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Design and Development of Low Cost Serial Communication Mobile Robot

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Abstract— *In the present work two automated obstacle avoiding robots are designed as master and slave robot. To establish the communication between master and slave Bluetooth has been used. Interfacings and programming of motor drives, microcontroller and sensors has been done using arduino mega as it is easy to program and supports almost many important features. The proposed work gives successful result according to the master robot the slave robot is following the predefined path. The proposed master and slave unit is cost-effective and will have wide ranging applications in the fields of manufacturing, security, extreme-environment, entertainment and ROV (Remotely Operated Vehicle).*

Keywords— *Master robot, slave robot, Arduino and path.*

I. INTRODUCTION

A robot is a reprogrammable, multi-functional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks. The technology associated with the robots is called robotics. A robot is a machine capable of being set up and programmed to perform a wide variety of tasks for which it must physically move itself or other objects. Most tasks that robots do are repetitive, difficult, or hazardous to humans.

A robot can be defined as a flexible versatile system, these include, mechanical structure to perform the manipulative tasks, a manipulator, and a power unit, to provide the necessary energy, a sensor to detect the manipulator state and environment characteristics, a control unit, to program the task operation and regulate the robot. The flexibility of a robot refers to the capability of reprogramming the operation of the system for a variety of tasks. The versatility of a robot refers to the capability of performing a variety of manipulation tasks. The design and operation of a robot requires integration of many different systems with a multi-discipline mechatronic approach.

Robot is an autonomous machine that taken the place of humans in many areas mainly in dangerous environments or in manufacturing processes etc. Today robotics is a rapidly growing field. As technology advances continuously, the robots are builds for various practical applications. Many robots do the jobs that are hazardous to people such as defusing bombs, mines and exploring shipwrecks.

A. *Objectives*

The statement of the dissertation work is as follows: "To develop an automated autonomous robot to travel on predefined path avoiding obstacles while resuming the path". The two robot is to be design in such way that one master and other is slave .To establish the communication between master and slave Bluetooth has been used.

To start working on the dissertation, initially, some significant research is quickly reviewed. The main objective of this review was to identify which are the current trends in this application area, along with the state of art technology. Then in second phase, the vehicle aspects i.e. motion, steering, and control, the various sensors and transducers, and allied component suitable for the microprocessor are identified.

In the final phase, the following objectives are defined and step by step they are achieved through proper component interfacing and microcontroller programming gradually developed.

- To detect the hurdle in the path and avoid it using appropriate sensors,
- To establish to connection between master and slave using Bluetooth,
- Interfacings and programming of motor drives, microcontroller, camera and sensors together.

II. VEHICLE LAYOUT

The design of autonomous mobile robots capable of intelligent motion and action without requiring either a guide to follow or a remote-operator control involves the integration of many different systems. This makes mobile robotics a challenge worthwhile. To solve the locomotion problems as associate with mobile robotics, it is important to understand mechanisms and kinematics, dynamics and control theory. The robot implementation is about mechanical design, manufacturing, assembly, electronic design, programming microcontroller, and integrating software and hardware

A. Design Development

The kinematic analysis of robot steering allows a preliminary determination of wheel velocities given the vehicle dimensions, the desired radius, and the desired turn rate. However, as in the below kinematic model in Figure 1, no forces are studied. Therefore, the slippage is not accounted for; thus the kinematic model is even less accurate.

v_o =outside wheel velocity [m/s]

v_i = inside wheel velocity [m/s]

V = vehicle velocity [m/s]

Ω_z = vehicle angular velocity [rad/s]

R = vehicle turn radius [m]

L = vehicle length [m]

B = vehicle width [m]

Figure 1: Model of four wheel robot

DESIGN 1 - Four wheels robot (rear wheels drive)

As shown in Figure 2, four-wheel robot is designed to test the skidding and turning radius. It is a rear wheel drive which uses two independent bow motors. The design is to be test by calculating turning radius. The required turning radius should be between 0.20 m and 0.25 m.

Components of Robot

- Base Plate – 140 x 65 mm
- Four wheels – 70 mm diameter and thickness of the wheel is 6mm
- Two geared bow motors- 6 mm shaft dia.
- One front side free wheel mechanism rod of 6 mm step.

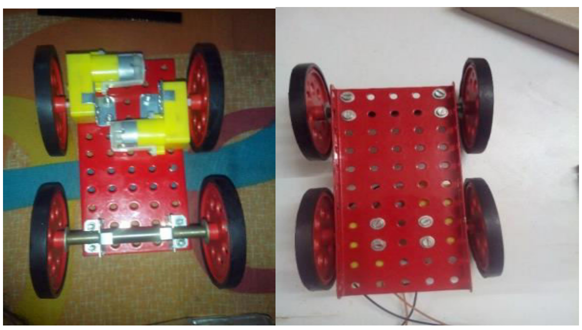
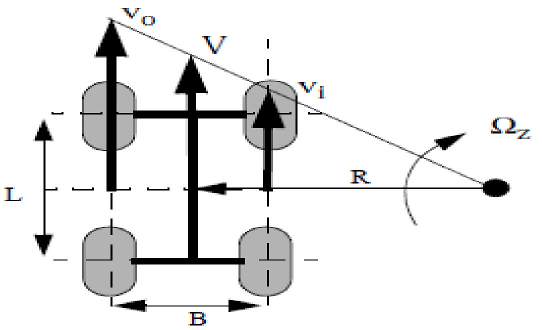


Figure 2: Design 1- Four wheel robot (2 wheel Drive)

Calculations of Turning Radius



The radius of the turn can be calculated from similar triangles:

$$\frac{v_o}{v_i} = \frac{R+\frac{B}{2}}{R-\frac{B}{2}} \quad (3.1)$$

$$R = \frac{\frac{B}{2}\left(\frac{v_o}{v_i}+1\right)}{\left(\frac{v_o}{v_i}-1\right)} = \frac{B}{2}\left(\frac{v_o+v_i}{v_o-v_i}\right) \quad (3.2)$$

Where R is turning radius.

B = vehicle width = 80mm = 0.08 m

L = vehicle Length = 90mm = 0.09 m

Wheel diameter = 70 mm

Calculating Speed of inner wheel v_i :

w = 150 rpm = 150 * 2phi / 60 =15.71 rad /s

Radius = 0.007 m /2 = 0.035 m

So,

v_i= rw = 0.035 * 15.71 = 0 .5498 m/s

Calculating Speed of outer wheel v_o :

w = 200 rpm = 200 * 2phi / 60 =20.94 rad /s

Radius = 0.007 m /2 = 0.035 m

So,

v_o= rw = 0.035 * 20.94 = 0.7330 m/s

So Turning Radius R is,

$$R = \frac{\frac{B}{2}\left(\frac{v_o}{v_i}+1\right)}{\left(\frac{v_o}{v_i}-1\right)} = \frac{B}{2}\left(\frac{v_o+v_i}{v_o-v_i}\right) \quad (3.3)$$

$$R = \frac{\frac{0.08}{2}\left(\frac{0.7330}{0.5498}+1\right)}{\left(\frac{0.7330}{0.5498}-1\right)} = \frac{0.08}{2}\left(\frac{0.7330+0.5498}{0.7330-0.5498}\right) = 0.28 \text{ m}$$

As calculated turning radius of the robot is 0.28 m, which is not according to requirement. While testing the skidding was also high. Hence, further research and experimentation has been done as per requirement.

DESIGN 2 - Two wheel ball bearing support robot (Rear wheel Drive)

As shown in Figure 3 two wheel ball bearing support robot is designed to solve the problem which occurred in design 1, i.e. the problem of turning and stability. This design 2 is quite well as skidding and turning radius meets our requirement, but stability problem was generated. It is hard to control due to its instability in straight path tracking. Hence, the further research and experimentation has been made to solve the problem of stability.

Components of Robot:

- Base Plate – 140 x 65 mm
- Two wheels – 70mm diameter & the thickness of wheel is 20mm
- Ball Bearing – 20 mm length
- Two Geared bow motors – 6 mm shaft diameter.

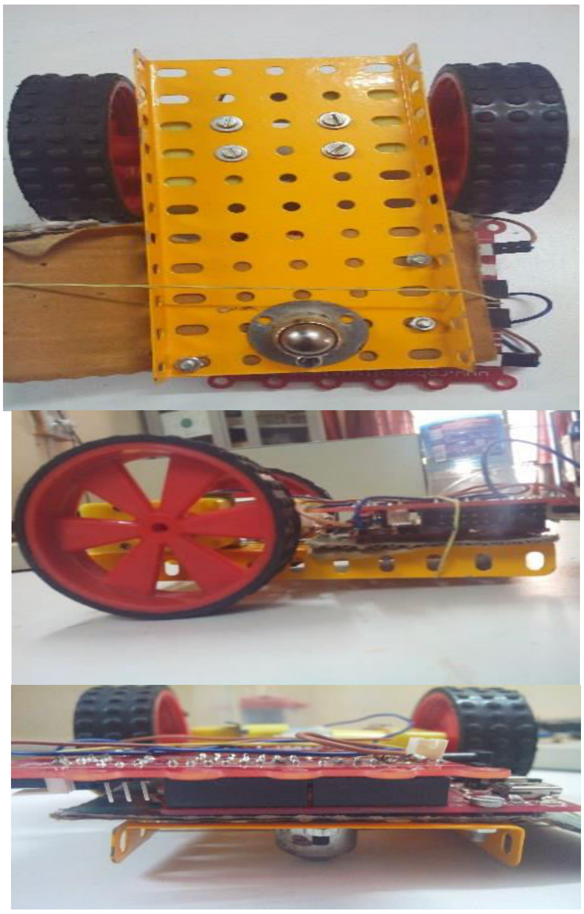


Figure 3: Design 2- Two wheel ball bearing support robot

DESIGN 3 – Four wheel Ackerman Steering rear wheel Drive

δ_2 = outside wheel heading [rad]

δ_1 = inside wheel heading [rad]

R = vehicle radius [m]
L = vehicle length [m]
B = vehicle width [m]
O = turn center location

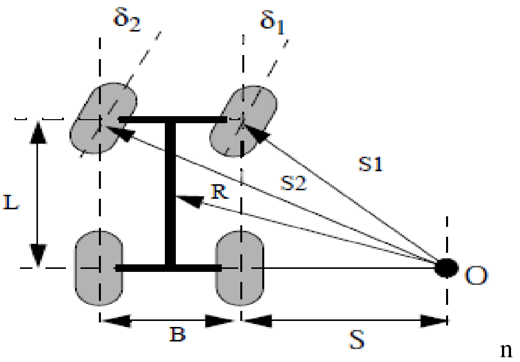


Figure 4: Model of four wheel steering

Calculations of design 3

To find turning radius calculation has been done as follow

Finding the turning location center of robot

$$S = \sqrt{R^2 - \left(\frac{L}{2}\right)^2} - \frac{B}{2} \qquad (3.4)$$

Outside wheel heading δ_1

$$\ddot{a}_1 = tan\left(\frac{L}{S}\right) \qquad (3.5)$$

Inside wheel heading $\ddot{a}_2$

$$\ddot{a}_1 = tan\left(\frac{L}{B+S}\right) \qquad (3.6)$$

As shown in Figure 5, four wheel ackerman steering with rear wheel drive is used. The skidding problem has been solved in this design. Minimum Turning radius is not as good as design 2 but it meets our design requirement according to calculation. The rear wheel contains a dc motor with geared box setup, which drive the robot in linear motion. To drive the ackerman steering of the robot a servo motor is used, which helps to steer the robot as per required turning radius. Hence calculation has been done, which proves that design is suitable for further experiment and research.

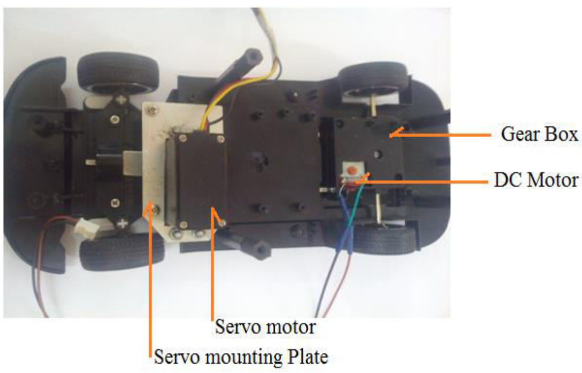


Figure.5: Design 3- Four wheel Ackerman Steering rear wheel Drive

Calculations of Turning Radius:

L = Length of robot = 140 mm = 0.14 m

B = Width of robot = 95 mm = 0.095 m

R = Vehicle Radius = L/2 = 0.14/2 = 0.7 m

Finding the turning location center of robot

$$S = \sqrt{R^2 - \left(\frac{L}{2}\right)^2} - \frac{B}{2} = \sqrt{0.7^2 - \left(\frac{0.14}{2}\right)^2} - \frac{0.095}{2} = 0.649 \text{ m}$$

Outside wheel heading $\ddot{a}_1$

$$\ddot{a}_1 = \tan\left(\frac{L}{S}\right) = \tan\left(\frac{0.14}{0.649}\right) * 57.296 = 0.216^{\circ}$$

Inside wheel heading $\ddot{a}_2$

$$\ddot{a}_2 = \tan\left(\frac{L}{B+S}\right) = \tan\left(\frac{0.14}{0.095+0.649}\right) * 57.296 = 0.188^{\circ}$$

Minimum Turning Radius for Ackerman Steering

Turning radius = track / 2 + wheelbase / sin (steering angle in degrees)

$$= \left(\frac{95}{2}\right) + 140 / \sin\left(\frac{55+38}{2}\right)$$

$$= 0.24 \text{ m}$$

The minimum turning radius of ackerman steering is 0.24 m as per requirement. It is also stable while travelling on straight path. So design 3 is better than other designs hence, design 3 has been finalized and it is ready for further modification.

B. Wheel Drive

In order to simplify the overall construction, several changes has been done in to the autonomous robot chassis. Due to complex mechanical structure and expensive to manufacture, a stable rear axle has been used instead of independent wheel suspension. This solution allows the chassis to deal with terrain irregularities and stay mechanically simple at the same time. The body of the robot is divided into two parts, the rear and the front. The rear axle has no mechanical differential fitted – the drive units of both rear wheels are independently controlled by the master control system to set appropriate speed to the wheels. In dependency on the actual steering angle and the desired forward speed of the wheels are computed and set to the drive the robot in desired way. Figure 6 shows the mechanism used for rear wheel drive. As described that one dc motor is used to drive the rear wheels of the robot, which is controlled by controller.

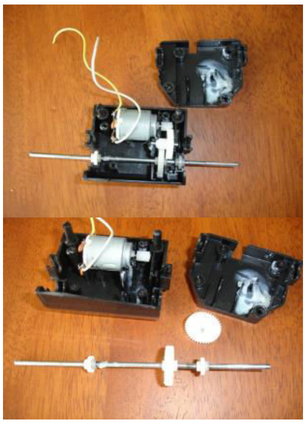


Figure 6: Rear wheel drive gear mechanism setup

C. Front Servo Steering

The real steering mechanism is controlled by a geared DC motor. For better control of the steering servomotor is preferred. Most important factor is the strength against upward force, which occurs when pressing the car against the floor for better load. Every floor is a bit bumpy, so without suspension the wheels would lose contact. So the steering is designed for flat surface based application only. The ratio of the rear wheel angular speeds is dependent only on the steering angle and the ackermann steering is supported by the rear wheel with speeds ratio for better control. The front steering consist servo motor with linear mechanism. To control the steering of the robot linear mechanism has manufactured as per requirement. The mechanism is shown in Figure 7. The servo angle set as per requirement for linear motion and the motor is control by the controller. The mechanism is light weight according to requirement.

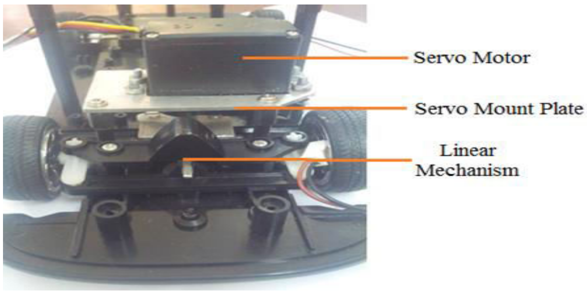


Figure 7: Front Servo Steering Mechanism

III. MOTOR DRIVING CONTROL

The PIC, 8051, ARM, AVR these are the controllers which are used while designing the robot. Recently AVR controller is used in many robots for their advanced features. arduino Programming is challenging and interesting as it has all the features, which are required to achieve all the objectives set forth in this work. The motor driving shield, master slave shield etc. shields are used in arduino, to make interfacing process easy. Such type of shields are not used in other microcontroller, so arduino mega microcontroller is used with driving shield.

Arduino Mega Microcontroller

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. Arduino receiving input signals from a variety of sensors, using these signals ardunio controlled lights, motors, and other actuators.

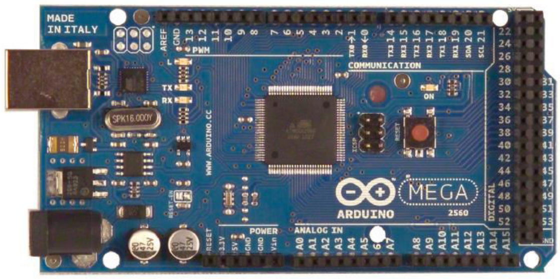


Figure 8: Arduino Mega 2560

The microcontroller on the board is programmed using the arduino programming software. The specification of ardunio mega has given in table 1.

Table 1 Specification of Ardunio Mega

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54
Analog Input Pins	16
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB
SRAM	8 KB
EEPROM	4 KB

Arduino Motor Drive Shield

While designing the robot motor driving shield is used for arduino. In this shield provision are given to connect the DC motors, IR sensors and servo motor. The setup is shown in Figure 9.

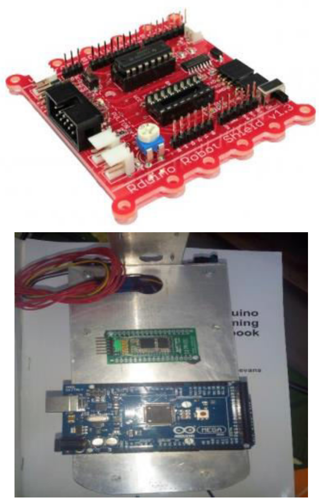


Figure 9: Assembly arduino Mega on robot & shield

IV. OBSTACLE AVOIDANCE

The sensors are used to detect the hurdle in the path and avoid it. There are different sensors such IR sensor, Ultrasonic sensor, LASER sensor, etc. Avoidance of the obstacles is important for autonomous robot to move from initial position destination.

TSOP-OBSD–Single

The TSOP (Thin Small Outline Package)-OBSD-single is a general purpose proximity sensor. It is used for obstacle detection purpose. The module consists of an IR emitter and a TSOP receiver pair. The high precision TSO receiver always detects a signal of fixed frequency. Due to this, errors due to false detection of ambient light are significantly reduced.

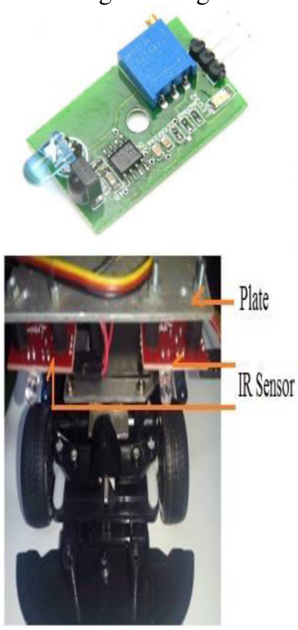


Figure 10: TSOP-OBSD

Features of IR Sensor

- Allows your robot to detect obstacles.
- Typical Maximum Range -20cm.
- Modulated IR transmitter to avoid any interference.
- Calibration preset for range adjustment.
- Indicator LED with 3 pin easy interface connector.

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The module consists of 555 IC, working in a stable multi vibrator configuration. The output of TSOP is high whenever it receives a fixed frequency and low otherwise. The on-board LED indicator helps user to check status of the sensor without using any additional hardware. The power consumption of this module is low. It gives a digital output and false detection due light is low.

V. WIRELESS SERIAL COMMUNICATION – BLUETOOTH

The PC to Arduino Bluetooth serial connection can be useful in many applications such as controlling servos, motors, and writing to LCDs. The arduino to host computer can be useful in applications, where the arduino reads sensors then pass their values via serial Bluetooth to a host computer for processing. The distance for this transceiver is about 30 feet or so but it really depends on many other variables. The module is used in robot to indicate host computer with message when robot is lost.

Figure 11: Bluetooth serial HC-06 assembled on robot

Features

- Bluetooth Spec v2.0+EDR Compliant.
- Enhanced Data Rate compliant with V2.0.E.2 of specification up to 3Mbps modulation modes.
- Full Speed Bluetooth Operation with Full Pico net Support and Scatter net Support.
- Incredible small size with 3.3V input.
- UART interface and with baud rate setup function.
- Support for 8Mbit External Flash Onboard.
- Support for 802.11Co-Existence.

Bluetooth Master- Slave

For master slave communication Bluetooth boards with shield is used in arduino board. The board use piconet networking inbuilt under arduino. A piconet is an ad-hoc network linking a group of devices using Bluetooth technology for master-slave communication.

Master – Slave serial communication structure

Master- Device in piconet whose clock and hopping sequence are used to synchronize all other devices (slaves) in the piconet. It also carries out paging procedure and also connection establishment.

Slaves- Units within the piconet that are synchronized to the master via its clock and hopping sequence. After connection establishment, slaves are assigned a temporary 3 bit member address to reduce the no. of addressing bits required. After establishing the connection the slave perform the operations as per instruction, which has been given by the master. In this dissertation concept of point to point piconet is used. Point to point piconet means 1 master and 1 slave robot.

VI. PROGRAMMING AND EXECUTION

The main objective of dissertation to avoid the obstacles and communicate with other robot using Bluetooth. The programming pat of robot is divided in two parts. First is programming for obstacle avoidance and second is programming for communication between master and slave.

Obstacle Avoidance

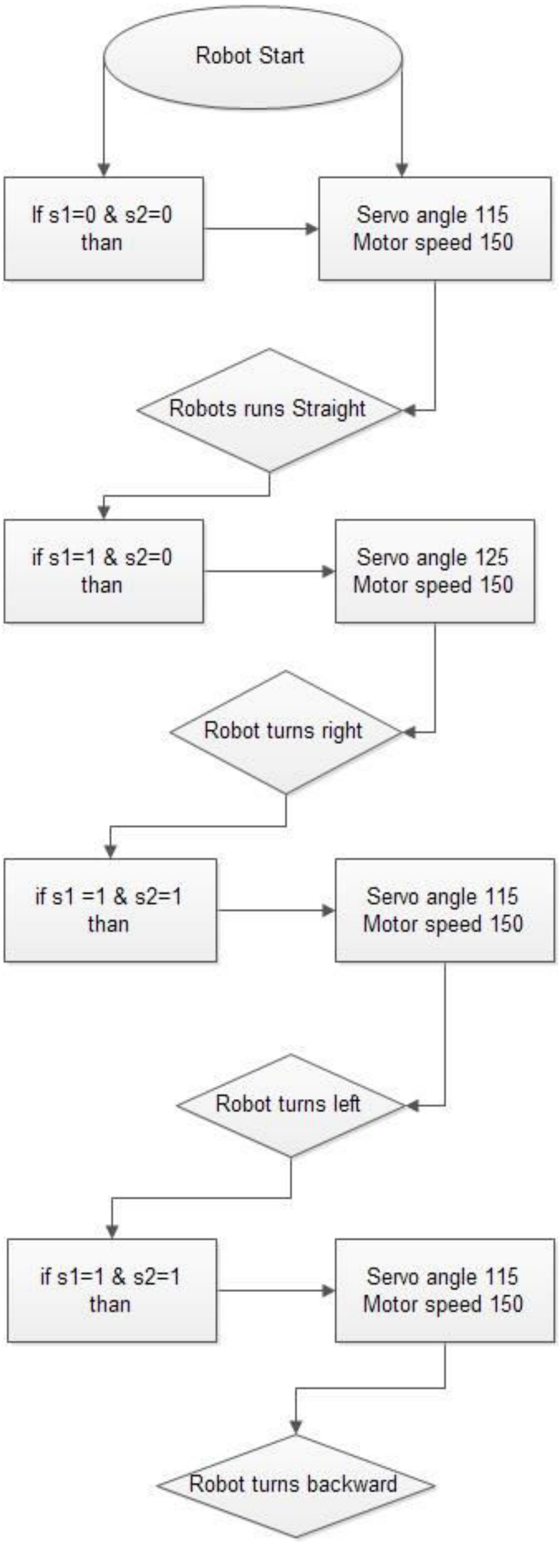

Fig 12. Flowchart on process of obstacle avoidance robot

Bluetooth master slave serial communication programming

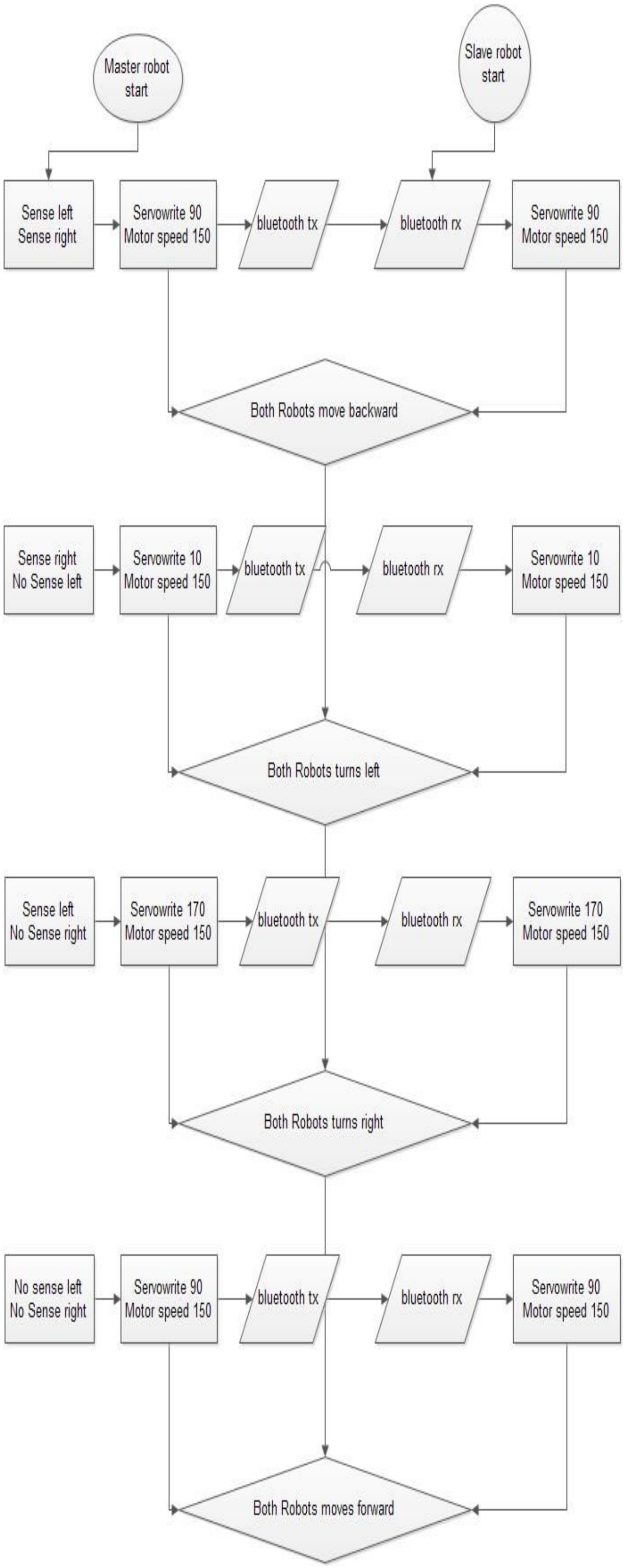

Fig 13: Flow chart on process of Master-Slave Robot

VII. FINAL ASSEMBLY OF ROBOT

The assembly of automated vehicle is shown in Figure 14. It consist of arduino mega 2560, which controls the operations of the robot. It is four wheel robot employing IR sensor to avoid obstacles. The Bluetooth is used for wireless serial communication between master and slave robot.

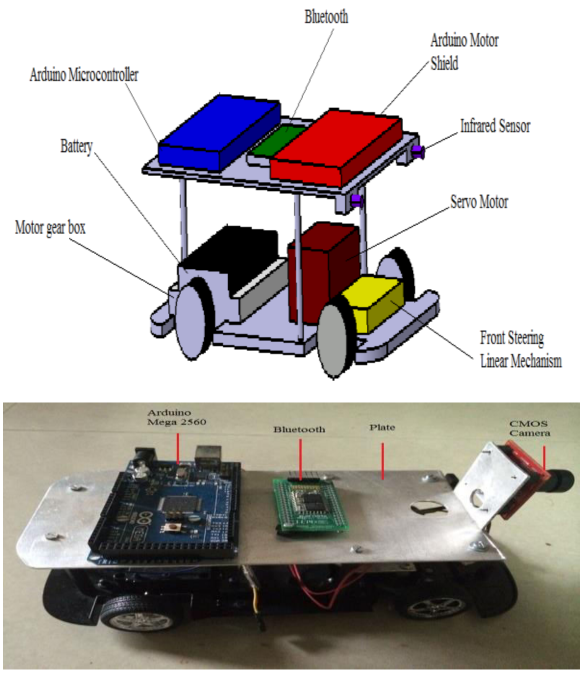

Figure.14 Assembly of automated vehicle

VIII. RESULTS & DISCUSSION

Master- Slave robot tracking in one arena

Two robot are designed to avoid the obstacle and as per requirement the first environment is created. There are total 3 obstacles that is used as shown in Figure 15. The green circle is master robot and blue circle is slave robot. The Path is predefined and robot. The black line is path of master robot while blue line is tracking path of slave robot. Master robot and slave robot is placed at a distance calculated with respect to delay in programming. Master robot detects obstacle and avoid it. Master robot sends signal to slave robot with help of Bluetooth. Slave robot follows master robot without using obstacle sensor as command prompt given by master robot. Master robot detects obstacle 1 and it gives instruction to slave robot while taking right turn. There is delay set in programming of receiving signal from master robot. When slave robot reach near the obstacle it takes right turn without using obstacle sensor. Master robot reach near obstacle 2. Master robot takes left turn and gives signal to slave robot. When slave robot reach at the position near obstacle 2, it also takes left turn. Master robot reaches obstacle 3 moves backward and take right turn. It sends signal to slave robot using Bluetooth and reaches end point. Slave robot follow the same path as instructed by master robot.

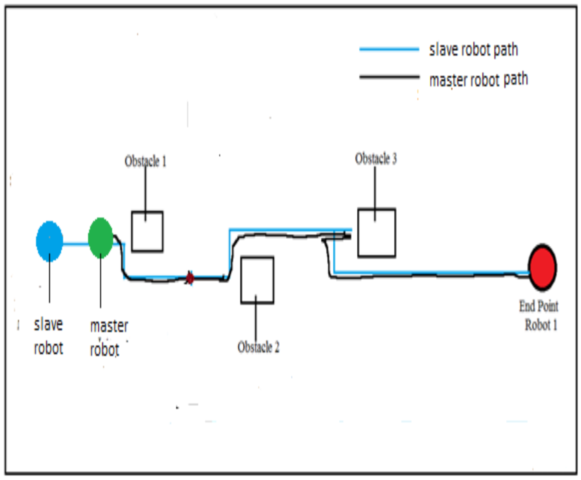

Figure 15: Master-Slave one Path following robot

Master- Slave robot tracking in two arenas

Two robots are designed to avoid the obstacle and as per requirement the second environment is created. Master robot is placed at one platform with obstacles as shown in figure. Slave robot is placed at other platform with same setup but without obstacle sensor. Master robot and slave robot communicates using Bluetooth.

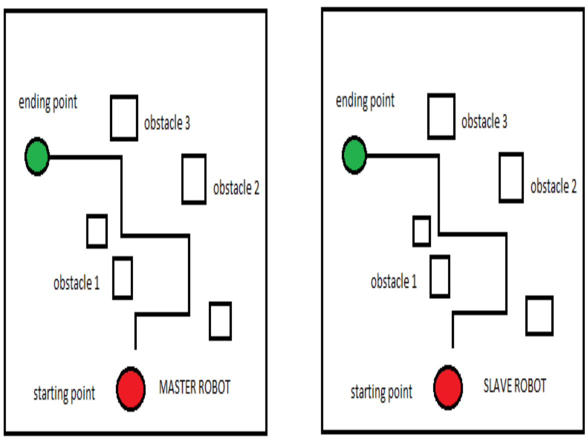

Figure 16: (i) Master Robot with obstacle sensors. (ii) Slave Robot without obstacle sensors.

Master robot detects obstacle 1 and take right turn and then take left turn. Master robot sends signal to slave robot without delaying. Slave robot takes command and avoids obstacle in other platform without using obstacle sensor. Master robot reaches obstacle 2 takes left turn and right turn. Slave robot takes signal from master and resumes the same path. Master robot reaches obstacle 3 and takes left turn till end point. Slave robot without any delay takes signal and executes the same process.

IX. SUMMARY

While designing of robot three types of designs has been implemented. The calculation has been done for better steering control of chassis. The design 3 gives turning radius around 0.24m and better stability so it is selected for further research. To drive the robot one dc motor is selected. For the control of steering special servo linear mechanism is designed and installed. Arduino shield is selected, which supports feature like RF pro module, 2 IR sensors and motors with additional IC. Arduino MEGA is used on basis of arduino shield. Components of robot like Bluetooth, Camera, Arduino Mega, Battery, etc is installed on robot. The motor drive control and Bluetooth master- slave serial communication programming has been done and result is quiet successful.

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