

THE ROBOCON DIARY

2012-2013



Robotics Club
Indian Institute of Technology Delhi

August 07, 2013

PREFACE

The most important focus of this diary is the National ROBOCON, 2013. It provides you with an insight into the details of each robot, technologies used and further improvements. The year 2003 saw IIT Delhi's first active participation in ROBOCON, an annual **ROBO**tics **CON**test. So far IIT Delhi has become champion once (in 2007), reached semi-finals four times (in 2003, 2004, 2006, 2008), and was in quarter-finals twice (in 2005 as well as in 2009). Over the years we have improved in terms of the quality of robots that we make, the components that we use and the techniques we implement. "ROBOCON" is not just about competing and winning. We learn a lot, not only in the field of robotics but also about project management, time management and most importantly, about team work. Apart from ROBOCON, the robotics club, IIT Delhi made its presence felt all across the campus and in technical festivals of various other universities.

All of above was possible only with the sincere efforts of Prof. S.K. Saha, and more recently with the support of Dr. Kolin Paul, and the help from the ROBOCON team.

At the outset it is to be remembered that always trying new technologies need not lead to the winning robots, as the technologies do not get matured. Hence, the robots may fail at ease. In order to win ROBOCON 2014, tested technologies in the previous years must be respected just like any other technologies in the market.

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This diary has been compiled by Shivang Shekhar

ACKNOWLEDGEMENTS

The team members of ROBOCON 2013 sincerely acknowledge the financial and logistic support provided by Prof. R. K. Shevgaonkar, Director of IIT Delhi, and his complete administrative and moral support; without whose blessings we would not be able to participate year after year in ROBOCON. The support of Prof. Anurag Sharma, Dean of Academics in helping us getting funds from IIT's account to purchase the components required for fabricating the robots. The help of Prof. S.K. Gupta, Dean of Students and his office is also acknowledged for allowing us to work in the Robotics Room of SAC. The ROBOCON team members would also like to thank Prof. S.K. Saha, the team mentor and Faculty-in-Charge and Prof. Kolin Paul for their guidance. Mr. Kamla Prasad, Assistant Registrars of the Accounts and Stores and Purchase Sections are also thanked for speedy actions on ROBOCON matters.

There is an endless list of people from different departments and sections of this institute without whose supports and blessings the participation in DD-MIT-ROBOCON 2013 would not have been possible.

ABU ROBOCON 2013, PUNE, INDIA

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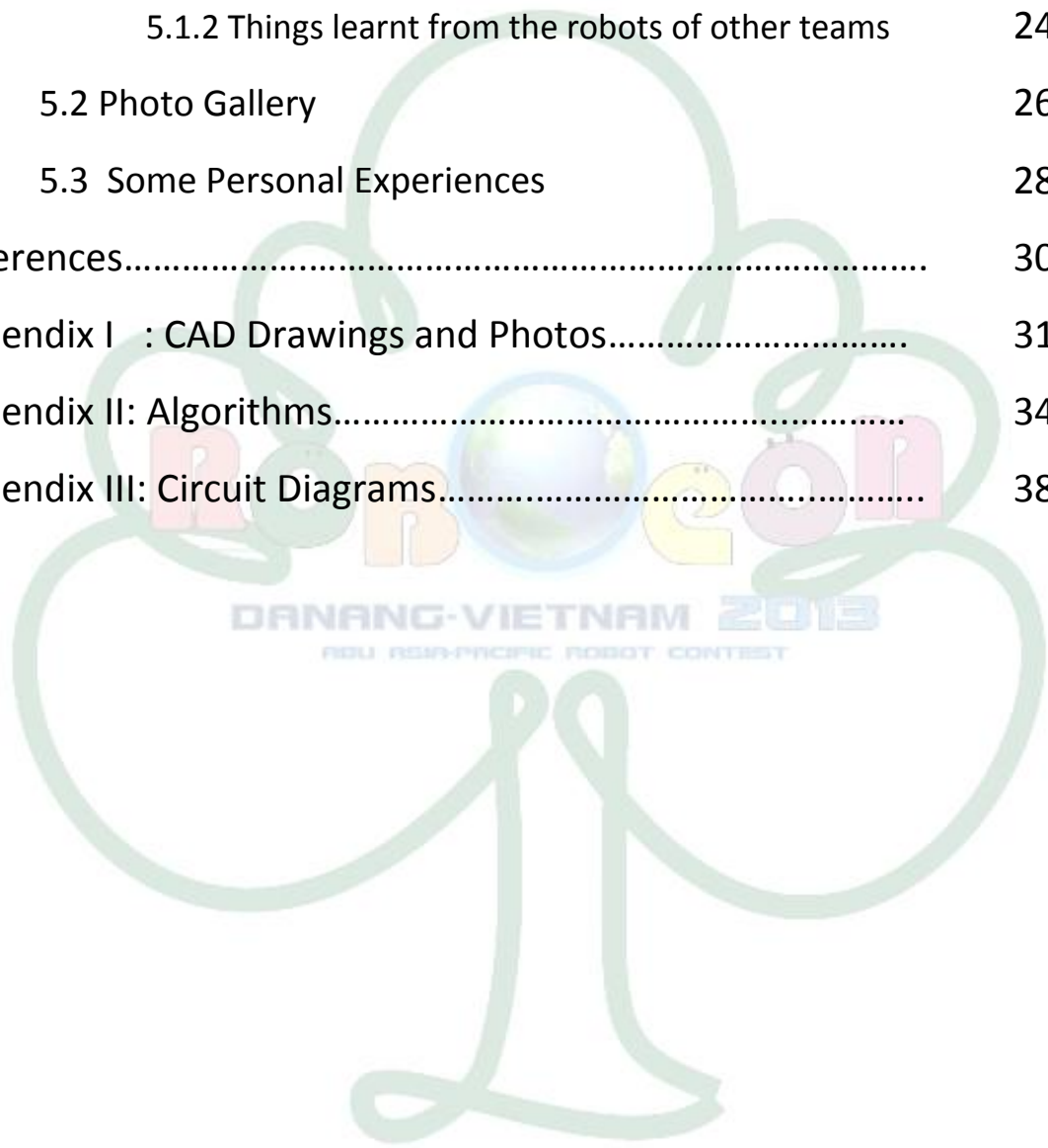
It is certified that all the above students have worked for DD-MAE-ROBOCON-2013 held in Balewadi Stadium, Pune (March 7-9,2013) after working on the design, fabrication and testing of the robots for the ROBOCON competition since September 2012 when the game plan was declared in <http://aburobocon2013.vtv.gov.vn/>.



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Chapter 1 THE CONTEST THEME

“THE GREEN PLANET”

Each nation is a piece of the puzzle that forms the world

The galaxy is vast and has experienced billions of years of collision and gravity attraction. Objects were thus formed and life began. The planet that is called **THE EARTH** has been chosen to nurture the seeds of life.

The first Ring that stirred to wake chose for itself the colour Green - **the colour of life.**

The green spreads from ancient woodlands to fields and plains, creating a soft, refreshing space that nourish the soul.

Along with economic development, people and their negative impacts have been causing the green to disappear on the planet. It is spreading like an epidemic, threatening the green planet and the life on it. Natural disasters, floods, climate change ... The nature is raging.

People's and individuals' awareness is the best vaccine to prevent the disasters that the Earth has to suffer.

Vietnam has chosen the theme **THE GREEN PLANET** for the ABU ROBOCON 2013 with the message: “Each nation is a piece of the puzzle that forms the world; the responsibility to protect the earth thus lies on the shoulder of each person living on it.

Awareness and actions - that is what we need to sustain life in our common home **THE EARTH”**.

Chapter 2 RULES

2.1 QUICK GUIDE:

Duration of the game is 3 minutes

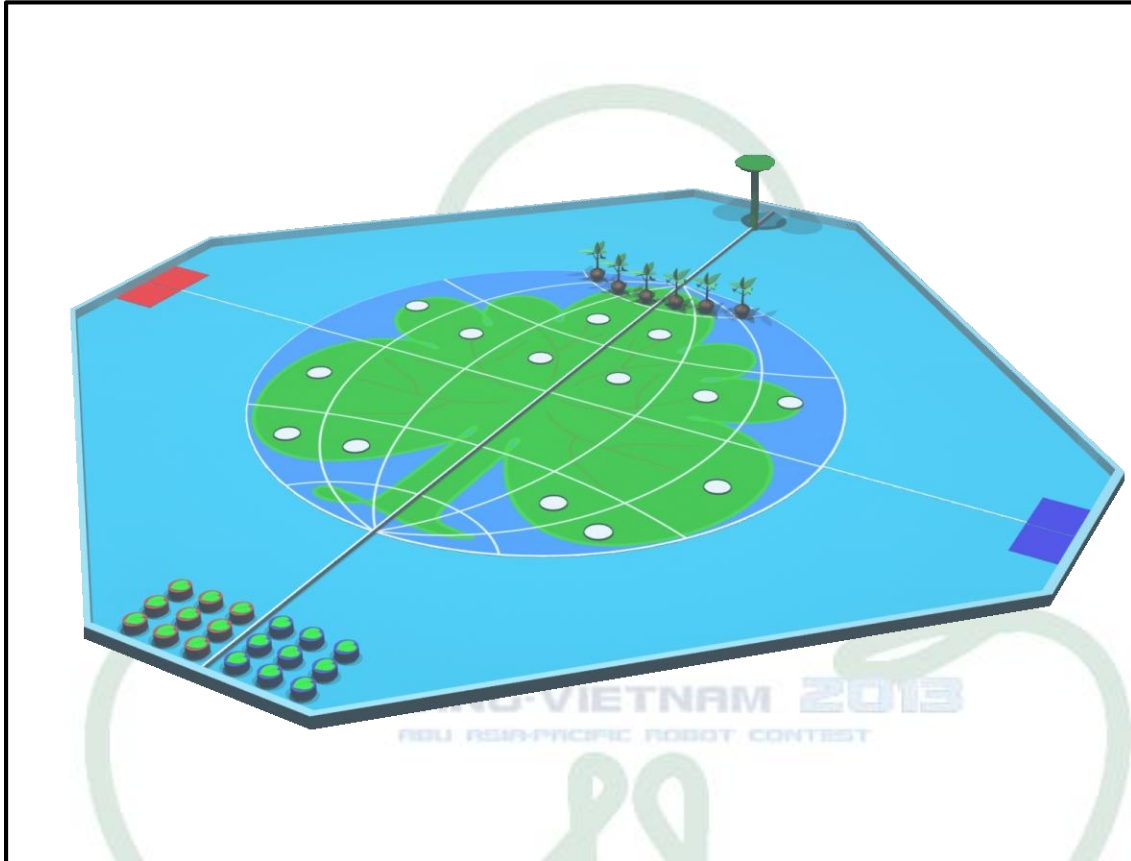


Figure 1 Game field

Each team will have 2 Robots

1 Automatic Robot

1 Manual Robot; Manual Robot is not allowed to enter the Earth Zone.

The Manual Robot picks up the Leaves in the “Leaves Store” and places them in the 3 Rings in the Southern Hemisphere.

Then, the Manual Robot loads "Leaves" which have been picked up from the "Leaves Store" onto Automatic Robot.

The Automatic Robot must place at least 3 leaves in the Northern Hemisphere (including two leaves in its own zone and at least one leaf in the common zone), then it is allowed to touch the Bud(s) in the Northern Hemisphere.

The Automatic Robot goes to the North Pole Zone and picks up the Buds (made by the team) and loads them into the Manual Robot.

The Manual Robot stands below the Limit Line 2 and throws the Bud(s) at the Moon. If the team's Bud stands successfully on the moon, the team achieves "THE GREEN PLANET" and wins the game.

2.2 GAME FIELD AND OBJECTS

The Game Field consists of an area having the dimension of 13000mm x 13000mm made by emulsion painted plywood and surrounded by an iron fence (100mm height-50mm thickness). The game field is divided equally by an iron fence (60mm height, 30mm thickness), along the Prime Meridian. (Reference Figure 1)

The Game Field is divided into 2 parts as follows:

The Earth Zone (*see drawing for more details*).

The Earth Zone is in Sphere Shape. It has a diameter of 8500mm. The white guidelines made of matt (non-shiny) sticker of 30mm width represent the Meridian and the Parallel.

A picture of a green tree is drawn, inside the Earth Zone.

There are 7 steel Rings (painted in dark green) in which to place the Leaves in each team's Earth Zone. Each Ring is of following dimension; 50mm height; 25mm thickness and the inside diameter is 350mm. The surface of the game field where the Rings are placed in the Common Zone are painted in yellow. The surface of the game field where other Rings are placed are painted in white (*see drawing for more details*).

The Northern Hemisphere (*see drawing for more details*) is the upper half of the Earth Zone. There is the Common Zone that covers 4 spaces in the center of the Northern Hemisphere (*see drawing for more detail*). Also, there is the North Pole Zone defined by The First Parallel, where each team arranges their Buds before the game start. (*See drawing for more details*)

The Southern Hemisphere is the lower half of the Earth Zone.

The Space Zone surrounds the Earth Zone (*see drawing for more details*).

There is **the Moon** in the Space Zone. The Moon is a round plate laid flat on top of the cylindrical stand. The height from the surface of the Moon to the surface of the contest field is 1500mm; The Moon is positioned along the Prime Meridian and the distance from the North Pole to the center of the Moon is 2700mm.

There are 2 Limit Lines (30mm width), namely Limit Line 1 is the continuation of the Equator; Limit Line 2 is drawn at 2950mm north of the Equator. (*See drawing for more details*)

The Manual Robot Area

The Manual Robot Area is the Space Zone and it is painted cyan.

Manual Robot Starting Zone

The dimension of the Manual Robot Starting Zone is 700 mm x 700 mm which is painted in red for Red Team and in blue for Blue Team.

Leaves Store

Each team's Leaves Store is located at the bottom of the game field. Before the Game starts, 12 Leaves will be arranged in the each Leaves Store (*see drawing for more details*).

The Automatic Robot Area

The Automatic Robot Area is the Earth Zone and the surrounding area. There are 02 Automatic Robot Starting Zones that have the dimension 700 mm x 700 mm, painted Red for Red Team and Blue for Blue Team.

The Leaf

Leaves are in the shape of a cylinder (250mm Diameter, 200mm Height, 200g Weight). Leaves are made of high-density polystyrene and are coated with emulsion paint, in red for Red Team and blue for Blue Team. The top and the bottom of the leaves are both painted in green.

The Bud

Each team must make 3 'Buds' in the shape of a tree.

- The height of the Bud must exceed 500mm;
- The diameter of the widest part of the 'Bud' must exceed 300mm

- The diameter of the bottom of the Bud must exceed 150mm;
- The maximum weight must not exceed 300g.

The 'Buds' must be placed by each team before the start of each match. The 'Buds' can be arranged in any ways as long as they are placed within the team's North Pole Zone.

The robot must be designed so that the 'Bud', under no matter what condition, cannot travel more than 8m when the 'Bud' is thrown from the robot. The travel distance of the 'Bud' will be measured from the 'Bud' to the robot's contact surface of the game field.

The Bud which has been thrown once cannot be used again in the same match.

2.3 ROBOT SPECIFICATIONS:

Manual Robot

The Manual Robot has to be operated via remote control using a cable connected to it or remote control using infrared rays, visible rays or sound waves. Controlling using radio waves is not allowed. Operators are not allowed to ride on their Manual Robot.

When operating via cable, the connecting point of the cable to the robot must be at least 1000mm from the ground. However, the length of the cable from the Manual Robot to the control box must not exceed 3000mm.

There is a size limit (700mm L x 700mm W and 1200mm H) for the Manual Robots at the Manual Robot Start Zones when the game starts.

After the game starts, the Manual Robot's size and form may be changed. However, the extension limit is 3m in diameter when checked from above.

Manual Robots are not permitted to separate during the game.

Only 1 member of each team is allowed to control the Manual Robot in the Game Field.

Automatic Robot

Automatic Robot must be completely autonomous.

When the Automatic Robot starts, team members are not allowed to touch the Robot.

Automatic Robot should fit within the size of 700mm L x 700mm W and 1000mm H at its Start Zone before starting.

After the game starts, the Automatic Robot's size and form may be changed. However, the extension limit is 2m in diameter when checked from above.

Weight

All Manual and Automatic Robots, including their power sources, cables, remote controller and other parts of each Robot shall be weighed prior to competition. The total allowable weight of all Robots for each team to be used throughout the contest must not exceed 40kg.

2.4 MATCHES

Duration of the Match

Before the match begins setting of the Robots need to be completed within 1 minute after receiving the signal for setting.

Each match shall last for 3 minutes

However, the first team to achieve "THE GREEN PLANET!" wins the match regardless of the point collected by the opponent. The match ends when "THE GREEN PLANET" is achieved.

Competition Rules

The Manual Robot picks up the Leaves in the "Leaves Store" and places them in the 3 Rings in the Southern Hemisphere;

After placing Leaves successfully in the 3 Rings in the Southern Hemisphere, the Manual Robot can load Leaves onto the Automatic Robot in the Automatic Robot Start Zone or the Manual Robot can carry the Leaves to the Limit Line 1 and drop the Leaves onto the floor of the Game Field. Any parts of the Manual Robot which are in contact with the floor of the Game Field shall not be allowed to cross over the Limit Line 1;

After the Manual Robot fulfilled the task under 4.2.2, the Automatic Robot is allowed to start;

The Automatic Robot goes to place the Leaves in the Rings in the Northern Hemisphere of their own game field and the Common Zone.

The Automatic Robot can place maximum of 5 Leaves in the Rings in the Northern Hemisphere and the Common Zone. However, it is allowed to place only 1 Leaf in the opponent's side of the Common Zone.

After the Automatic Robot successfully placed at least 3 Leaves in the Northern Hemisphere including 2 leaves outside of Common Zone:

The Automatic Robot is allowed to pick up the Bud(s) which are placed in the North Pole Zone;

Once the Automatic Robot picked up any Bud(s), the Automatic Robot cannot place any more Leaves in the Rings.

The Manual Robot can cross the Limit Line 1 to receive the Bud(s) from the Automatic Robot and throws the Bud(s) at the Moon. However, when throwing the Bud(s) at the Moon, the Manual Robot has to stand behind Limit Line 2.

Once the Bud(s) thrown by the Manual Robot successfully stands in the Moon, "THE GREEN PLANET" is achieved and the match ends immediately. If neither team achieves "THE GREEN PLANET" within 3 minutes, the team with more score will win the match.

Points Award

The team gains point when their Robots successfully place their own Leaves in the Rings.

Scoring:

Place the Leaf in the Earth Zone: 10 points/Leaf

The Manual Robot receives the Bud from Automatic Robot: 10 points/Bud

Violations and deduction of points

The following actions will be regarded as violations and 10 points will be deducted for each violation:

Robot enters or extends over opponent's zone (except Common Zone).

The Manual Robot enters the Earth Zone.

The Automatic Robot starts before it is allowed pursuant to 4.2.2.

Automatic Robot continues to place Leaves after picking up the Bud(s).

The act of using adhesives for the 'Buds' to stand in the Moon or to pick up objects in the game field and leaving adhesives on any objects, contest tools and the game field is strictly prohibited.

Robots move out of the game field.

Start before referee's whistle or signal.

DECIDING THE WINNER

The first team to achieve THE GREEN PLANET shall be the winner.

If the two teams achieve THE GREEN PLANET at the same time or neither team achieved THE GREEN PLANET within 3 minutes, the winner will be decided by the following priorities:

Total scores after points deduction in that match (if any).

Time record of the first Bud(s) to be received by the team's Manual Robot.

The first team accomplishes the mission in 4.2.1.

Chapter 3 DESIGN OF ROBOTS

3.1 Manual Robot

3.1.1 Tasks

- Picking up of leaves from the leaves store
- Placing them in the three rings of the Southern Hemisphere
- Placing the leaves for the Automatic Robot
- Taking the bud from the Automatic robot
- Shooting the bud at the moon

3.1.2 Strategy

The strategy was as follows:-

- The manual robot starts and goes to the leaves store.
- Using the front three grippers, it grabs the leaves and then turns 180 degrees.
- It then grabs three more leaves using the three back grippers.
- It moves towards the southern hemisphere and drops three leaves in the three rings using the front grippers.
- It then moves towards the starting zone and drops the three leaves in front of the automatic robot.
- If required it goes again and brings more leaves using the three back grippers and drops in front of the automatic robot.
- After this, it waits for the automatic robot to complete the task and then takes the bud from it. This process will be clear after the description of the bud.
- It then shoots the bud using a high pressure air supply.

3.1.3 Final design

One design was finalised on the basis of speed, task completion and reliability.

Mechanical aspects

- The robot had a four wheel holonomic drive for easy traversal and rotation.

- It had 6 pneumatic grippers, three at the front and three at the back.
- The three back grippers were attached to the main body using three revolute joints, so that when they drop down they are able to grip three leaves.
- The middle gripper at the front was attached over an expandable arm to drop the leaf at the ring farthest from the manual zone.
- The two side grippers at the front were attached to two separate rack and pinion mechanisms for dropping the leaves in the other two rings.
- The three back grippers placed the leaves in front of the automatic robot exactly as it picked from the leaves store.
- Over the bot there was a shooting mechanism, which was a hollow aluminium rod connected to an air supply and adjusted using a pulley mechanism.

Electrical

Objective

To redesign and augment the manual robot, designed by mechanical guys, with sensors so that the manually controlled part of the mechanical robot (as mentioned in Appendix I) can be completed in the minimum time possible

Components used in our design

Inertial Measurement Unit(IMU) with onboard ATmega328 and Serial output, PS2 Remote for manual control, Sabertooth DC-DC converter driven PMDC motors, Light Sensors for curve tracing, Solenoid-valves to drive pistons, MOSFET based controllers for solenoid-valves, IR transmitter, Inexpensive High Torque PMDC Motors and above all Arduino Microcontroller (to encode the commands given by PS2 and parallel execute different functions)

Sub-Objectives

- To use the sensor data from IMU to produce a Heading Reference System which gives the heading/direction of the robot in 2 Dimensions (Direction Cosine Matrix-DCM Implementation to fuse accelerometer and gyroscopic data)
- Interfacing Light sensors with Auto-calibration feature and designing feedback mechanism for curve tracing

- To interface PS2 remote with the microcontroller so that it is convenient for the manual controller to control the robot
- Interfacing all the solenoid and motor drivers with the microcontroller
- Adding mechanical limit switches and PMDC motors for gripper movements and including their functions into the microcontroller
- Breaking up the task to be done on the arena into subtasks, automating each subtask and adding a function to the PS2 to switch through these automated tasks easily
- Adding back button to PS2 to undo the subtask already done in case the task is wrongly completed. Also, adding a button to switch the control completely to human controller if tasks fail badly in the particular task
- Debugging and making the bot competition ready

For details of the design see **Appendix II**.

3.1.4 Problems

There were many problems faced some of which are as follows:-

Four point contact

The main problem in the manual robot was the four point contact. After trying many things springs were used between the motor mounting and the chassis. This was not a good choice since this affected the stability of robot.

Weight

Weight was also a problem. In an earlier design, the two side grippers were mounted over an arm which was geared to a power window. The gears, being of Mild Steel, and arms increased the weight so much that we had to remove them.

Motor axle

The major problem in the driving motors was that the axle was of diameter 6 mm only which turned out to be not enough to drive the robot smoothly. This problem was identified much later and so it persisted.

Repeated mechanical iterations

Due to constant mechanical iterations, the electrical guys had to start fresh each time. This was a major problem and delayed the practice of the robot.

3.2 Design of the bud and the Shooting Mechanism

The addition of new rules for the making of the bud was as follows:-

1. The Bud must consists of 'root', 'trunk' and 'branches and leaves'. The 'root' and the 'branches and leaves' must be directly attached to the trunk. The 'root' must be situated at the bottom of the Bud and must be painted brown for an easy recognition. There must be minimum of three 'branches and leaves' and they must be painted green.
2. The root of the Bud must be in contact with the contest field when the Bud is place in the North Pole Zone. The overall height of the Bud must exceed 500mm in vertical when placed in the North Pole Zone. However, the longest part of the Bud must not exceed 1000mm during the match.
3. When the Bud is placed in the North Pole Zone, the widest part of the Bud must exceed all sides of a 300mm square when checked from right just above.
4. There must always be a portion protruded from all the circumferences 150 mm in diameter during a game in a root. The widest part of the root must be over 150mm but should not exceed 250mm during the match.
5. The weight of the Bud must be less than 300g during the match. There is no limit for minimum weight.

As long as the Buds satisfy the conditions under the rule 2.6.1-2.6.5, they can be placed at anywhere within the team's North Pole Zone. However it is prohibited to enter opponent's zone including its space above.

Initial ideas for the shooting mechanism included the following:

1. **Spring based mechanism:** The design consisted of a square platform attached to 4 springs near its four vertices. The springs were compressed using a motor and then the coupling between the motor and platform was retracted to cause a sudden change in momentum of the object placed on the platform. Initially, a range of only about 2 meters was achieved; but by using springs of correct stiffness and smoother, good quality bearings, we were able to achieve a range of 5 meters which was required to complete the task. Major problems with this

mechanism were its bulkiness and high current requirements. (See Figure 2)

- 2. Exhaust Air Mechanism:** In this design, the bud was supposed to be in the form of a bottle filled with compressed air. Once in position, the valve at the inlet was retracted to cause the compressed air to flow out providing the bud with a forward momentum. The problem with this mechanism was that the valve retracting mechanism was proving to be difficult to fabricate and also the range achieved with a maximum pressure of 6 bar was not enough for the task.
- 3. Compressed air impact mechanism:** In this design, the shooting rod was placed inside the hollow trunk of the bud which was closed at the other end. Compressed air was allowed to flow through the rod which provided an impulse on the closed end of the trunk causing it to sail through the air and land on the required spot. This mechanism was much better than others because it was very lightweight and easy to control and modify.

Many trials were conducted with the bud and the third shooting mechanism. After compiling the data from the experiments and calculations based on the trajectory of the bud, an optimum initial angle of 55° and pressure of 5 bar were finalized. Trials were conducted with these values and the bud landed successfully on the platform 15 out of 17 attempts. (See Figure 3 and Figure 4)

To make the bud stop on the platform (and not overshoot) when it lands, we came up with many ideas including sand bags, dampers, parachute etc. but finally the base of the bud was covered with vacuum cups which stuck temporarily to the platform on impact thus preventing the bud from overshooting and falling off the platform.

Advantages: very lightweight, cost effective, easy to manipulate and reload

Disadvantages: Every bud was slightly different in structure hence the pressure needed to be adjusted for each throw which was a daunting task. Range decreased after each throw because of the loss of pressure in the previous attempt. The cups attached to the base of the plant kept falling off because of repeated jerks. The clearance between the trunk of the bud and the shooting rod was to be minimized to make the mechanism air tight, but this increased friction and also made it difficult to mount the bud on the rod.

For satisfying all these constraints we tried many new materials, but couldn't find required durability, lightness, stiffness etc.

Finally we used hollow aluminium rods for the bud as the mechanism we had was a pneumatic powered shooter.

Basic characteristics of the bud and the shooting mechanism were as follows:-

- The shooting rod was also a hollow rod of lesser diameter, so it was inserted into the bud.
- When high pressure air was supplied, the bud flew due to the momentum of the air.
- The rod was welded at an angle with the base so that when launching took place the base should be horizontal.
- The bottom portion of the bud was of funnel shape to facilitate easy insertion of the shooting rod.



Figure 2. Other mechanisms tried for shooting such as spring mechanism

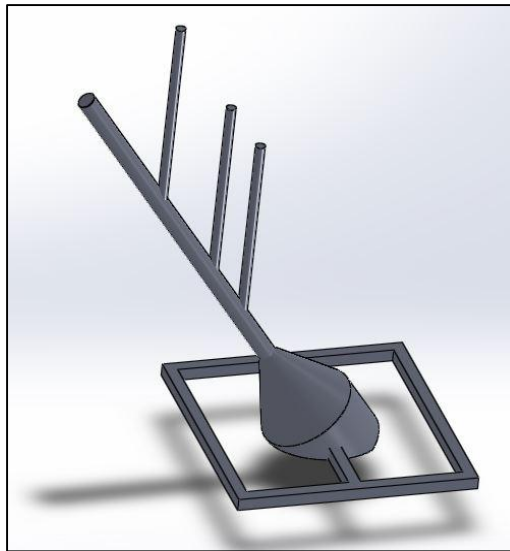


Figure 3: CAD model of the bud



Figure 4: Bud throwing practice

3.3 Automatic Robot

3.3.1 Tasks

- Getting leaves from the manual robot.
- Placing leaves in the northern hemisphere.
- Reaching the North Pole zone.
- Grabbing the bud from the North Pole zone.
- Getting into a position for the manual robot.
- After manual robot takes the bud, leaving it and going for the next bud and so on.

3.3.2 Earliest strategy and design

After the release of the problem statement, due to the lack of detailing in it, it was decided to first focus on the three rings of the northern hemisphere.

Since the rules regarding the bud were not released, anything about picking up the bud or transferring it couldn't be done.

Our strategy was this:-

- The manual robot puts the leaves over the automatic robot.
- The automatic robot starts and goes to a position between the rings and over the white line.
- The two arms open and drop the leaves in the two rings.
- The third arm which is a conventional gripper drops the leaf over the ring in the common zone.
- At a later stage, the design of this gripper can be changed for holding the bud accordingly

Design

Mechanical

- It was a three wheel holonomic robot to traverse in any direction without changing its orientation.

- It had two unconventional arms which when closed had a hole of size greater than the leaf and concentric and when opened were able to reach above the two rings.
- There was a rack and pinion mechanism in the lower arm to make it move outside.
- Finally it had a big piston at the front end to drop the leaf in the opponent's ring of the common zone.
- Pistons were attached to hit the leaf when it comes above the ring.
- For moving the third arm earlier banebot motors were used which were later replaced by robokits motors.
- Motors were used for rotating the arms and moving the third arm up and down using a pulley mechanism.
- Two mouse were mounted parallel to each other near the omni wheels.
- A mechanism was separately designed for the back portion of the manual robot so that it is able to place the leaves in the same line. (See Figure 5 and Figure 6)



Figure 5: For picking up the leaves from the ground it was required to be on the same level



Figure 6: After picking it would have rotated and stacked like this

Electrical

The three omni wheels were placed at an angle of 120 degrees to each other so that robot can be moved in any direction. Despite the advantage of robot being able to move in any direction we can't utilise it fully as the motors were not capable of providing sufficient torque and hence our correction for keeping the robot at a particular angle was not implemented properly.

Correction for Holonomic Drive: For correction in the motion of holonomic drive we used the mouse sensor. We decided to use mouse sensor over conventional encoders as mouse sensors are not surface dependent i.e., they don't have much effect due to slipping. Mouse Sensor work on the principle that the sensor takes continuous images of the area under it and based on the change in the image it calculated the differential change in its position (dx and dy). This differential change in the position can be used to determine the position of robot and also the trajectory in which it is currently moving. This information was used for correction in holonomic drive. But the problem was that the error in dx and dy keeps on accumulating and hence it becomes significant after moving small distance.

Algorithm for Correction: We used two mouse sensors for correcting the motion of robot, since with one mouse we can only determine the position of robot but can't determine its orientation. The two mouse were placed in parallel to each other. Based on the difference of the two mouse readings its error in orientation can be determined. We took the difference in the reading of two mouse continuously and used a correction that was proportional to the error generated. We used the PD (Proportionality and derivative) controller for correction in its position. The correction was the angle that the robot should move to correct its trajectory. Further to correct the orientation we provided it an angular velocity proportional to the error.

Electrical Aspects (Components Used)

Microcontroller: We used the open source microcontroller Arduino. We used an Arduino Mega and two Arduino Uno. We implemented parallel programming which was used first time by any team in ROBOCON India. We established Serial Communication for communicating between Mega which was the master and two Uno's which were the slaves. The Uno were used to interface the mouse sensor and send their data to the Master whenever it ask for the data. Except for using in interfacing the mouse they were also used for small purposes like controlling arms.

USB Host Shield 2.0: This device from SparkFun is used to interface any USB device from the Arduino Microcontroller. This takes the reading from the USB device and sends it to the Microcontroller using SPI communication protocol. This was used to interface mouse sensor by the Arduino UNO.

Mouse: The mouse we used were from the Dell Inc. These mouse stores the dx and dy (16-bit 2's complement) reading in two buffers of 8 bits. Hence there were two registers of 8-bit each for each of dx and dy. For getting the readings of dx and dy these registers were read. The readings from two registers (X_High and X_low) were combined to get the correct 16-bit 2's complement. This was converted to decimal value by us for using in any computation.

Motor Driver: The motor drivers we used for driving motors are Sabertooth Motor Drivers. These could be used to drive two motors with current rating of 25A. These could be used in many different modes and can be controlled by the PWM or Serial communication. We used the packetized Serial communication in which upto 6 motor drivers can be controlled by just one SERIAL. The packetized serial works on baud rate of 9600.

For controlling other motors we used the low current MOSFET motor drivers by the company Robokits, which were controlled by PWM and a digital input for direction.

Line Following Sensors: We used the Photodiode Sensors which give different analog values at different colours for line following. The problems with these sensors were that

there value was affected largely in different lighting conditions. Though once set up for the lighting conditions they gave good response.

Encoders: The encoders we used were from the Vex Robotics. These gave 90 readings in one complete rotation. They were used to measure the rotations of arms.

3.3.3 Problems

The major problems were as follows:-

- The mechanism designed for stacking was not implemented correctly in the manual robot. So the automatic robot was not at all compatible with the manual robot.
- Due to significant error accumulated in mouse sensors they were not that effective and we used it just for alternate feedback.
- The disadvantage of using the holonomic drive was that the speed of robot was less in any given direction as compared to normal two wheel and a castor drive as there was only a component of velocity available Holonomic Drive.
- In this design, the reliability of leaves falling through the holes and landing upright was not satiable.

Due to these problems the design was changed completely after the winter vacations

3.3.4 Final Strategy and Design

Mechanical

The earlier design was changed to a completely new one.

Now, we were picking the leaves from the ground using two arms with grippers. (See figure 7)

The back portion of the manual robot was now compatible. It placed the leaves in the front of the automatic robot.

Advantages

- The robot became light so the weight problem was reduced.
- It was easier to place the leaves in the rings.

Disadvantages

Picking the leaves from the bottom with less clearance between them was very difficult.



Figure 7: Automatic robot picking up leaves from the ground

Electrical changes

The drive was retained as earlier. New sensors were now needed for starting operation.

Proximity Sensors: We used the Ultrasonic Sensors as the proximity sensors. These were used to detect the distance of Leaves from the arms for gripping them.

Chapter 4 Status before Going to Pune

Before going to pune, we completed all the above mentioned objectives more or less.

We even completed the task except shooting in synchronization within three minutes.

However these were some of the **concerns** we had:-

- The automatic robot was not able to grip the bud properly and transfer it without rotation.
- The idea of having a dummy plant as a backup was not able to be implemented. This was required because transfer of plants had as much as 30 points.
- The drive of the manual robot was of concern. Since the springs used for the four point contact made the bot unstable and so it required frequent tightening of nut bolts of the coupler connecting the motor and the shaft extender.
- Due to space constraints, the other half of the field was not completed. So the automatic robot didn't get the chance to practice for the red zone at all.
- There were still concerns about picking up of the leaves from the ground by the automatic robot.

Chapter 5 Experiences

5.1 Events Details

5.1.1 League Matches

On reaching Pune, we didn't take much time in finalising our robots and were ready for our first practice slot.

In the first practice slot, the manual started and ran some time and the nut bolts loosened earlier than expected. So it was returned to the pit area. The automatic robot did pretty well except having some difficulties. It was not detecting a line required for turning and iterations were required for proper placement of leaves.

In the subsequent practice slots, the problem of automatic robot was removed turn by turn and also it was practiced for the other half. The automatic robot was now able to complete the tasks and even lift a dummy bud for the manual robot which was designed there only.

But the manual robot's problem persisted each time. We tried many things but nothing worked.

Series 1

In the first series of matches, the drive of the manual robot suffered. It moved slowly as expected and had to be operated carefully. So, out of three only one time the automatic robot was able to get started which resulted in earning just 90 points.

After this, we decided that we can't continue with this drive further or else the motors will get permanently damaged. In one night we changed the complete drive with the spare Mechatek motors we got for the automatic robot since it had an axle of diameter 12 mm. Only problem was it was very slow.

Series 2

In the next series of matches, we saw many ups and downs. In the first match, the manual had problems but it was able to complete its task in two minutes. First time our automatic robot earned points and dropped two leaves in the rings. It was dropping two more but the time expired. However in the next two matches, the manual struggled and the automatic robot didn't get a chance to move. We ended up with a total of just 160 points and thus first round exit from ROBOCON 2013.

5.1.2 Things learnt from the robots of other teams

- The team MIT Pune had used very light fabricated grippers with a centre piston mechanism. Thus they must have never faced problem related to weight.
- The idea of using spring couplers used by many teams for four point contact and better stability was in our mind but we were not able to find the manufacturer in time.
- Teams such as Nirma University had extensively used pistons and they designed like that so as to minimise the use of motors and problems related with their feedback. (See Figure 8 and 9)
- The type of gripper used by IIT Madras and COEP pune, was very good which provided them more clearance by picking the leaves from above and using just a point.



Figure 8: Nirma University manual robot

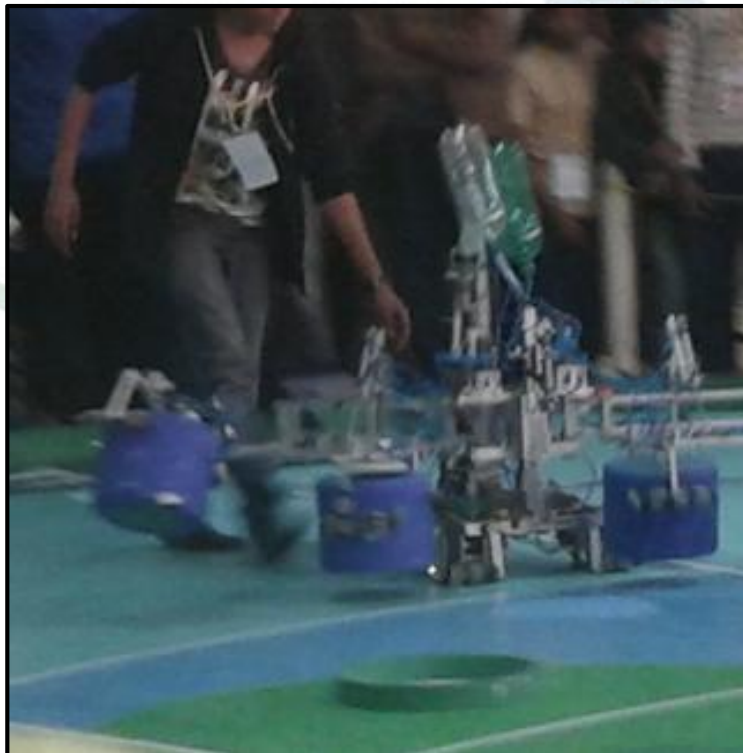


Figure 9: Nirma university automatic robot

5.2 Photo Gallery



Automatic robot (left) and manual robot (right) before leaving for pune



5.3 Some Personal Experiences

Participating in ROBOCON requires knowledge, application, aptitude and above all perseverance to continue in spite of the difficulties you face. This year what I learnt from ROBOCON was an experience of a lifetime. In the *end* it is not the result that matters, what matters is the Journey and how you learn from your mistakes. We saw many new things implemented this year such as navigation and correction through mouse, use of pneumatics etc. It was great to explore and try such things. Overall, working in Robotics Club is *one* of the most crucial things I did coming in IIT

- Shivang Shekhar (2nd year)

In future whenever I would be dejected, sparing a thought for ROBOCON would suffice for an adrenaline boost. When at last it all boils down to one whistle timing that may go awry and jeopardize the months of tireless efforts of the team, it felt such a thriller to be entrusted with such a responsibility. The way to ROBOCON is long and troubling but it makes a real man out of you. Learning while building (and blowing up :P) is the basic method here which one keeps iterating. Only now I can comprehend that a big team translates to a big rational product. But I believe that games are not always the perfect way to compare your quotient. Overall Great people, great time and great learning.

- Mohit Agrawal (2nd year)

I had the most amazing year at Robotics club working with a team of students from different branch and different year. I got to learn a lot by conducting workshops for freshers, leading my team into a national competition, working together day in and day out and combining all the efforts into a single robot. It feels wonderful to make a masterpiece after successfully facing a lot of challenges. It was an enjoyable process of making robots for ROBOCON 2013. This year we had many new technologies inducted in our robots and we hope to continue this innovating process for the coming years as well. I hope the coming batch puts in even more effort and takes the Robotics club to new heights.

- Vishal Mehta
Overall co-ordinator
Robotics Club 2012-13

As a 1st year student it was a great experience for me to see the awesome event conducted on a very large scale. The teams from all over India participated in the competition with only one dream to win the title of ROBOCON. But for me it meant far too more, it taught me how to work as a team and never to lose hope whatever the situation is. Working for ROBOCON made me familiar with many new technologies of great utility. I also made a manual bot that responds according to arm action. Overall working for the club taught me a lot and I also hope to work more for the club.

- Rishabh Agarwal (1st year)

REFERENCES

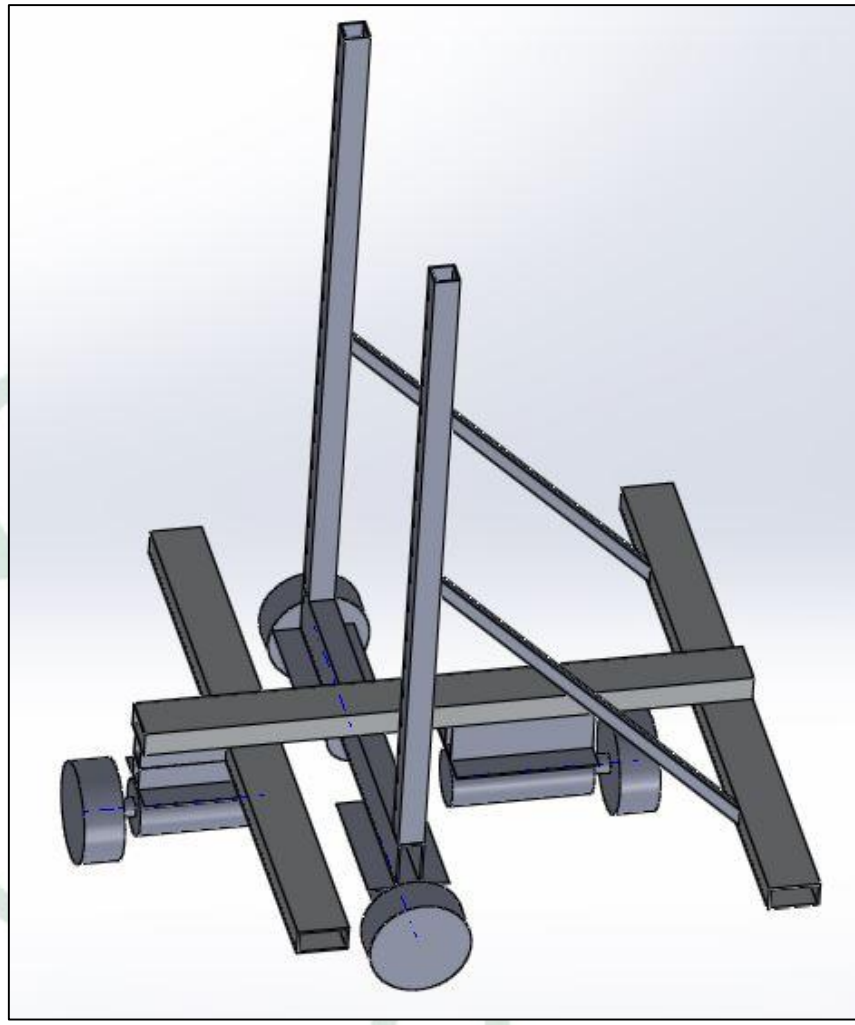
1. <http://www.arduino.cc/>
2. <http://www.igus.com/default.asp?C=US&L=en>
3. <http://www.dimensionengineering.com/sabertooth2x5.htm>
4. <http://www.ifm.com/ifmus/web/home.htm>
5. <http://www.mechtex.com/>



Appendices

Appendix I:

CAD Drawings and Photos



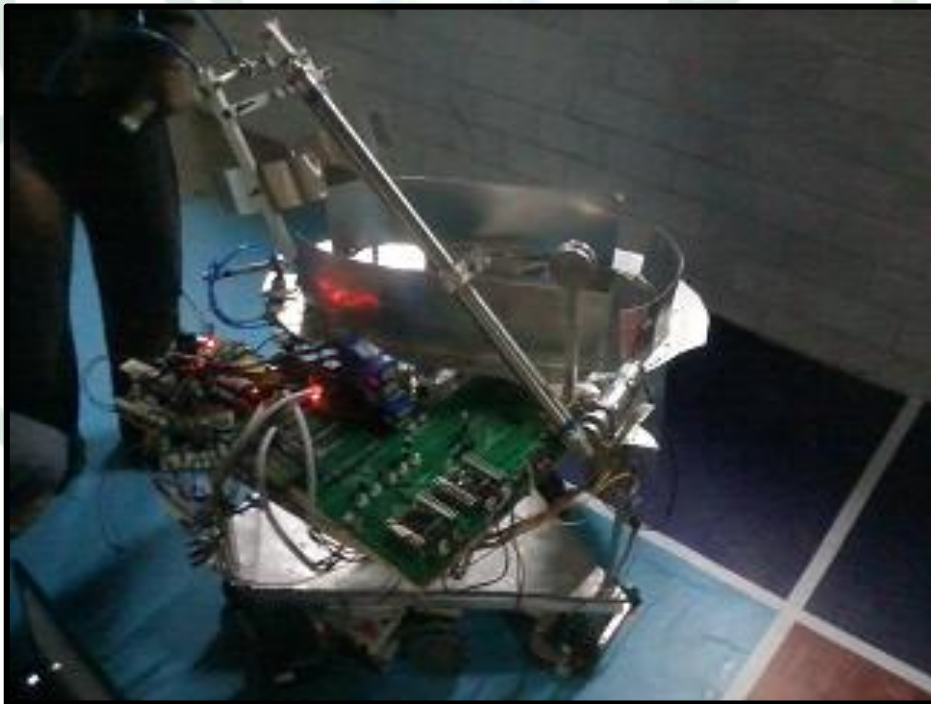
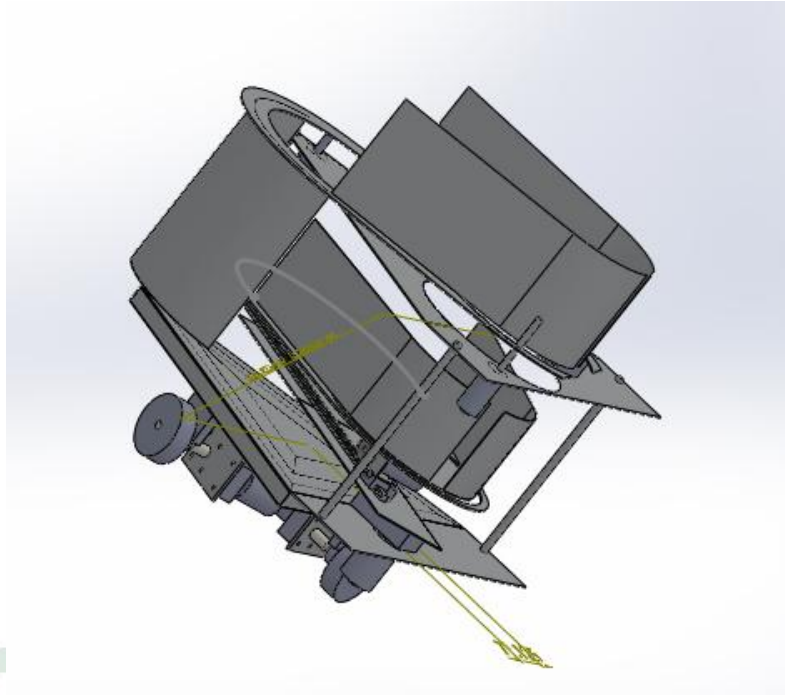
Chassis of the manual robot



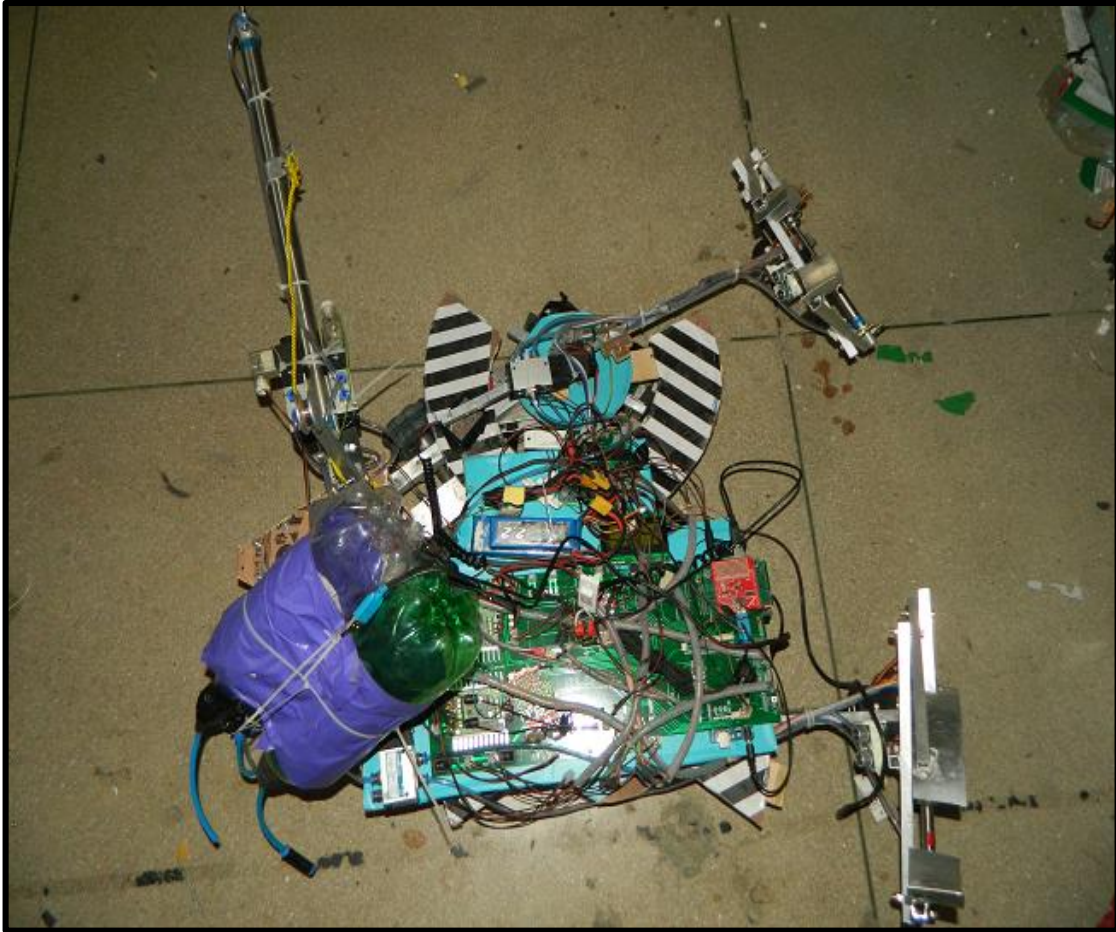
Design of the manual robot



Back portion of manual robot



Design of automatic robot earliest design



Automatic robot final design

Appendix II:

Algorithms

Implementation of DCM algorithm for IMU heading system

Using this DCM algorithm, heading of the IMU was calculated in respect to earth using rotation matrices.

Sensors:

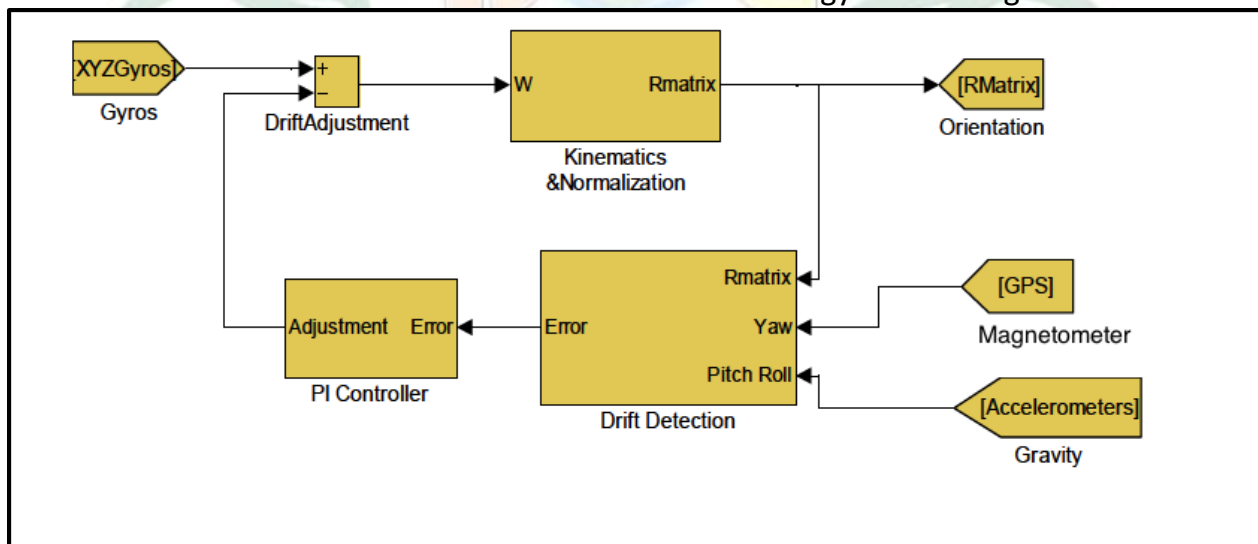
Accelerometer measures Gravity minus acceleration

Magnetometer measures Earth's magnetic field

Gyroscope measured angular velocity

Unaffected by gravitational or magnetic field, gyroscope sensor is the primary sensor used to calculate orientation of system. Accelerometer and magnetometer are used to obtain a reference vector. Gyroscope's have certain offset which when integrated causes result to drift. The accelerometer is not affected by drift, therefore, it is used as an orientation reference in the X and Z axis of the rigid body to compensate the roll-pitch error (gyro's offset error).

The magnetometer's readings are used to calculate the heading of the rigid body. The magnetometer must be three axes to be able to calculate the heading of the system in any position of the sensor platform; to compensate yaw error. The heading of the system used as the reference vector in the Y axis (yaw error), in addition to the roll-pitch error calculated by the accelerometer, it allows the system to calculate the rotation correction matrix. Afterwards, the algorithm uses a proportional plus integral feedback controller on the correction matrix to the remove the drift from the gyro's readings.



The compensated gyroscope values are then fed to the “Normalization & Kinematics” block (as shown in figure). The rotation matrix's columns are unit vectors. Thus, before calculating the kinematics portion it must be normalized. Once normalized, the gyroscope along with the previous rotation matrix is used to calculate the current

rotation matrix (R Matrix). Finally, the Euler angles are calculated from the updated rotation matrix.

Reference: http://www.starlino.com/dcm_tutorial.html

Starlino Electronics // Spring, 2011

Interfacing and programming for PS2 controller

Technologies Used:

PS2 controller, SPI protocol, Parallel programming, EEPROM storage

Connections:

A Ps2 controller was used to control the manual bot. The complete manual referenced is available at <http://www.billporter.info/2010/06/05/playstation-2-controller-arduino-library-v1-0/>. The connections were made as mentioned in above reference. Owing to error "No controller found. Check wiring" even after the procedure, following steps were performed

1. Pull up the data line by connecting a resistor of 10k between data and 5V.
2. Change CTRL_CLK in 'PS2X_lib.h' from 2 to a higher value ranging from 4 to 100.

Step1 could remove the error.

Development

Initially the joysticks were used to control the motion of the bot. Since our manual bot is of 4-wheel holonomic drive the four wheels are given velocity in order using the ps2 controller. Left analog stick was used to control the linear motion of the bot. Right joystick was used to control the rotation. Initially the manual bot was made to move in 16 directions by giving the velocity in a certain ratio to 4 wheels. A lookup table was used to calculate the trigonometric values for motion. The bot was then made to translate by cutting down the 360 degrees to 16 parts. When the joystick is kept at an angle in the range of one of these 16 parts the bot is allowed to move in that direction. The analog values of the analog stick (both x and y) range from 0 to 255. The readings of the analog stick were discrete and non-linear. So a mapping to 16 directions is made by making

observations from the serial monitor for finding the range of analog values.

Strategy and Parallel Processing

After the arms were added the bot was to be made semi-autonomous. Initially time was used to control the motion of the arms. The millis() function was used to find the time and based on that the position of the arms was estimated. But the problem with this method is that the motors being non-linear never had gone the same distance as before. It resulted in breakage of arms. Later limit switches were used to control the arms. Both limit switches and time were used in conjunction for more efficiency in case one of them fails.

All the functions were called in parallel i.e. in the void loop every function is called each time, which performs the function until its task is completed. This resulted in making the bot perform parallel actions so that we could open the arms while in motion etc. The entire task is divided into various modes and except motion, picking all actions were made semi-autonomous so that if we click the mode button every time it resulted in the bot performing the action by itself. There is a button to enter the previous mode in case of a mistake in the action performed. Then the control of motion is transferred from analog stick to analog buttons to prevent the confusion. In case the automation fails there is a button to take back the control to perform the actions manually. Since there is a need for restart in our game the code was made so as to skip from the one state to the particular another state any time. Buttons on PS2 were Mode specific i.e. the whole task of automation was divided into 32 modes and each button was designated a specific task based on that mode. Then there is also a button to store the mode in EEPROM to load it back in case of a restart.

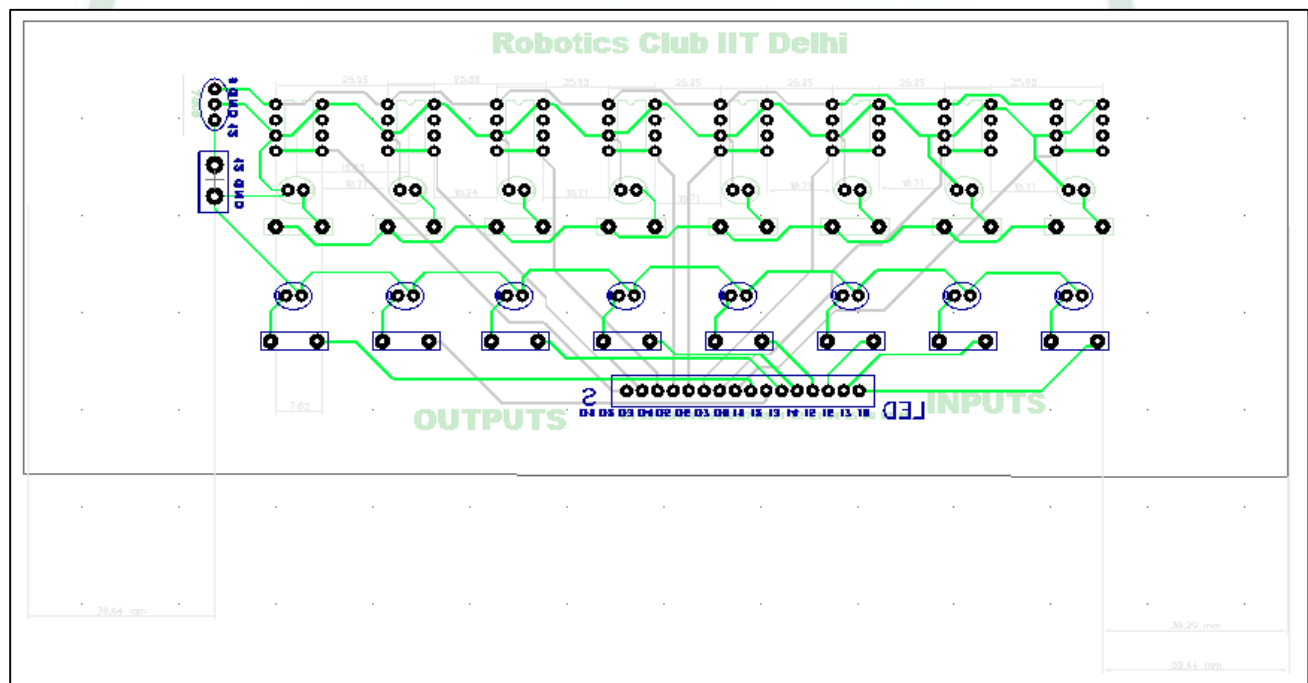
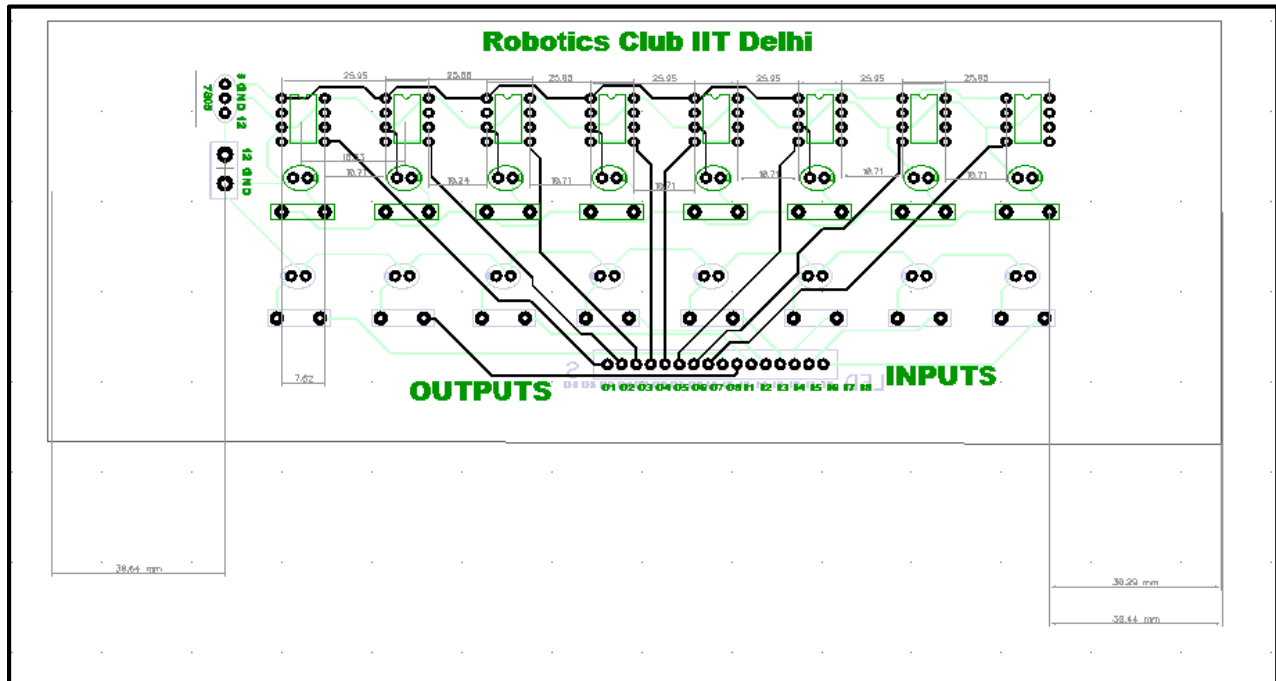
Problems faced

1. The code had many bugs initially which resulted in the bot getting out of control many times. The bugs were corrected over the time.
2. Another problem, which puzzled us, was mid-way failure of PS2 remote, which resulted in an uncontrollable state of bot. For the same, Separate power was given to ps2 (not from arduino board).

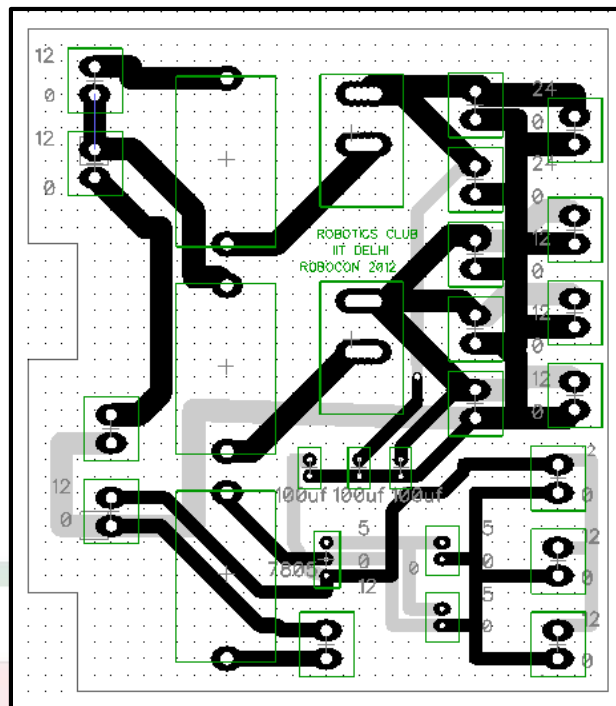
Appendix III:

Circuit diagrams

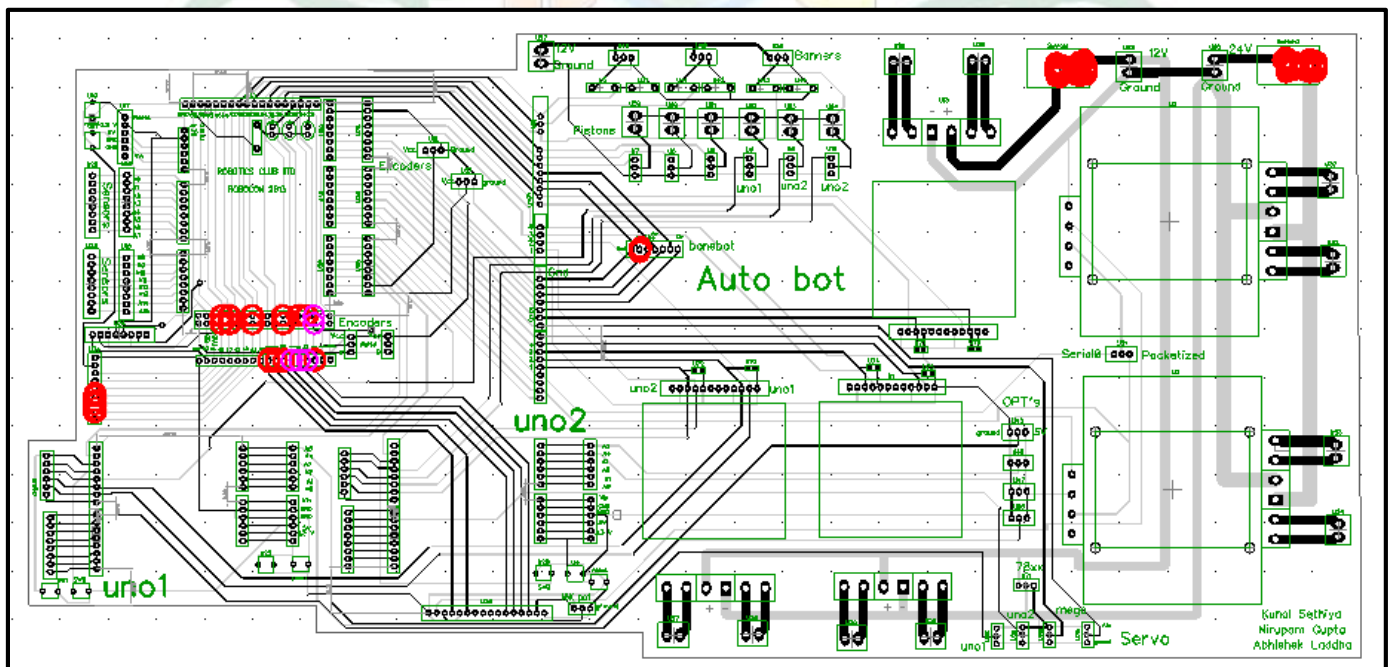
1. Sensor plate (both sides)

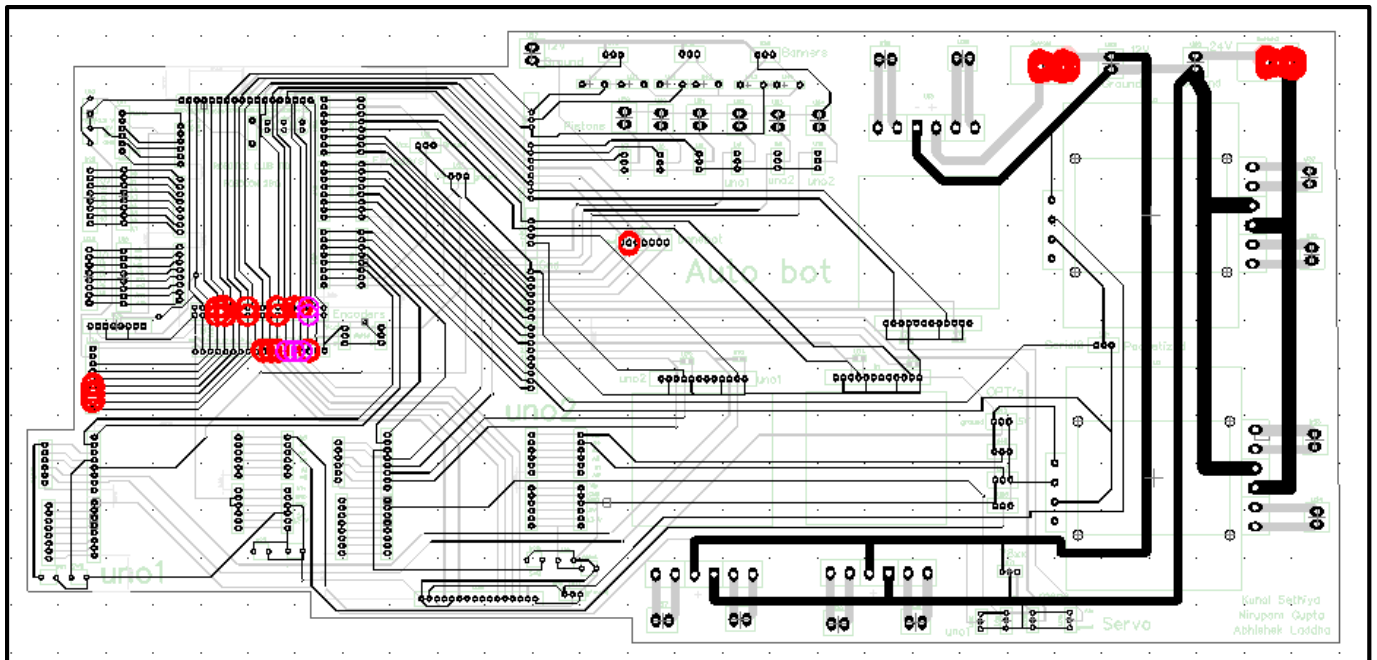


2. Power Board

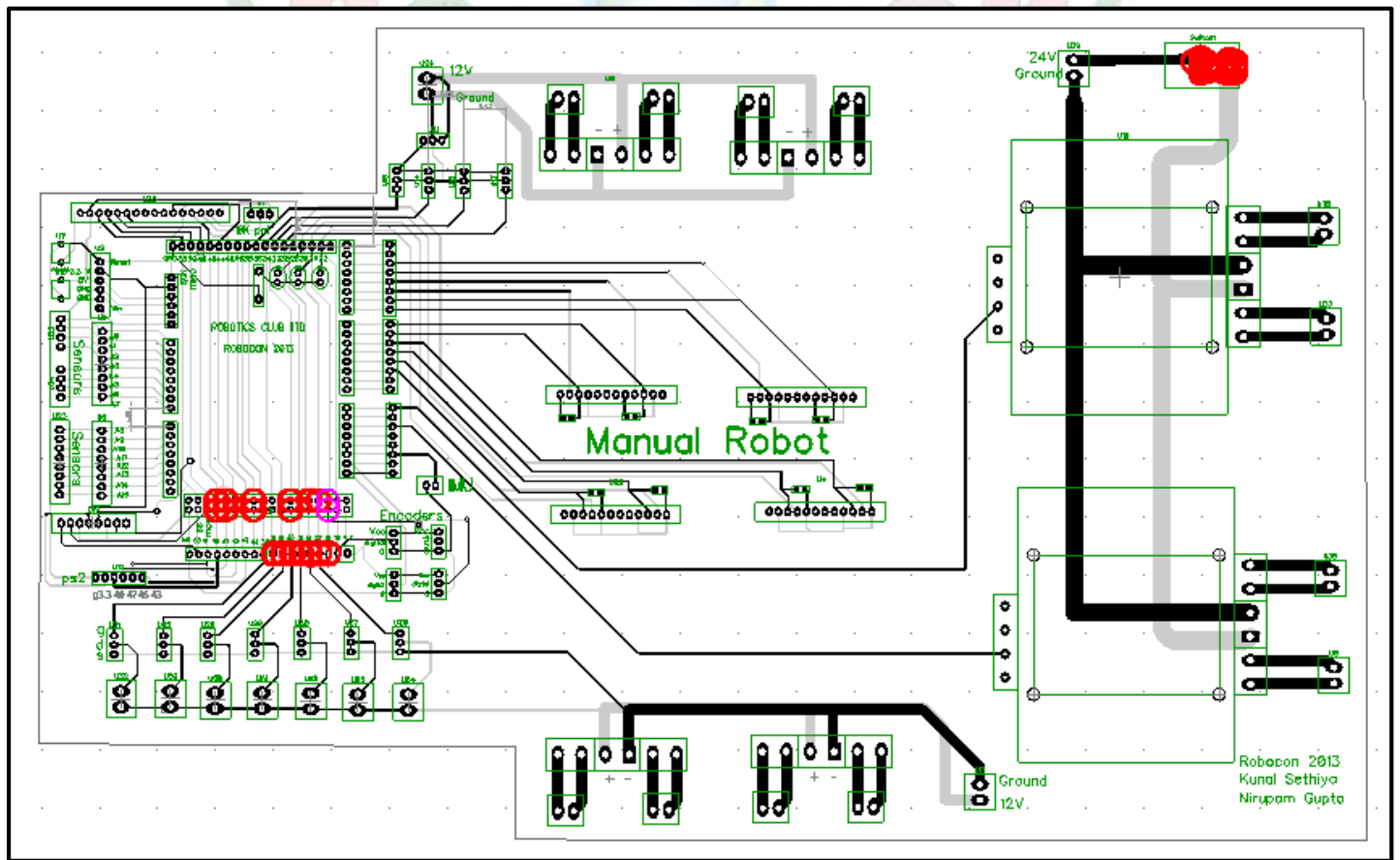


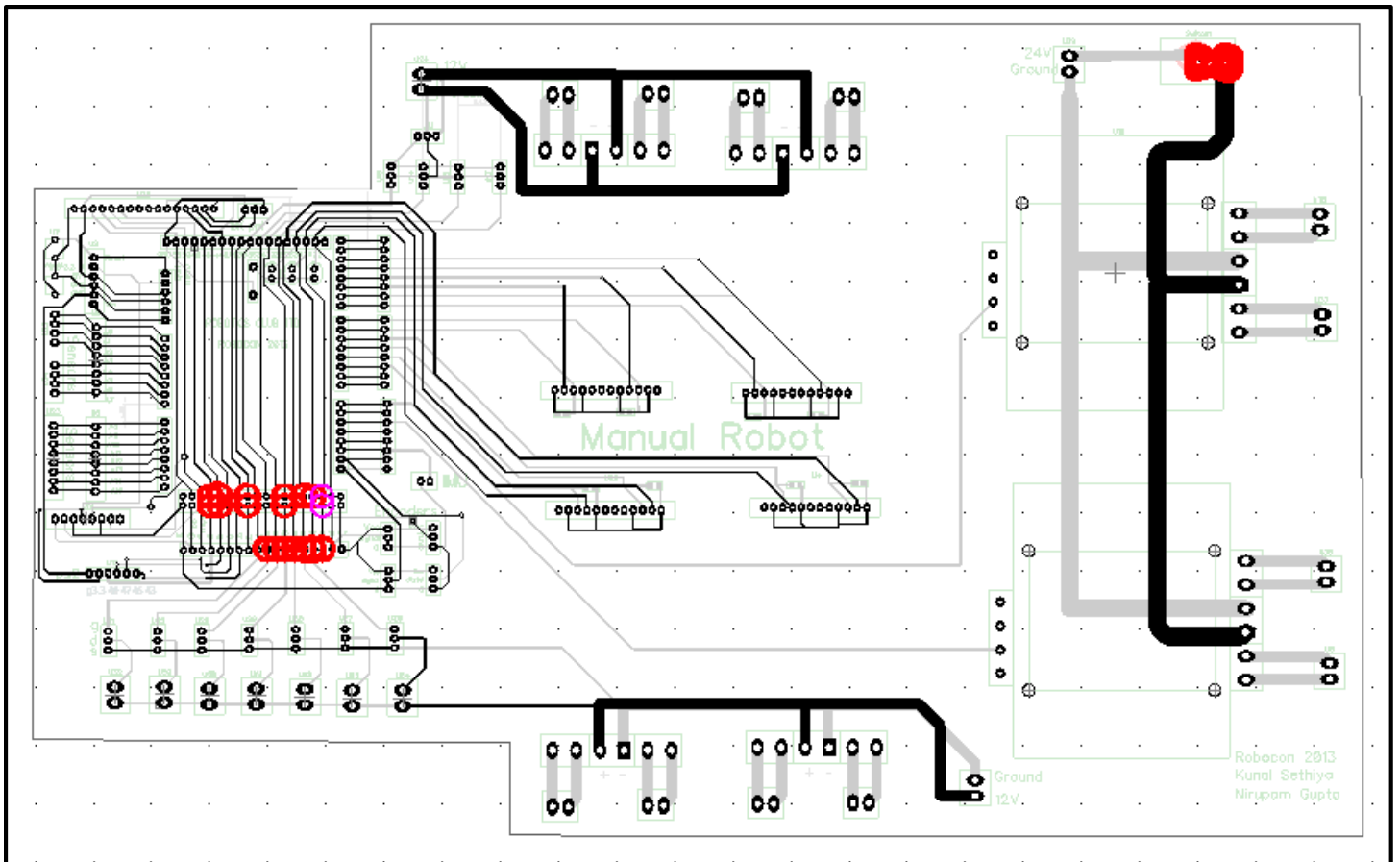
3. Automatic Robot (Both sides)





4. Manual Robot (Both sides)





For details of the code used by us for ROBOCON 2013, go to

<http://goo.gl/AqrzuL>