Moksha

Unmanned Ground Vehicle

M S Ramaiah Institute of Technology's entry into the
2011 Intelligent Ground Vehicle Competition

Team Members:

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Faculty Advisor:

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I. Introduction

The robotics team of M.S. Ramaiah Institute of Technology is proud to present its Autonomous Unmanned Ground Vehicle MOKSHA. The project MOKSHA was conceptualized in November 2010, and was inspired by 2010 entry to the IGVC. Even though the team name has been retained, the present entry was built entirely from the beginning taking into account the merits and failures of the previous entry by the college.

The project has been interdisciplinary with students from different branches such as Electronics and Communication Engineering, Computer Science and Engineering, Electrical and Electronics Engineering and Mechanical Engineering.

The objective of the project was to build an autonomous ground vehicle capable of following a prescribed track while avoiding obstacles in its path, to reach specified geometric locations without any obstruction autonomously and to be capable of competing with the best in the world and to come out on top.

I.1 Team Structure

Team MOKSHA-UGV is a mixed bag consisting of robotics enthusiasts from various fields. As the Unmanned Ground Vehicle is built by integrating diverse type of components hence involvement of expertise in the corresponding fields is ideal.

Then the entire team was divided into 5 groups based on the different requirements of the project, namely Computer Vision, LIDAR, GPS, Motor Controller and Power Systems.

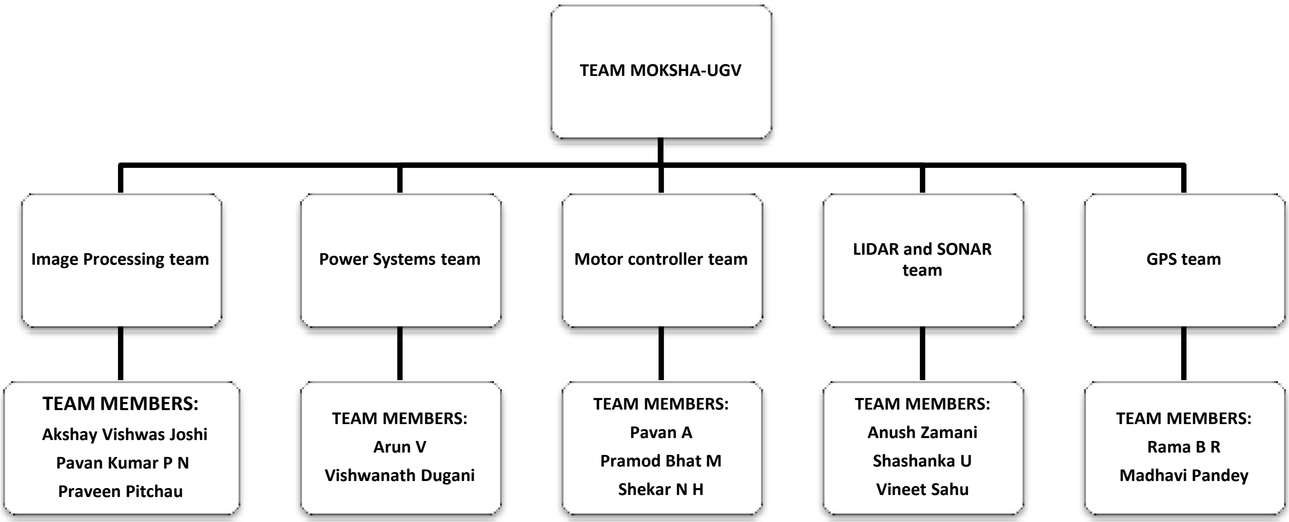


Fig I.1 Team Hierarchy

I.2 Design Approach

The process of building the UGV started with the team understanding the rules and the challenges of the competition and also knowing more about what the teams from other countries are likely to put up in the competition and how our project can be distinguished from other teams. After analysis of the rules and the challenges of the competition, the requirements of the project were finalized and the optimal components for the development of the UGV were selected.

The project progression can be split into six stages planning, design, implementation, integration and testing. We have used the spiral method of development, where in sufficient time to plan, design, implement and test the components and the system on the whole has been allotted.

The following segment illustrates these stages in detail:

Planning: Every system in engineering requires planning and this project is no exception. Planning consists of:
1) Recruiting robotics enthusiasts.
2) Discussing the competition rules.
3) Dividing the task and identifying individual expertise and allotting the appropriate task.
4) Setting deadlines for the stages.

Design: This stage consisted of a lot of research in order to find just the right thing for the job. All the sub teams were encouraged to go ahead and work on their fields and come up with as many propositions as possible. Development of algorithms, identification of the right components and architecture of the UGV marked the successful completion of this stage.

Implementation: Once the components to be used, algorithms to be deployed were documented next was the task to implement the proposed plan. The sub teams implemented their propositions independently and hence could extract the pros and cons of their conception.

Integration: Now as the individual components were developed and their independent working was confirmed, it was time to put them together and evaluate their functioning as a system. The inter component communication established using the master program was developed. And the data flow between the components was observed. Hence the successful completion of this stage was marked with UGV ready for the basic operations.

Testing: As the UGV was complete with all the integration it was tested to verify the various functional and non functional requirements. This stage was marked with error detection and debugging sessions. The components were test individually and as a system on the whole.

II. Hardware Design

II.1 Hardware Innovations

As team MOKSHA-UGV we have always strived towards conceiving and implementing new ideas. As the project nears completion we can perceive the importance and hence enjoy the yield of our innovations. Our innovations can be enlisted as follows:

Split frame chassis: The chassis of the UGV has been designed using split frame technology. The chassis is split into two frames a rear frame and a front frame. The two frames are interlinked via a flexible joint supported by an efficient suspension system.

This split frame design help the robot overcome difficult terrains without any maneuvering risks. Thus the UGV can easily cross ramps and rugged terrains. The efficient suspension system helps keep the UGV stable.

Fig: Split Frame Chassis

Camera angle: As a convention, cameras are placed facing front in the vehicles so that scenario can be captured as a whole. In our implementation of image processing we have used only one camera which is inclined downwards to amplify the details that we can capture from the camera. This also prevents the unnecessary details which creep in when a conventional position is used. Hence by making small changes we have avoided the major overhead of filtering out the details.

Fabrication: The body of the UGV has been fabricated using Polyurethane material which is very light and a sturdy material. Several compartments have been made to keep the several components that are being used in the UGV. The body provides protection to the components and also acts as an insulator.

Solar Energy: Power system includes a compact battery and solar panels. Solar panels provide energy to the vehicle even if the battery fails. The use of Solar panels on the vehicle also ensures that the size of the batteries is reduced. This introduces the use of Green Technology.

Power Supply Board: The power supply board has been made from wood and terminals have been mounted. The power supply board helps in power division and also provides sturdy connections. From the power supply board, the power is provided to all the parts of the vehicle. Power system has been meticulously designed taking the real time scenario under consideration, in such a way that it provides power to system without any fluctuations. Power system includes a compact battery and solar panels.

II.2 Hardware Description

Hardware of the unmanned vehicle is divided into three subunits; the drive train, the control and the perception. The UGV is a four wheeled, two DC motored differentially driven vehicle.

The control unit consists of RS160D motor controller. The motor controller is connected to a laptop, which serially communicates with the controller to control the motion of the vehicle.

The computer also receives and processes data from a ROD 4-20 LIDAR, a MAXSONAR and a GARMIN 18HVS GPS device which comprise the perception unit.

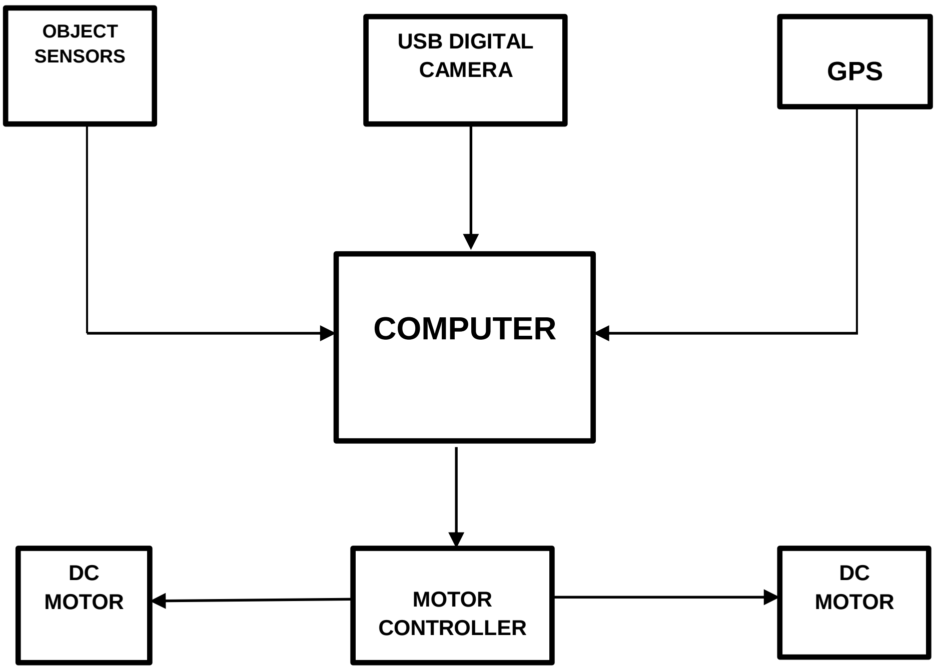


Fig: Hardware Overview

Sensors: 'MOKSHA' uses the three sensors, to perceive its surroundings .

ROD 4-20 is an optical distance cum angle sensor, which uses infrared and laser light sources to detect objects, sweeps 180^0 and returns distance and angle at a rate of 25 scans/sec. (Range adjustable).

MAX SONAR is an ultrasonic range finder sensor that can detect objects in range of 0 – 254 inches. Needs only 5 volts of power supply with analog output which is easier to process.

GARMIN GPS 18 OEM™ is WAAS-enabled available in CMOS-level serial or USB 2.0 full-speed versions and comes with an integrated magnetic base, which is sufficient to provide an extremely high level of accuracy

II.3 Mechanical Design

The Mechanical Design consists of a unique split-frame chassis which has been designed keeping in mind the real time scenario, and hence the design has been made robust and sturdy. The obstacles and hindrances faced by the previous team were also considered.

The main requirements of the design were:

1. To provide enough space.
2. To be able to run on multiple terrains.
3. To provide better stability.
4. To provide better turning radius.
5. To facilitate ramp climbing.

First, a brainstorming session was held among the Mechanical Design team in which several designs were suggested. After evaluating the feasibility of the designs, the present design, which consists of a split frame chassis, was finalized.

Structure overview

The body of the Unmanned Ground Vehicle is built using a unique split-frame technology which ensures better stability and multi-terrain maneuverability. The split frame technology is an innovative idea wherein the body chassis is divided into two parts. The front and the rear portions of the chassis have independent motion and hence this enables the vehicle to run on rough terrains as well.

This design ensures better locomotion capabilities of the vehicle. The front wheels are independent and can rotate 360 degrees; this enables the vehicle to turn sharply when the vehicle gets very close to the obstacles.

The design also permits the UGV to negotiate ramps in a better way. The split frame technology enables the independent motion of the 2 frames and hence the ramp climbing becomes easier, and the burden in the motors gets reduced. Even if one of the four wheels of the UGV gets stuck in potholes, the split frame technology ensures that the other three wheels are placed on the ground. This helps the UGV to negotiate uneven surfaces and hence the use of the encoder is evaded.

The designing was done on Solidworks and was fabricated using Mild Steel material and has been designed to take a weight of 150kg. The materials were laser cut and were welded to together. Then, painting was carried out.

The following designs represent the split frame technology that has been used in the design of the Unmanned Ground Vehicle. The designs have been prepared in Solidworks.

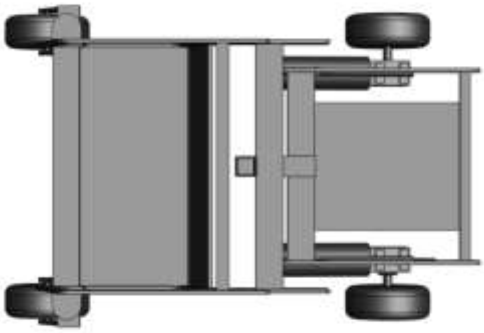


Fig: Top View

Fig: Side View

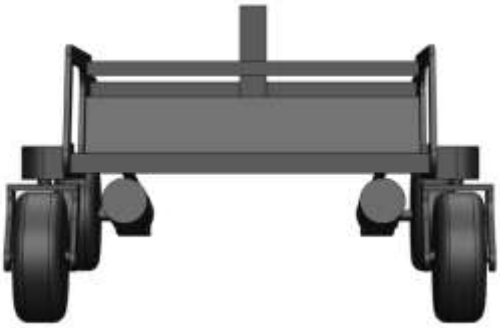


Fig: Front View

Fig: Actual Vehicle

Hardware Specifications

Material Used	Mild steel
Length	3 feet 10 inches
Width	2 feet 5 inches
Height	3 feet 2 inches
Wheels	4
Motors	2(24 VDC,1.8 Amax,120 W)

II.4 Fabrication

The various mountings for the camera, solar panels, and GPS have been made using Mild Steel. The height of the arms for the camera is varied with a simple slot and screw mechanism. To optimize the usage of space, the battery unit kept below the vehicle in drawer. Every component is kept in separate compartments made of a special material called poly Urethane. These compartments are customized for each component, so that the components remain in place even when the vehicle moves.

II.5 Motor Control

The motor control used is the RS160D by Robot-Solutions. The RS160D servo uses custom software to implement a 2.5 channel high-powered servo system. The servo uses a quadrature encoder feedback mechanism to control torque, velocity, and position of the output. The RS160D operates in the PWM mode communicating serially with the processor through a RS232 cable.

Data is sent in ASCII format from the processor using the Visual C++ platform. The RS160D is a 2 channel controller. Each channel controls 2 different motors (right and left).
Data is sent as: "@0sm1" selects mode 1 i.e., PWM mode
"@0sj0" selects serial communication mode
"@0st255" torque control

Differential drive is used to turn the vehicle left or right depending on the data received from the sensors. Torque values for the controller varies between -255 and +255. Different speeds were tested for the two motors in order to optimize the degree of the curve to which to vehicle has to turn in order to avoid obstacles and stay within the lane. The following is a sample of the set of values that were tested on the motors and their upshots:

LEFT MOTOR	RIGHT MOTOR	UPSHOT
@0ST120	@0ST120	Both Motors Off
@0ST130	@0ST130	Low Voltage, Vehicle Moves With Jitter Motion, Not Stable
@0ST170	@0ST170	Vehicle Moves Straight Smoothly At Average Speed Of 2 Mph
@0ST170	@0ST140	Vehicle Moves Right at an angle
@0ST140	@0ST170	Vehicle Moves Left at an angle

II.6 Electrical Design

The electrical system consists of a central custom made power distribution board made of wood as it is has electrical insulating property. It has two metallic terminals which are firmly mounted on the board and are connected to a power source of 12 Volts, 34 Ampere hour and this connection is made using thick copper wires of rating 40 Amperes.

We also plan to use solar cells to recharge the battery. These solar panels also ensure that the size of the batteries is reduced. This also introduces the use of Green Technology.

The other connections from Motors and supply board to the motor controller, Mechanical E-stop and Wireless E-stop are connected using 14 American Wire Gauge (AWG) wires.

A basic layout as to how the circuit works is shown in the figure. All the components have a common ground and the since the E-stops are connected in series disconnecting the circuit with one push of a button.

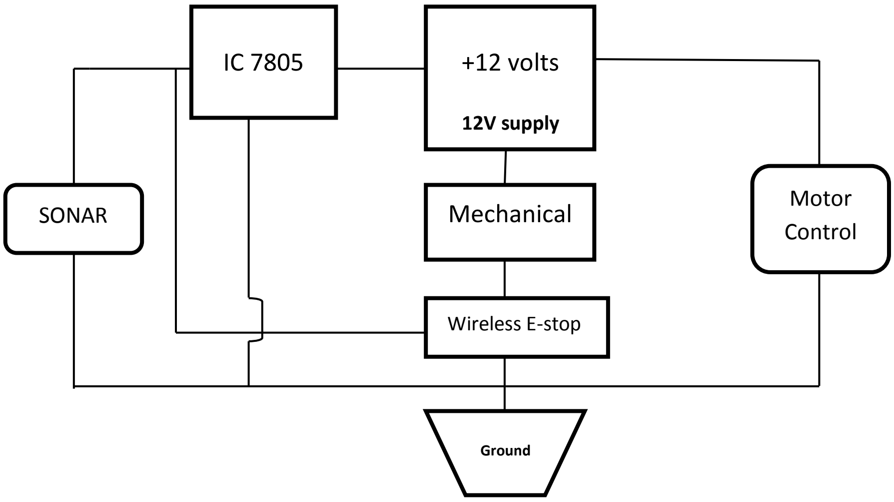


Fig: Electrical System Design

II.7 SAFETY

II.7.1 E-stop (Emergency stop):

There are two types of E- stop one is the **mechanical switch** and the other one is a **wireless E-switch**. When an E-stop is used it cuts the supply from all the components with just a press of button. When required the emergency stop must be accessible, recognizable and must work, reliably and safely.

Mechanical E-stop: It is a switch when pressed turns off the supply to all the components. It is placed at the back of the robot at a very accessible position. It is a NC (normally closed) switch by default.

Wireless E-stop: As the name suggests it is wireless and employs a relay within itself to switch contacts between NC (normally closed) and NO (normally open).

The receiver takes 5 Volts, when signal is sent it switches between NC and NO. The wireless E-stop has a range of about 100 feet.

III. Software Design

III.1 Software Innovations

The Autonomous Challenge Algorithm

Team Moksha has an ingenuous approach for the Autonomous Challenge. The basic flow of the algorithm used in the program is as shown below.

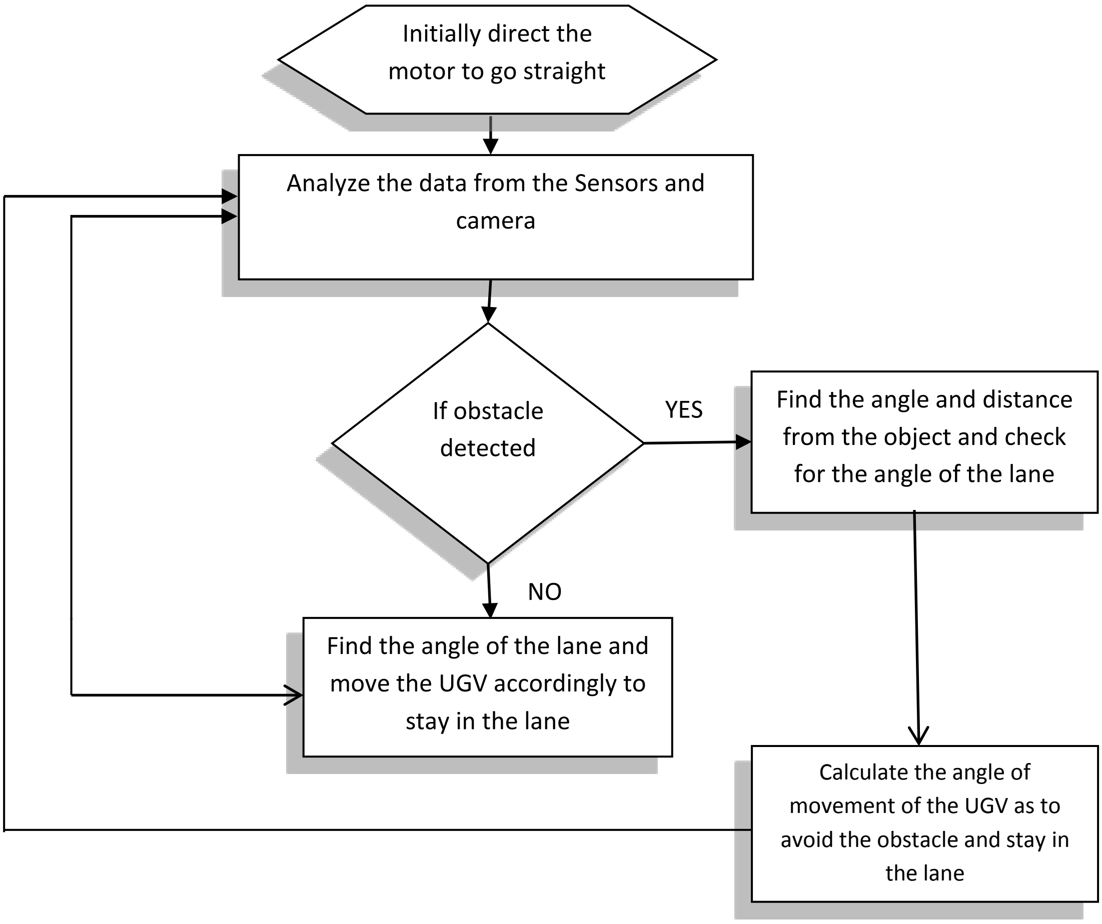


Fig: Image Processing Algorithm

III.2 Platform

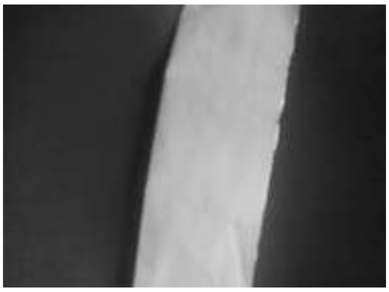
The different devices on the UGV are controlled by a C++ program which includes an integrated algorithm which uses the data from the sensing devices camera, LIDAR, SONAR and directs the controlling device RS160D motor controller which controls the motor.

The different devices are connected to the processor using the USB ports which are interfaced to the devices using USB to RS232 converters. This is done since the data is exchanged between the processor and the sensors and motor controller serially.

III.3 Image Processing

The images are continuously taken from the video captured by a 5 MP camera and are processed using different image processing algorithms to detect the lane. This is done using the functions in the OpenCV library .Then the angle of the lane is calculated using the co-ordinates of the detected lines from the processed images and the instructions are sent to the motor controller which controls the motor to move the UGV in the directed angle. The camera is placed at an angle facing the ground in front of the vehicle at about 3 ft height. This is done to avoid any unnecessary lines being detected due to noise in the image. Also proper calibration is done in the program to match the angle of the lane and the angle of the line that appears in the image. The processing of image is done as shown below:

1. First the RGB image is converted to a gray scale image.
2. The gray scaled image is processed using Canny algorithm to detect the edges in the image.
3. Then the resulting image is processed using Hough (Probabilistic) transform to detect only line segments in the image.



Gray scaled image

After Canny
Edge detection

Line detected using
Hough transform

III.4 Obstacle Detection:

A serial communication program reads the values continuously from the LIDAR through the serial port. The values are in HEX format and are converted into integer. The protocol structure consists of the following bytes that may be received, START, OPERATION, OPTION(1,2,3), SCAN NUMBER, ANGULAR STEP SIZE, START ANGLE, STOP ANGLE, DISTANCE. Angular step size specifies the angular separation between two successive transferred measurement values and is equal to 0.36 degrees.

The difference between start and stop angles gives an approximation about the width of the obstacle. The difference is multiplied by the angular step size which calculates the width of the obstacle. The distance bit is the measured distance of an obstacle from the current location of the Lidar. Using the distance, start and stop bits the area around the UGV can be mapped. Having the distance and the angle of the obstacle, appropriate commands are given to the motor controllers.

III.5 Waypoint Navigation

We upgraded the GPS unit to GARMIN GPS 18 OEM™. This 12-parallel-channel GPS receiver is WAAS-enabled available in CMOS-level serial or USB 2.0 full-speed versions and comes with an integrated magnetic base, which is sufficient to provide an extremely high level of accuracy. It provides non-volatile memory for storage of configuration information, a real-time clock and raw measurement output data in NMEA 0183 format (industry standard).

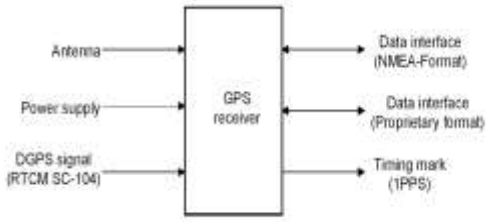


Fig: GPS Receiver Block Diagram

Each GPS data set is formed in the same way and has the following structure:
$GPDTS, Inf_1,Inf_2,Inf_3,Inf_4,Inf_5,Inf_6,Inf_n*CS<CR><LF>
For Example a GLL data set is shown below :
$GPGLL,4717.115,N,00833.912,E,130305.0,A*32<CR><LF>

Extraction of Data:

We are using a Brute force algorithm which relies on the map to navigate both challenges. This algorithm evaluate the safest, shortest path to a given location based on cost calculations, that is determined on the frequency of encountering the obstacles. For the Navigation Challenge, the desired location is always a GPS waypoint.

After extraction of data, the co-ordinates have been obtained, we manually input the destination co-ordinates into a sub-controlling program, which then continuously calculates the relative angle between the destination point and the present direction of the vehicle. It decides, first, which point is closest to its present location, selects that point, and then makes its angle calculations as follows using "Haversine Formula".

R = earth's radius (mean radius = 6,371km)

$\Delta lat = lat_2 - lat_1$

$\Delta long = long_2 - long_1$

Haversine formula:

$a = \sin^2(\Delta lat/2) + \cos(lat_1).\cos(lat_2).\sin^2(\Delta long/2)$

$c = 2.\text{atan2}(\sqrt{a}, \sqrt{(1-a)})$

$d = R.c$

This data is returned continuously to the main controlling program, where decisions are made. Once the point has been reached, the next nearest uncovered point is selected, and the process will continue till the sixth waypoint has reached.

The GPS receiver returns coordinates, which are converted to decimal degrees. The data input from the GPS software and that from the obstacle detection sensor is interfaced in the main controlling program. Our robot is then to find its way to the waypoints and continue to the next ones. The GPS data are updated continuously.

IV. Cost Estimate and Team Organization

Cost Estimate:

Component	Cost
LIDAR (Leuze ROD 4-20)	$4,609
GPS (Garmin 18 OEM)	$200
Fabrication	$250
Batteries	$1,000
Motor & Motor Controller	$1,050
Camera	$50
Chassis	$400
E-Stop	$200
Electrical Components	$100
Solar Panels	$500
Laptop	$1,000
Miscellaneous	$100
Total	**$9,459**

Team Organization:

Name	Area of Work	Academic Details	Input Hours
Pavan Kumar P N	Image Processing	3rd Year ECE	450
Akshay Vishwas Joshi	Image Processing	3rd Year CSE	450
Praveen Pitchai	Image Processing	4th Year ECE	200
Pramod Bhat M	Motor controller	3rd Year ECE	450
Pavan A	Motor controller	3rd Year ECE	450
Shekar N H	Motor controller	4th Year ECE	250
Anush Zamani	SONAR and LIDAR	3rd Year EEE	450
Shashanka U	SONAR and LIDAR	3rd Year ECE	450
Vineeth Sahu	SONAR and LIDAR	4th Year ECE	200
Vishwanath Dugani	Power Systems	3rd Year EEE	350
Arun V	Power Systems	3rd Year EEE	350
Rama B R	DGPS	2nd Year CSE	250
Madhwi Pandey	DGPS	2nd Year CSE	250

V. Declaration

This is to certify that the design and engineering of the vehicle by the current student team has been significant and equivalent to what might be awarded credit in a senior design course.

The design and development of the vehicle has been entirely different when compared to the previous team that had participated in IGVC 2010. The student has taken feedback from the students who participated last year and has developed the vehicle from the beginning. There have been significant improvements both in the hardware and software design.

In the hardware design there have been changes in the chassis, sensors used, motor control, the body fabrication, and the electrical system. The team has developed a unique split frame technology for the chassis. The drive train includes 2 wheel drive when compared to the 4 wheel drive used by the previous team.

In the software design, the current team has used the Hough transform for image processing when compared to the blob detection method used by the previous team. The current team also has a new algorithm for the autonomous challenge, and for the navigation challenge.

Dr. S Sethu Selvi
Faculty Advisor

VI. Acknowledgements

TEAM MOKSHA would like to thank our guide Dr.S.Sethu Selvi who stood by us throughout the project. We would also like to thank our sponsors M.S.Ramaiah Institute of technology, Alumni Association of MSRIT,LEUZE ELECTRONIC, Department of technical education(Government of Karnataka, India).We would like to acknowledge the following people for their technical help :Mr.Hari Vasudevan and Mr.Suhas Naik.

Finally, we would like to thank the IGVC organizers for giving us an opportunity to showcase our skills.

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