Minor Project

Unmanned Mapping Vehicle Using L.O.A.M.[1] in Real-time

Technical Report

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Automation and Robotics Dept.
B. V. Bhoomaraddi College of Engineering and Technology, Hubli.

Team 9

Adarsh Belvatagi	2BV13AR002
Darshan Bafna	2BV13AR018
Manikanta Pujar	2BV13AR031
Prajankya Sonar	2BV13AR043

[1] L.O.A.M. - Lidar Odometry and Mapping in Real-time

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Abstract:

This project is about an Unmanned Mapping Vehicle Using L.O.A.M. in Real-time that is achieved by using ROS(Robotic Operating System) which will map any indoor environment, RPlidar is an sensor that will help us to map the environment, for navigation of the bot IMU(Inertial measurement unit) is used. RPlidar and IMU are connected to Arduino and inturn it is connected to NUC mini computer which is on the bot, all the commands are sent to master in NUC from the maincontroller.

Introduction:

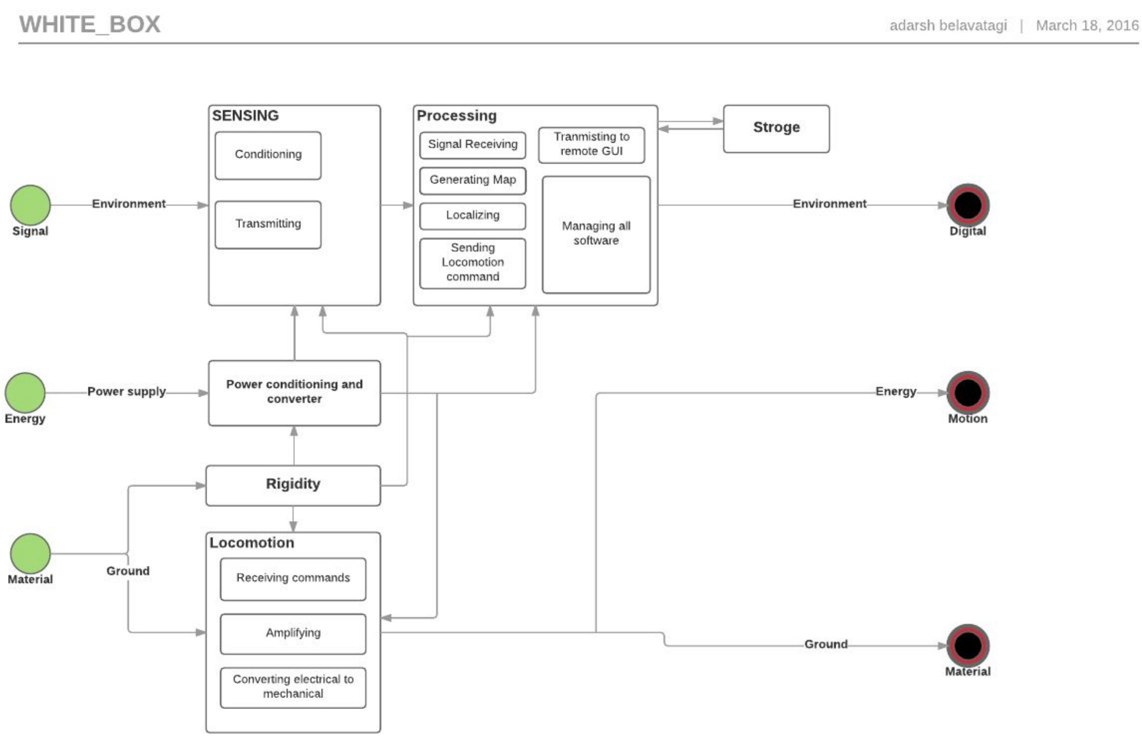
Mapping, localization, and path-planning are three fundamental problems of robot. Robot needs a map to perform actions like path-planning. When positioning system is not available, the map is also used for localization. Therefore here we use an RPLIDAR to help us map the indoor environment with the help of Robotic Operating System in 2D.

1. Requirement list

1.1. Autonomous 3D mapping device
1.2. Bot should be compact
1.3. Generate 3D map of the environment and save it
1.4. It should avoid obstacle
1.5. It should be independent
1.6. It should locate itself when left in an unknown terrain`
1.7. Bot should be light weight
1.8. Should have emergency stop button
1.9. Battery backup should be good
1.10. The bot could be manually overridden with the help of an Graphical User Interface

2. Functional Analysis

2.1. 3D mapping
  2.1.1. RP LIDAR(sensor)
2.2. Autonomous
  2.2.1. Locomotion
  2.2.2. Power supply
  2.2.3. Obstacle detection
2.3. Storage
  2.3.1. Memory to save the data of the 3D map
2.4. Manual control
  2.4.1. Use of an remote joystick to manually control the bot using an GUI.



3. Performance specification

3.1.Rplidar

3.1.1. Range: 0.2 m(min)\
3.1.2. 6.0 m(max)
3.1.3. Angular range : 0-360 Degree
3.1.4. Distance Resolution: 60mm
3.1.5. Angular Resolution: 1 Degree
3.1.6. Sample Frequency :>=2000 Hz
3.1.7. Scan rate : 5.5 Hz
3.1.8. i/p voltage : 6V

3.1.9. o/p voltage : 6V
3.1.10. Weight: 170 gm

3.2.IMU [GY80]

3.2.1. L3G4200D: Gyroscope
3.2.1.1.Measurement range:± 500 dps
3.2.1.2.Sensitivity :17.5 mdps/digital
3.2.1.3.Digital zero rate level: ±15dps
3.2.1.4.Zero rate level charging v/s temp:±0.04dps
3.2.1.5.Non linearity:0.2 of measurement range
3.2.1.6.Rate noise density: 0.03 dps/sqrt HZ for 150 HZ
3.2.1.7.Operating temp: -40 to 80 c\
3.2.2. ADXL345- Digital accelerometer
3.2.2.1.Measurement range: ± 2 ±4 ±6 ±8 ±16 g
3.2.2.2.Output resolution: 12 bits for ±8 g range
3.2.2.3.Noise (x,y axis): 0.75 LSB rms Z direction 1.1 ILS me
3.2.2.4.Power supply: min 140mA 5V
3.2.2.5.Operating temp: -40 to 85 ◦C
3.2.3. HMC5883L 3 axis Digital compass
3.2.3.1.Supply voltage: 2.16 to 3.6V
3.2.3.2.Field range: -8 to +8 gauss
3.2.3.3.Magnetic dynamic range: ±1- ±8 gauss
3.2.3.4.Sensitivity: 220 to 1370 ISB /gauss
3.2.3.5.Operating temp: -40 to 85 ◦C

1.1. Intel NUC DN2820

3.2.4. Processor: Intel Celeron Processor N2820
3.2.5. Memory: 8gb max
3.2.6. Graphics: Intel HD graphics up to 756 MHz
3.2.7. Peripheral Connectivity
3.2.7.1.1 * USB 3.0 port on the front panel
3.2.7.2.2 * USB 2.0 port on the back panel
3.2.7.3.Front panel 1R sensor
3.2.8. Storage: Internal for 2.5 inch HDD or SSD
3.2.9. Dimensions: 116.6 mm *112mm*515mm
3.2.10. Power adapter: 12V 36W wall mount AC

3.3.Power supply

3.3.1. Lithium polymer - (11.2V 5.5A)
3.3.2. UBEC - Input 24V Output 12V
3.4.Screw & Bolt
3.4.1. Size M4
3.5.Material for base

3.5.1. Acrylic

4. Morphological chart

Sl.no	FUNCTION	Alternative1	Alternative2	Alternative 3
1	Sensing			
1.1	**obstacle**	IR	LIDAR	Proximity
1.2	**Position/Orientation**	Gyro	Magnetic	IMU
1.3	**Surrounding**	LIDAR	Kinect	Image processing
2	Processing			
2.1	**Signal Receiving**	ATMEL	Intel NUC	RASBERRY
2.2	**Generating Maps**	ROS	Hector_mapping	
2.3	**Localizing**	AMCL	ROS_hector	
2.4	**Localizing commands**	Microcontroller (arduino ,PLC)	Microprocessor	FPGA
2.5	**Managing all programs**	ROS	Custom programming	Player_Stage
2.6	**Storage**	Hard Drives	Google Drive(cloud)	Intel NUC
2.7	**Transmitting to Remote GUI**	RF	wifi	Optical link
2.8	**Power conditioning**	Transformer filter circuit	Battery Eliminator circuit	Linear regulator circuit
3	Locomotion			
3.1	**Receiving commands**	Microcontroller (arduino,PIC)	Microprocessor	FPGA

3.2	**Amplifying**	Motor driver	H-bridge	Relay operated
3.3	**Converting electrical to Mechanical**	solenoid	motor	
4	Rigidity			
4.1	**Between motor and base**	L clamp	C CLAMP	Screw and nuts
4.2	**Between two acrylic sheet**	C clamp	Screws and nuts	Studs and screws

WHY Rplidar?

	Hokuyo URG-04LX Scanning Laser Rangefinder	Parallax 15-122cm Laser Rangefinder	Hokuyo UTM-30LX-EW Scanning Laser Rangefinder	Loke 0.2 to 30m Industrial Laser Distance Meter (10Hz)	Loke 0.2 to 35m Industrial Laser Distance Meter (50Hz)	Hokuyo UXM-30LN-PW Scanning Laser Rangefinder	Hokuyo UST-10LX Scanning Laser Rangefinder	RPLIDAR 360° Laser Scanner	LeddarTech LeddarOne Optical Rangefinder (RS-485)
	RB-Hok-01	RB-Plx-257	RB-Hok-16	RB-Hok-11	RB-Hok-09	RB-Hok-14	RB-Hok-24	RB-Rpk-01	
Serial (UART) Pins	1	1	0	0	0	0	0	1	0
USB	1	0	1	0	0	1	0	1	0
Nominal Current [A]	0.5		0.7	0.0042	0.0042	0.3		130	
Nominal Voltage [V]	5	5	12			24		5	5
Voltage (Min) [V]			0	10	10		0.15	3.6	5
Weight	160 g		370 g	500	4000 g	800 g	130 g	200 g	
Accuracy [mm]	60mm à 1m : ±10mm, 1m à 5m : 1% de la distance	<5%, average 3%	0.1 to 10m:±30mm, 10 to 30m:±50mm*1	±2 mm à ± 5 mm	Environ ±2mm	0.1 to 10m : ±50mm, 10 to 30m : ± 100mm	+/- 40mm	<0.5mm (1% of the distance)	50
Angular Resolution [°]	0.36		0.25			0.25	0.25	1	
Distance Min	20 mm	0 mm	30000 mm	200 mm	200 mm	100 mm	20 mm	200 mm	0 mm
Angle [°]	240		270			190	270	360	
Scan Time	100		25			50	25	0.18	

Voltage (Max) [V]				30	30			9	5
Distance Max	4000 mm	2400 mm	60000 mm	150000 mm	150000 mm	30000 mm	10000 mm	6000 mm	20000 mm

From the above comparison of sensors ,We can Notice that Rplidar as good characteristics and its cost is also less comparative to other sensors..

1.Sensing

1.1 & 1.3 Obstacle detection and surrounding sensing

- Rp lidar 360°- is preferred than IR and PROXIMITY sensor because A laser scanner development kit with omnidirectional laser scan,it works on the principle of laser triangular whose speed is very high, it is the ideal sensor for robot localization, mapping & obstacle detection and safety ,it has the range of 6 meters ,1 degree angular resolution,5v power supply.

1.2 Position and orientation- IMU

- IMU is used because it consist of 4 sensors i.e ADXL345 digital accelerometer ,HMC5883L digital compass, L3G4200D gyroscope and BMP085 digital barometer which gives the sensor 10DOF , there are built in regulator and logic converter to support 3.3V/5.0V microcontrollers, 12C digital interface,The sensor is very compact too.

2.Processing

2.1 Signal receiving - Intel NUC

Intel NUC is a compact mini computer with full-size computing power, lots of I/O ports ,IR receiver and with a smaller footprint than a wireless modem, the Intel NUC with the 4th generation Intel Core i5 processor It also includes Intel Rapid Start Technology, ensuring you are quickly up and running, and Intel Smart Connect Technology to keep you up to date at all times.

2.2 Generating maps: ROS

Robotic operating system has an 3D visualizer tool called as RVIZ which helps us to generate the map with utmost accuracy and helps us to visualize the map in real time .

2.3 Localizing: ROS_HECTOR

Hector_mapping is a SLAM approach that can be used without odometry as well as on platforms that exhibit roll/pitch motion (of the sensor, the platform or both). It leverages the high update rate of modern LIDAR systems like the Hokuyo UTM-30LX and provides 2D pose estimates at scan rate of the sensors (40Hz for the UTM-30LX).

2.4 Localizing commands: Micro controller

Commands to the bot are given by the microcontroller

2.5 Managing all programs:ROS

ROS is an open-source, meta-operating system for your robot. It provides the services you would expect from an operating system, including hardware abstraction, low-level device control, implementation of commonly-used functionality, message-passing between processes, and package management. It also provides tools and libraries for obtaining, building, writing, and running code across multiple computers. ROS is similar in some respects to 'robot frameworks’

2.6 Storage: Intel NUC

Since we are using mini computer we have an storage space of 1.5 to 2 TB of data can be stored which is more than enough to store the maps and navigation data.

2.7 Transmitting to Remote GUI: Wifi

Since our mini computer has the facility of wireless communication we take the advantage of this facility and reduce the complication of keeping an receiver and transmitter.

2.8 Power conditioning:UBEC

It is an universal battery eliminator circuit is an electronic circuit designed to deliver electrical power to other circuitry without the need for multiple batteries. Historically the expression was sometimes used to describe devices used to power battery-driven equipment from mains electricity. This is still the case in many products offered in retail electronic supply stores.

3.Locomotion

3.1 Receiving commands:Microcontroller (arduino,PLC):

Commands are sent to the bot via arduino software through ROS and microcontroller receives the commands and induces locomotion.

3.2 Amplyifying : Motor driver

Signals from the microcontroller are sent to motor via motor driver where the signals gets amplified

3.3 Electrical to mechanical:Motor

Motor converts the electrical signal received from the driver and converts them into mechanical energy for the locomotion.

4.Rigidity

4.1 Between motor and base of the bot: C clamp

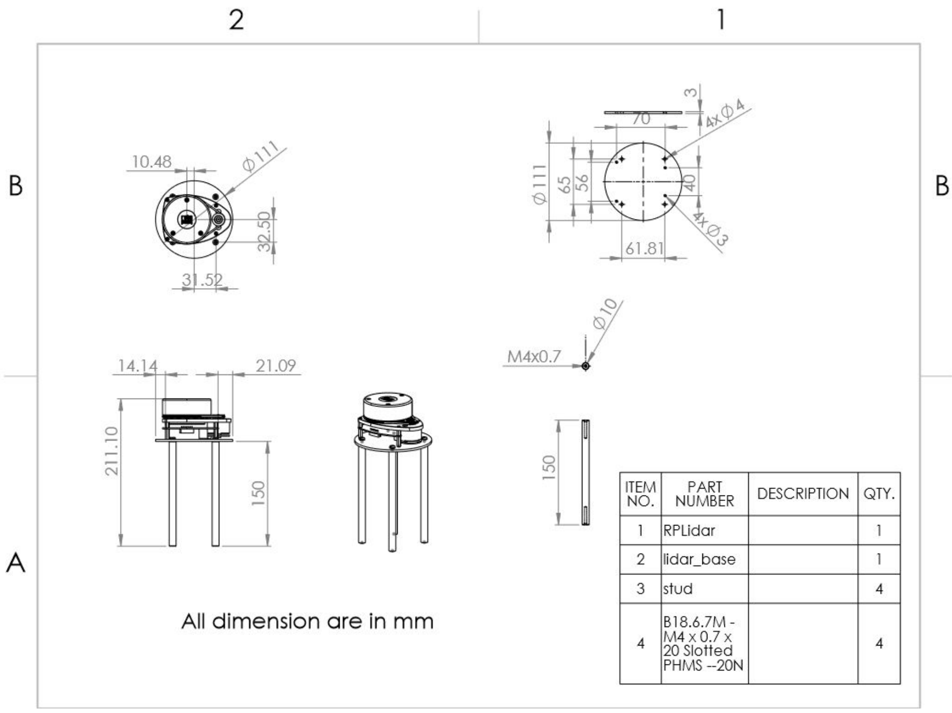
As the motor is placed between two acrylic sheet(base) so C-clamp is used to fix the motor to the bot base for stability

4.2 Between 2 acrylic sheet: Studs and screws

To fix the two acrylic sheets we use Studs and and screws of size M4

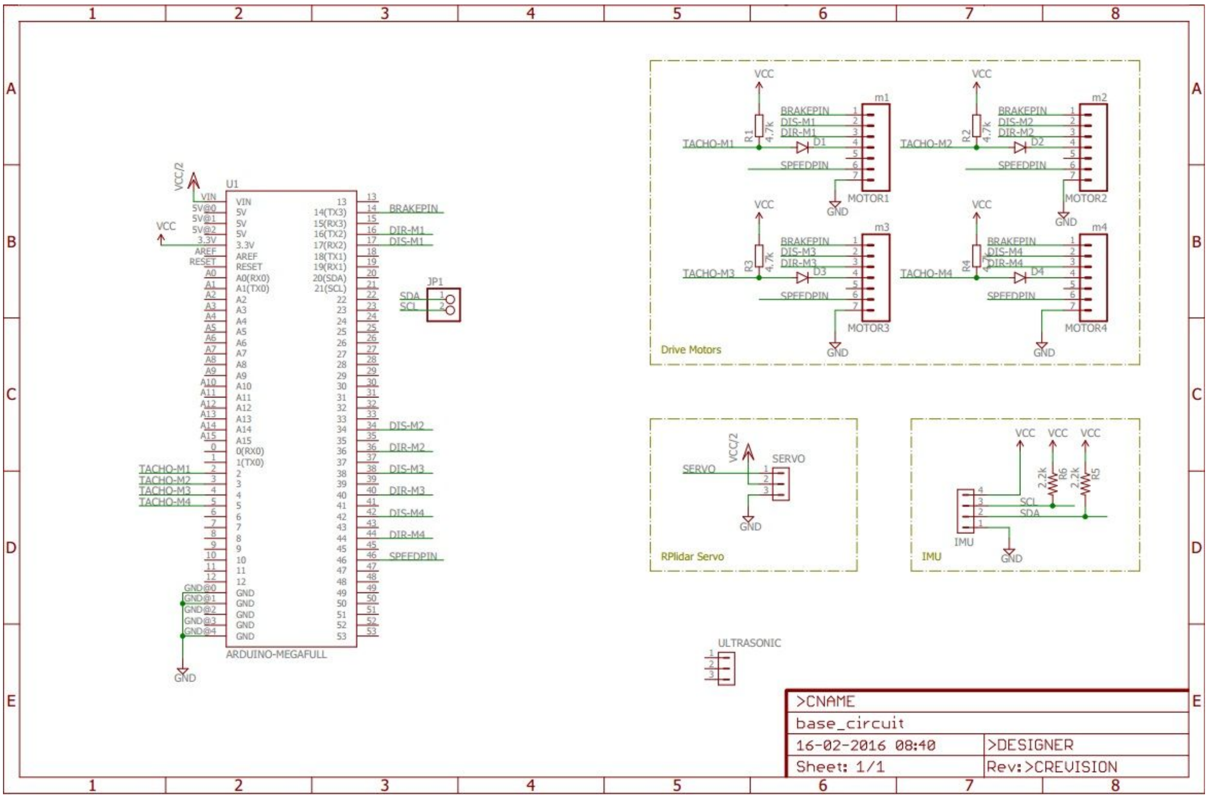
5. Detailed design and Production drawings

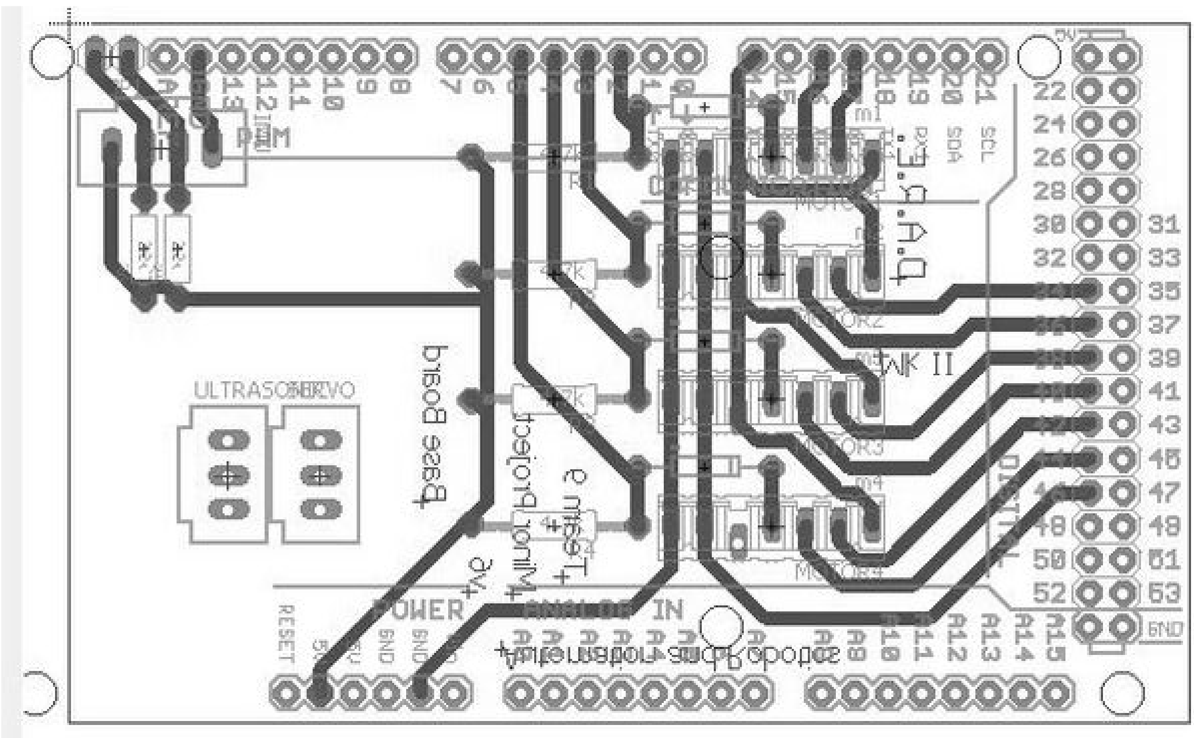
5.1. Mechanical



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	RPLidar		1
2	lidar_base		1
3	stud		4
4	B18.6.7M - M4 x 0.7 x 20 Slotted PHMS --20N		4

5.2. Electronics





6. Bill of materials & Component Procurement

6.1. Electronics

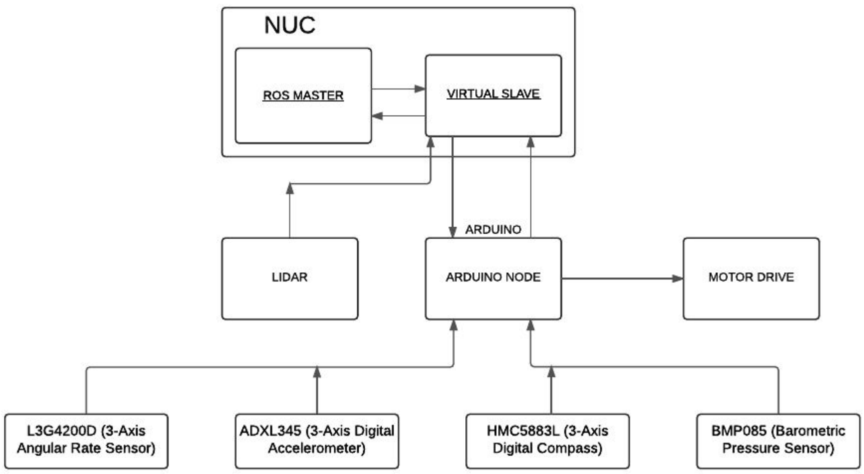
SL.NO	COMPONENT	QUANTITY	VENDOR	Price
1	RPlidar	1	Tennettech.com	37000₹
2	IMU 10dof	1	Probots.co.in	1000₹
3	NUC mini Pc	1	Dept. of Automation & Robotics	10000₹
4	Resistors 330 ohm	2	New Gokhale Electronics	4₹
5	Motor	4	Robu.in	20000₹
6	Motor Driver	4	Robu.in	20000₹
7	Resistors 2.2k ohm	4	New Gokhale Electronics	4₹
8	8pin connector male	4	New Gokhale Electronics	60₹
9	8pin connector female	4	New Gokhale Electronics	60₹
10	PCB	1	New Gokhale Electronics	30₹
11	Power supply 22.2V	2	robomart.com	13800₹
12	UBEC	1	robomart.com	1000₹
13	Screw Terminal	2	micro electricals	20₹

6.2. Mechanical

SL.NO	COMPONENT	QUANTITY	Material VENDOR	Price
1	OMNI wheels	4	Robu.in	36000₹
2	C-clamp	4	Fabricated	285₹
3	Studs 2 1/2	35	Asian hardware	169₹
4	Base board	2	Fabricated	1480₹
5	Nuts(M4) and Bolts(M4)	78	Asian hardware	565₹
6	motor shaft	4	rupa metals	245₹
7	Side link	1	Fabricated	50₹
8	Feedback wheel	1	Fabricated	60₹
9	Feedback base	1	Fabricated	60₹
10	Hight plate	1	Fabricated	60₹

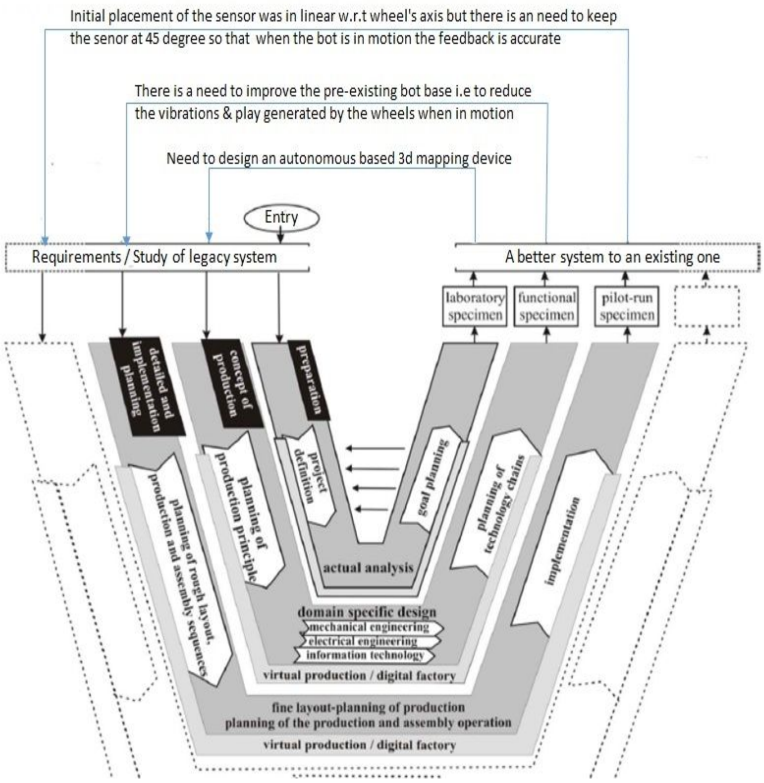
7. Hardware / Software architecture

Hardware / Software architecture Team 9 | March 12, 2016



Hardware consists of NUC mini computer which has the ROS master which communicates with a Virtual slave within it, RPlidar sends the real time information to the virtual slave i.e in NUC which intern communicates with the master and makes the map of the surrounding along with this we have have arduino communicating with the slave through a Node that is created by ROS and controls the motor drivers,we have IMU i.e inertial measurement unit which consist 4 sensors Angular rate sensor,Digital accelerometer, Digital compass and Barometer all this sensors communicate in real time with ROS via arduino node in arduino and virtual slave in NUC.

8. Model In Iterations & Improvement Cycle



This is an iterative V-model where we have shown how our project was carried out from the start .

- Preparation for the project ,we defined the project definition followed by the project goal planning
- According to the plan we have to design an autonomous 2d mapping device
- In next iteration we started to modify the design of the existing according to our requirements
- We did the analysis our bot in software as well as the physical existing one in terms of mechanical stability ,electrical side and programming part
- After the analysis we verified the results with our requirements, there was a need in the improvement of the bot i.e ,maintain the stability and control the vibrance , make a feedback system for the odometry fix RP lidar on the bot.
- Now we did the detailed

9. Component testing

9.1. Electronics

9.1.1. IMU “Tested by interfacing with arduino: example programs were used to check the working of each of the 4 sensors, and all the values were found to be same as per the commands given ”

9.1.2. LIDAR “Tested by interfacing with ROS: lidar was interfaced to Robotic Operating system and RViz tool was used to check the map created by the Lidar after the lidar was made to scan the room, it was found that the range if the Lidar is 6m as mentioned in the specs of the sensor and error in the measurement was negligible i.e 0.02cm ”

9.1.3. Motor Driver “ Tested by interfacing with arduino: Signals from arduino were given to the driver and it was found that the motors were working as the commands were given to the driver by the software ”

9.1.4. Arduino “ Tested by Uploading & Running Blink LED program :Working of the arduino board ”

9.1.5. Motors “Tested by connecting with battery: all four motors were connected to LIPO 22.3V battery and were tested ”

9.1.6. PCB board “Probe Test: board was designed in Eagle software and then board was fabricated by the method of etching,then with the help of probes connectivity and continuity check was done ”

9.1.7. Power supply 22.2V “Tested Using Multimeter: Tested continuosly the battery ”

9.1.8. UBEC “ Tested Using Multimeter ”

9.2. Mechanical

9.2.1. OMNI wheels “Tested by Creating Solidworks model and mounting to shaft ”

9.2.2.

9.2.3. C-clamp “ Tested by Creating Solidworks model and mounting to motor”

9.2.4.

9.2.5. Studs “Tested by Creating Solidworks model and mounting between the base boards ”

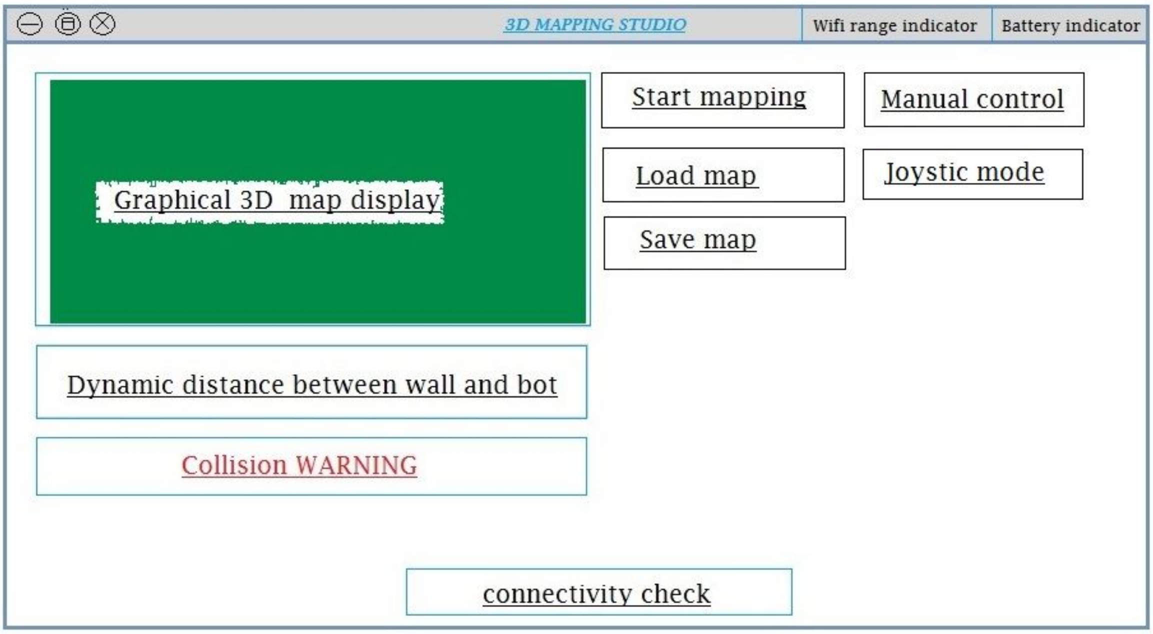
9.2.6. Baseboard “ Tested by Creating Solidworks model”

10. Characterization

SL.NO	Component	Expected values	Measured values
1	LIDAR	6M,0°-360°rotation	6M,0°-360°rotation
2	Gyroscope (L3G4200D)	±2000 dps	reasonable
3	Digital accelerometer (ADXL345)	At± 2g sensitivity=256 LSB/g	±0.005 g noise at stationary position
4	Digital compass (HMC5883L)	Accuracy 2deg	1~2 deg drift

11. Software prototyping

The RPlidar is connected to a mobile computer,which give a information about surrounding.In the mini-computer the robot oprating sysytem is installed,This help to set mini computer as Master node and help in creating slave nodes .there is a virtual slave in the mini-computer which is receiving and prosessing the input from the RPlidar .A hardware slave node (i.e.,Arduino) connected to mini-computer which give motor feedback and IMU input to mini computer.The RPlidar and IMU work together to collect the information about surrounding ,the collected information is processed and 2D map of Environment is created in the GUI,Based on the 2D map the bot avoid the obstacles and move.



Graphical user interface prototype (Front end)

12. Components Manufacturing

12.1. Mechanical components manufacturing

SL.NO	components	material	manufacturing process
1	C-clamp	aluminium	bending & machining
2	Pulley Shaft	aluminium	machining(lathe machine)
3	Baseboard	acrylic	machining(cnc router)
4	Studs 150mm	aluminium	machining(lathe machine)
5	LIDAR base	acrylic	machining(cnc router)

12.2. Electronics components manufacturing

SL.NO	components	manufacturing process
1	Baseboard PCB	etching

1.Cost of the components

List of the component	Cost of the component
RPlidar	37000/-
wheels	36000/-
Motors and Drivers	40000/-
Timer pulley	16000/-
Stud	10000/-
NUC	10000/-
IMU	1000/-
UBEC	1000/-
Batteries	8400/-
Wires	500/-
Other electronics	1000/-
GPU	42000/-
Total :	**203000/-**