DELHI TECHNOLOGICAL UNIVERSITY
TEAM RIPPLE
Design Report

May 16th, 2018

Faculty Advisor Statement: I hereby certify that the development of vehicle, described in this report has been equivalent to the work involved in senior design course. This report has been prepared by the students of Team Ripple under my guidance.

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1. Introduction:

UGV-DTU is a team of undergraduate students from Delhi Technological University (formerly Delhi College of Engineering) devoted to developing an Unmanned Ground Vehicle (UGV). Our eight member team carries out interdisciplinary work across domains such as Image Processing, Navigation, Embedded Systems, Power System Design and Mechanical.

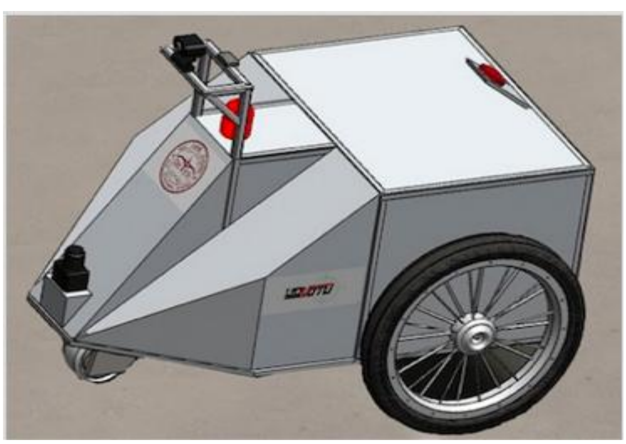
The vehicle operates autonomously with the help of LIDAR, camera (computer vision), IMU sensor and GPS. The vehicle can detect and follow lanes, avoid obstacles and follow GPS coordinates.
The distance from the obstacle is measured using two dimensional LIDAR and the whole system is operated on ROS (Robot Operating System) where sensors and actuators acts as nodes and communicate with each other.

2. Mechanical Design

2.1 Overview:

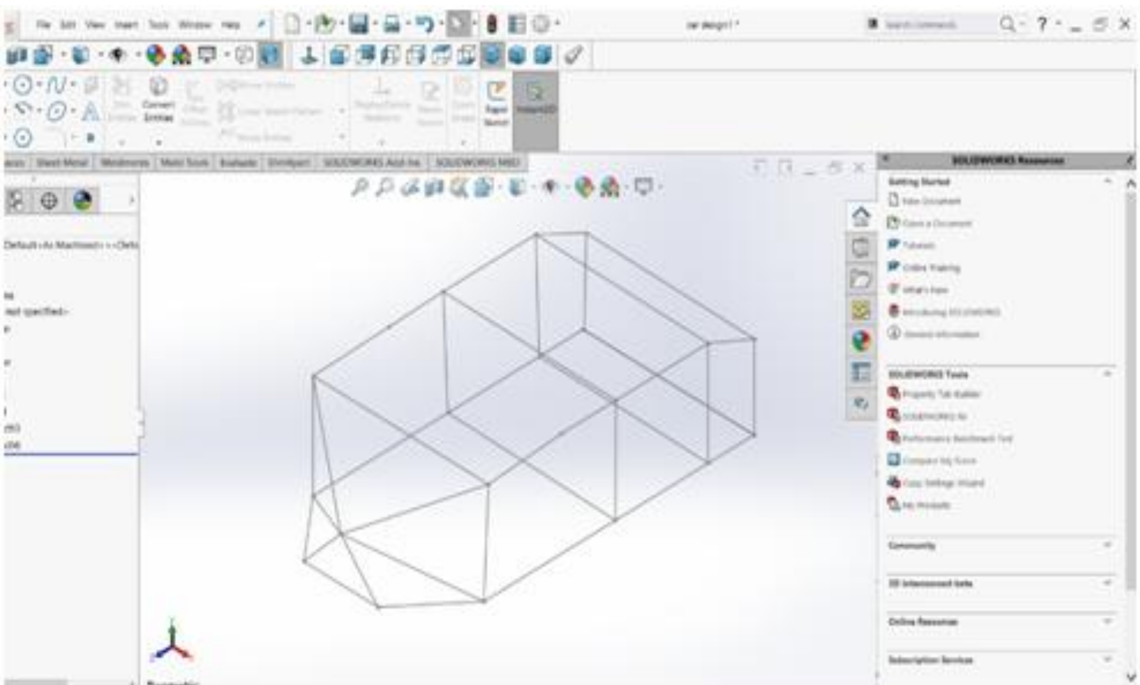
<u>Goals:</u>

- To meet the requirements for the IGVC 2018 competition.
- Weight reduction for more efficiency.
- Robust design which adds to the vehicle aesthetics.
- Ground clearance of 20 cm.
- Covering the vehicle optimally to prevent the electronics from coming in contact with water.



2.2 Decision on frame structure, housing, structure design

Ripple’s design has been modelled using Solidworks 2017.The analysis and altering of the design was done according to the requirements of various departments after discussion with all team members before fabrication of the vehicle body. The vehicle chassis is made of square Aluminium tubes welded together.

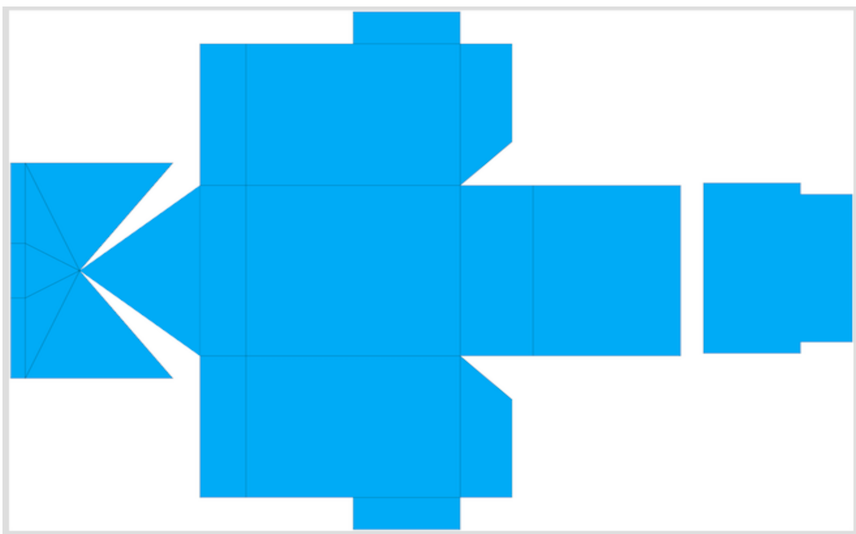


The base and the secondary electronic bay have been made out of plywood and mica sheets, thus making it more cost effective. Ripple’s body has been fabricated using Acrylic sheets, attached to the chassis using bolts and nuts, giving it an edgy look.

2.3 Weather proofing

The Acrylic sheets are then covered with Carbon fiber sheet to cover up small openings and to prevent water from coming in contact with the electronic components placed on the payload section.

The design consists of triangular shaped sheets, which in turn help in recovery when the vehicle meets with a collision. Triangle, being the most stable shape, absorbs the impact and divides across all its sides, thereby reducing its effect on the vehicle.



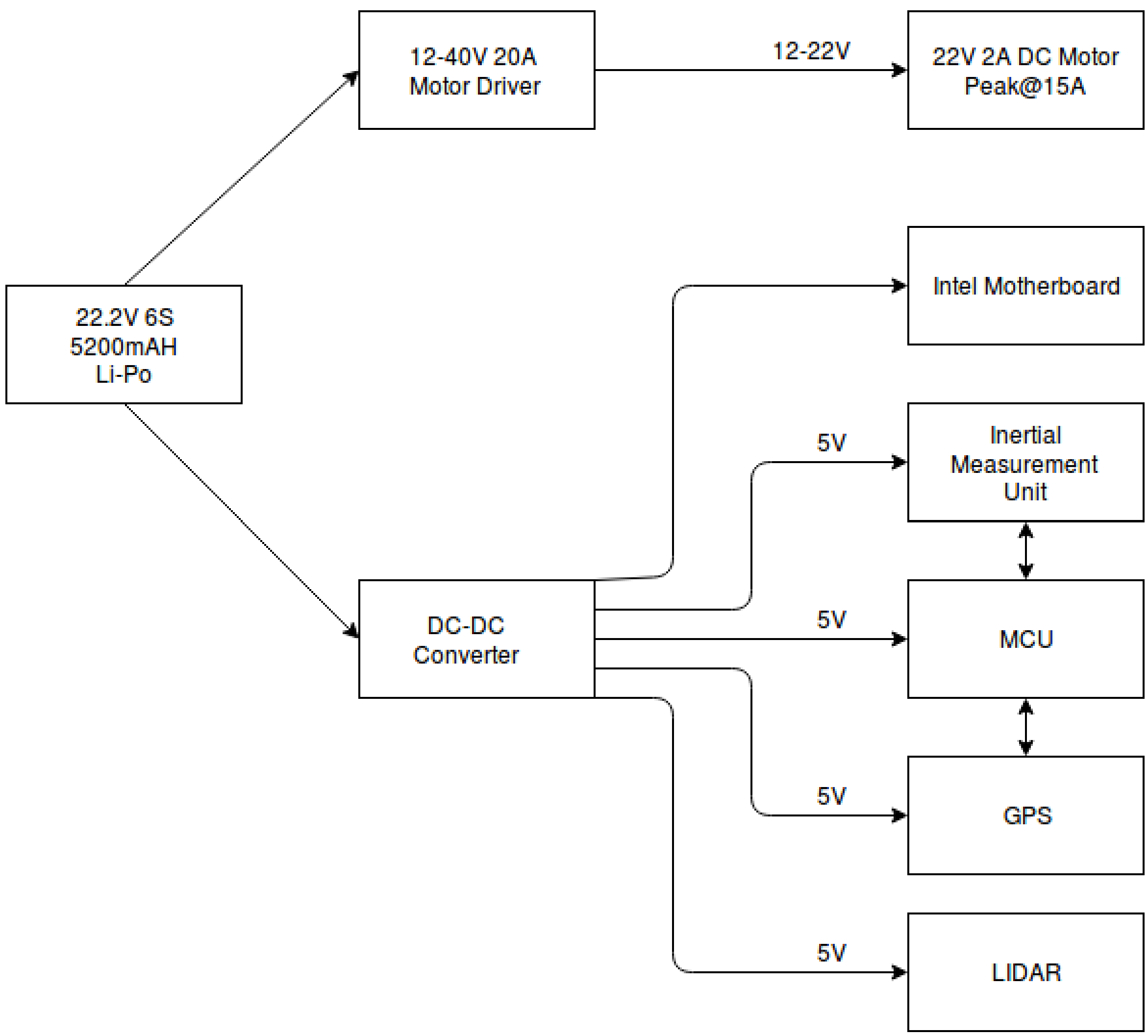
CDR File in .jpg format

The CDR file was created to help with the laser cutting.

3. ELECTRICAL AND POWER SYSTEMS

3.1 Power Distribution System

The main power source for the Unmanned Vehicle is a 22.2V, 6 Cell, 5200mAh Lithium-Polymer (Li-Po) Battery. It can give great instantaneous discharge current upto 130A. It weighs just 784 gm and is smaller in size compared to alternatives such as Ni-Cd, Ni-MH and Lead acid batteries.



This battery powers two Direct Current motors rated for 22V volts 2 Ampere with a starting peak current of 15 Ampere. 40V / 20A Motor Drivers with speed and direction control using PWM (3GHz) with back emf and current protection have been used.

The rest of the sensors and microcontrollers on board are powered using a standard 5V supply down-converted from 22.2V available from the Li-po battery using a DC-DC converter. The components operate reliably in the 3.3-5V range and draw a maximum current of 40mA.

3.2 Safety devices:

A Lithium-Ion charge protection circuit (CF-6S12A) with over-charge, over-discharge, over-current and short circuit protection ultra-high temperature charge and discharge, is used in the distribution circuit.

3.3 Sensors description:

The following sensors are used by the unmanned ground vehicle for precise motion control.

1. Camera :

1. Logitech C270 HD 1280 x 720 pixels resolution
2. Dimension: 13 x 5.2 x 18.1 cm

2. Inertial Measurement Unit

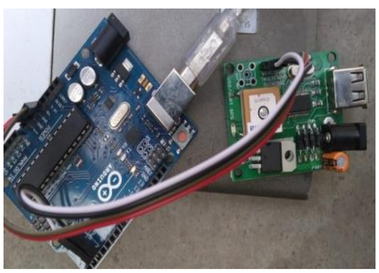
The triple axis MEMS accelerometer in MPU9250 includes a wide range of features:

Accelerometer normal operating current: 450μA
400kHz Fast Mode I^2C for communicating with all register
Factory calibrated sensitivity scale factor and Self-test capability
Digital-output triple-axis accelerometer with a programmable full scale range of ±2g, ±4g, ±8g and ±16g and integrated 16-bit ADCs

3. LIDAR :

1. Hokuyo's URG-04LX detectable range is 20 mm to 4000 mm
2. 100 msec/scan
3. 5V operating voltage
4. 240° area scanning range with 0.36° angular resolution
5.USB and Serial (RS-232) interfaces for maximum flexibility.

4.GPS Receiver

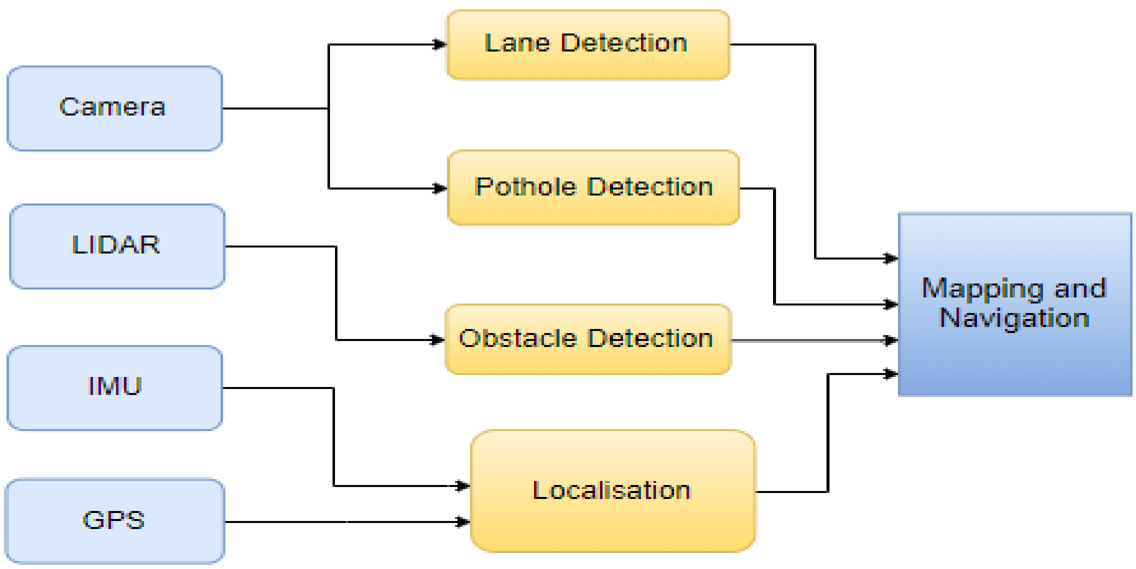


Dimension：	16mm x 16mm x 6mm
Low Power ConsumptioN	55mA @ acquisition, 40mA @ tracking
High Sensitivity：	Up to -158 dBm tracking, superior urban performances
DGPS(RTM,SBAS(WAAS, EGNOS,MASA)):	2.5m 2D-RMS
Data output Baud rate：	9600 bps

4. SOFTWARE STRATEGY AND MAPPING TECHNIQUES:

4.1 Overview

The vehicle uses the combination of inputs from camera and LIDAR to navigate through the lanes and detect obstacles. The vehicle uses two cameras for lane detection (one for each lane) which helps in detection of wider lanes and gives a comparatively closer view of the lanes i.e. where the vehicle is currently located with respect to the lanes and hence we can know are when the vehicle is deviating from its desired path at a faster rate. The use of two cameras thus gives an advantage over a single wide angle camera. The 2D Hukoyu LIDAR is used to map the obstacles and find the distance from them.



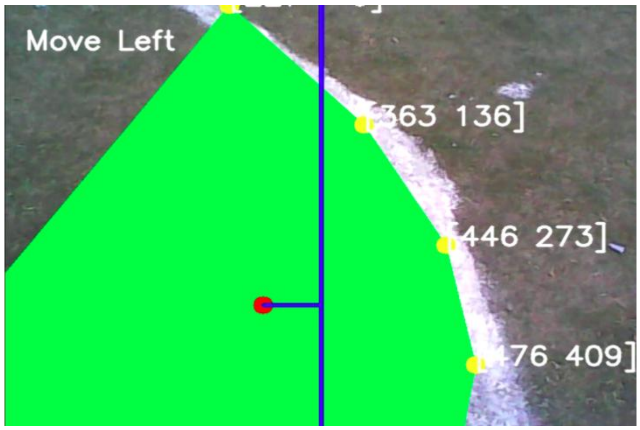
Sensors Control Flow Chart

4.2 Software strategy and path planning

4.2.1 Lane detection

To detect lanes initially the noise in the image is removed through Gaussian blurring. After blurring adaptive thresholding is used to detect the pixels of white color. The HSV(Hue, Saturation, Value) color format was used as by applying threshold to only hue and saturation we can make the detection light intensity invariant (since 'Value' defines the intensity of the color). This would give a binary image with white pixels representing the lane.

Further noise is removed using ‘Opening’ morphological operation i.e. erosion followed by dilation. A histogram is generated that shows high intensity points hence showing white color in the image. Then the lane is detected from the white pixels by using polynomial approximation as shown below.



A polynomial is mapped over the detected points hence giving us the lane. Another advantage of using polynomial approximation is that when the view of some part of lane is obstructed by some obstacle even then we can get the whole lane by approximating the lane using the visible lane points.

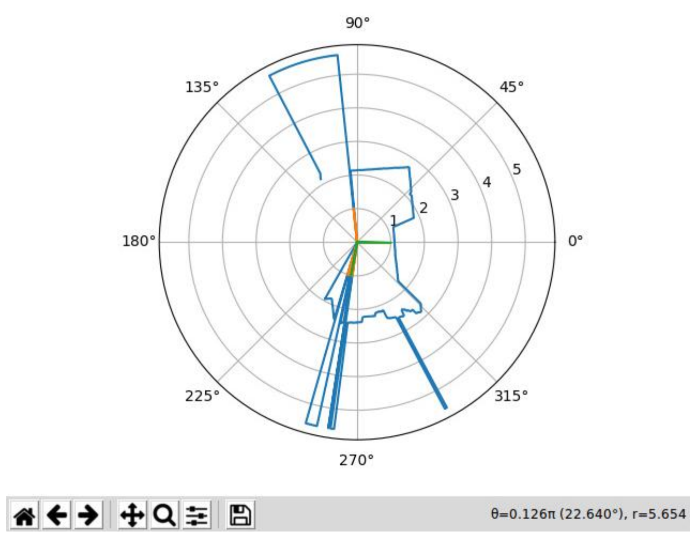
Once the lane is detected, multiple points were taken from the lane and the slope was calculated giving the direction of the lane. Then the motors are given commands accordingly to keep the vehicle at a fixed distance from the lane and parallel to it.

The arrow in the above figure shows the slope of the lane and the red line indicates the distance in pixels of the vehicle from the lane.

4.2.2 Obstacle detection and Avoidance

LIDAR is used to detect obstacles. A threshold distance is set and when the vehicle is closer than the threshold distance, command is given to avoid the obstacle. Exact angle of turn is calculated and a command in terms of vector is given to the motors to turn in a certain direction. A combination of lane and obstacle's position information is required for obstacle avoidance to make sure that the vehicle stays within the lanes while avoiding the obstacles.

To avoid obstacles, the position of the lane and the obstacle is noted and then the possible path with maximum gap is followed. For example in the case where an obstacle is placed in the middle of the lane, the algorithm would measure the pixel distance between lane and obstacle and either side and will choose the larger distance.

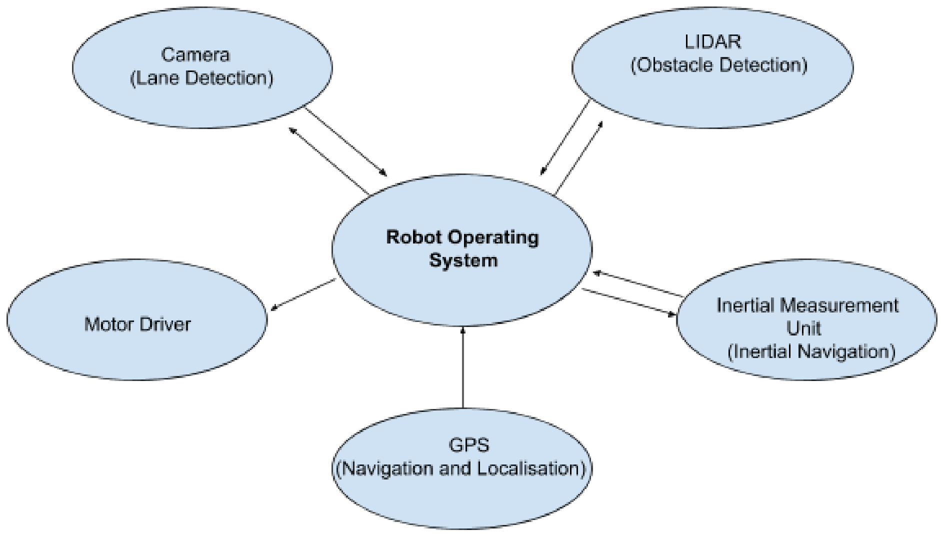


LIDAR output showing distance and angle of obstacle from vehicle

4.3 Software Integration:

Robot Operating System : For efficient resource management, and to enable seamless communication of data between modules the open source Robot Operating System developed by Willow Garage has been used.
Building the system over an Operating system, helps maintain real time constraints and avoids resource conflicts.

The Lidar driver, Object Detection, Image Processing Stack and the microcontrollers used for reading sensor data and generating pwm for motor direction and speed control are each assigned separates nodes within the system and share data with each other using different ROS topics which use Multiarray messages.



State Map of the System

4.4 Additional Creative Concepts

- The values used for slope and deviation are the mean of the values received from five previous image frames. This helped in the reduction of error due to noise.

- Use of polynomial approximation helped in detection of complete lane even when lane was partially blocked due to obstacle.

- To avoid the interference of white obstacles in the lane detection algorithm an extra condition was added which checks the dimensions of each contour, when the length and breadth of the contour is above a certain threshold value, then it is treated as an obstacle and ignored in the lane detection algorithm.

- The slope of lane was used to give commands to the motors, more the deviation of slope from vehicle's direction, more would be the angle by which the vehicle would turn and hence it would try to be parallel to the slope of the lane.

- The use of two cameras each dedicated to a single lane was done instead of using one wide angle camera. This provided more accuracy in lane detection and helped to know the current location of the vehicle with respect to lane.

5. Description of failure modes, failure points and resolution:

5.1 Vehicle failure modes and resolutions:

- If the vehicle fails to detect the lane properly and starts to go out of bounds, at that point the vehicle will retrace its path i.e. it will go in backward direction. To retrace the path GPS is used which stores the last few location points in form of an array.

- If the LIDAR couldn’t detect the obstacle on time and when the detection is made if the vehicle is too close to the obstacle to pass it without colliding then also it will reverse its direction of motion and try again, this would give the vehicle opportunity to avoid the obstacle without colliding.

- A power control IC is used which would help in avoiding any power failure or errors due to peak current at the start of the vehicle.

Vehicle Testing

5.2 Testing:

The vehicle was tested in the outside environment. The lane detection algorithm was tested robustly by navigating the vehicle through lanes of different widths and sharp turns. The vehicle detected and followed the lanes successfully. The detection algorithm was tested during different day times to test robustness to light intensity variation.

5.3 Vehicle safety design concept:

A Lithium-Ion charge protection circuit (CF-6S12A) with over-charge, over-discharge, over-current and short circuit protection ultra-high temperature charge and discharge, is used in the distribution circuit. The vehicle has emergency stop feature which can be accessed wirelessly.

The vehicle uses power control IC for protection against high magnitude current. The vehicle is completely covered with acrylic sheets which is completely weather proof and hence would avoid any failure even during rain. The mechanical is designed to be highly stable during turns and while carrying payload.

6. Performance testing to date:

The obstacle detection algorithm was tested and was working for different obstacle arrangements in the lane. The obstacle avoidance algorithm was partially tested and the output given by the IMU was used as a feedback to know if the vehicle turned in the desired direction by the desired angle.

The testing was done with 10kg payload. Also the vehicle was able to traverse the ramp of about 15 degrees with the payload. The lane detection algorithm is working successfully under different conditions.