of project activities

- Current activities of project is good but can be managed better in terms of scheduling and proper communication

5.2 Any comments on the current schedule of events

- clash of MTP stage 1 schedule and embedded system project schedule
- Not able to deliver useful throughput due to above constraints

5.3 Are you satisfied with the way the course activities have gone – specially the project?

Yes – could have been schedule later or earlier

6. Bug Report

- Initial position should be such that red/blue/green (in that order) poles should be in detectable 180 degrees of servo motor rotation. To remove, we can first detect red pole, align the bot so that red is roughly close to 0-15 degrees and move back till green pole is in range. Functions to do it are already made. It should be roughly 25 lines of code to implement it. We couldn't do it due to time constraints. [Algo: turn left till red pole is detected (function: DetectRedPole(angle)) then move back (function: move with argument 'b') till green pole is detected (function DetectGreenPole()]
- It sometimes sends the wrong value of angle of green pole. we have not able to detect the reason. Same code is running for red/blue poles without error.
- Aligning takes some time. Algo can be more complex to reduce it.
- Due to unavailability of extra bots, we couldn't perform collaboration. (functions are already there, can be implemented using very little work.)

7. Challenges:

- Image Processing,
    - the pole color should be detected only if it is large enough and in center of image. This is because sharp sensor is mounted on rotating servo motor and it should be aligned to pole if it has to measure the distance correctly
    - Hardware is not accurate so we have to align the bot on red/blue line or red/green line (so that it should be on the line and also perpendicular to it) using only two poles was difficult. Function has been made for it, which is pretty accurate even though it takes time.

- Remembering position of bot at each point is difficult and without it we cannot specify the starting point and area to covered. To overcome this, we divide the area in parts (each part of width=diameter of bot, and length=side of rectangle). After this we align the bot to starting point and specify how many parts should be cleaned to its left. We align it whenever it reaches the other end of rectangle. Its not very accurate but it works if area is large.
- Communication
    - Synchronizing bot and matlab such that matlab reads from zigbee exactly when bot sends. To overcome this, bot sends in a loop - 10 times at regular intervals. Also flush the read buffer in matlab every time we read.
    - Sending the command to bot which involves numbers (for example move 50cm) was difficult. We had to first send character 'n' to specify that whatever comes next is a number. Then after that send a command which instructs the bot as to (what to do with the number, like '8' means move forward etc...)

8. Future Scope

- Scalability – Multi robots can be included to increase parallelism
- Area can be of any shape
- Instead of zigbee communication, Bluetooth can be used
- Increasing accuracy of localization

9. Learning

1. Image processing
2. Problems with Zigbee communication and solutions

10. Conclusion

- Able to position itself

- Covers the area which it has divided and assigned to it
- Can be extended to include more robots
- Some times hardware may not work as desired