
# Delhi Technological University

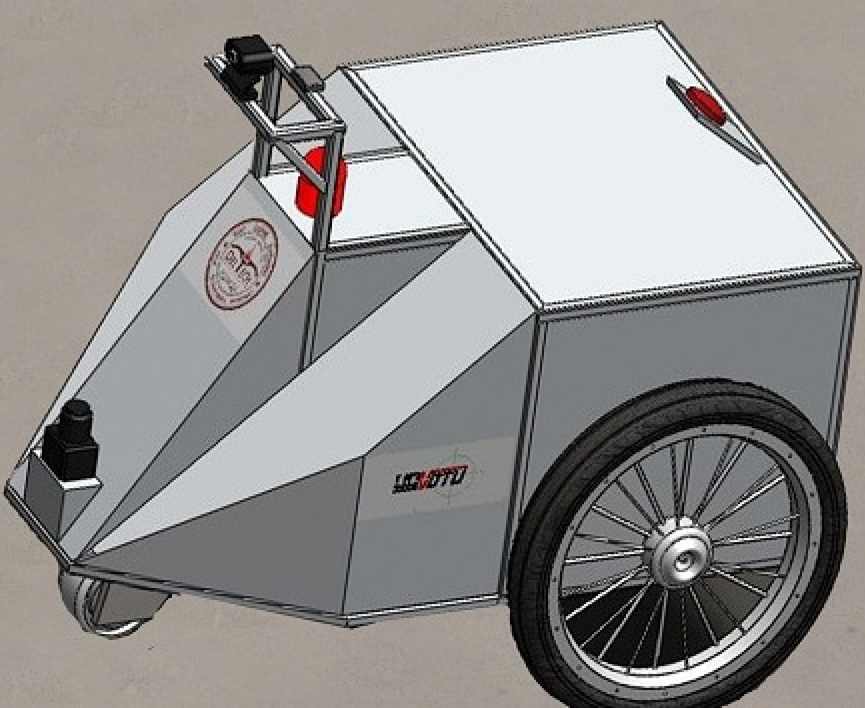
(formerly Delhi College of Engineering)

New Delhi,INDIA

# Lakshya-II

## Unmanned Ground Vehicle (UGV-DTU)
## Design Report 2013

The 21st Annual Intelligent Ground Vehicle Competition
At Oakland University in Rochester, Michigan on June 7 - June 10, 2013



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## Introduction

UGV-DTU is a team of undergraduate students of Delhi Technological University (formerly Delhi College of Engineering), devoted to developing Unmanned Ground Vehicle (UGV). One of the most passionate student teams in India dedicated to designing of an Unmanned Ground Vehicle.

The project is guided by Dr. Narendra Kumar of the Department of Electrical Engineering, Delhi Technological University (formerly Delhi College of Engineering). The team consists of Undergraduates from a multitude of departments –Electrical, Electronics and Mechanical.

Main idea of the projects is to include as many young engineers as possible in applying the theory learned in the classrooms on a real world problem. The projects are of great importance for education system in India and especially for the Delhi Technological University. Opportunities given to the students to gain practical experience are unique and unmatched.

## Innovation in Software & Obstacle Avoidance Techniques

UGV-DTU uses a very innovative technique for obstacle avoidance, we focus for more and more application of image processing in our vehicle rather than relying on laser technology as the laser technology leads to more consumption of battery energy and thus reducing the energy efficiency of the vehicle. We are trying to make a more environment friendly vehicle devised our software to tackle the obstacle more accurately using the image processing technique. Applying different algorithms we first tried to isolate the obstacle and lanes.
(Isolation technique is a technique for clear detection of objects with very less noise. it is implemented in black and white format of images. Normal BW image can have tough stained noises, the output is some form of dilated BW image of obstacle) which cannot be easily removed by just thresholding and other common techniques. Further to clearly separate the lanes from the obstacles we used the obstacle detection techniques based on their colour and shape. Using just lidar sensor to work accurately, we needed to rotate it up and down for complete detection of the obstacle, as the lidar sensor just work for a pitch value of at max 3 degrees.

To make the vehicle best in the class, state of art technology "Ibeo LUX" is implemented in the vehicle Lakshya-II. The ibeo LUX T is a real all-rounder for use in urban traffic and on the motorway. Ibeo LUX sensors work accurately and reliably even at high speeds, in poor weather conditions and heavy traffic. Maintaining high field of vision and all weather capabilities ibeo LUX provides object tracking and wide horizontal field of area.

# Mechanical Engineering Section

## Chassis of Lakshya II :

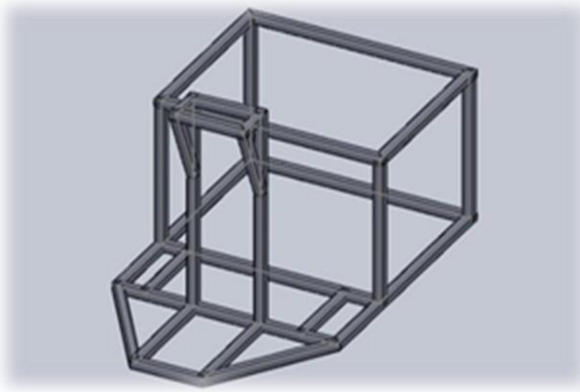


**Fig: Frame of Lakshya 2**

The frame of Lakshya 2 has been fabricated using Aluminium 6063 because it is lightweight, has robust structure and is also very cost effective. The basic frame weighs just about 5 kilograms. The structural members made of aluminium 6063 are gas welded. The members are square aluminium tubes with dimension 19 X 19 mm and thickness of just 2 mm. the frame has been provided with a camera mount of about 2ft 6in height on which the camera and GPS antennae will be placed. The vehicle has a very strong aluminium frame so it can easily withstand impact forces without affecting internal components of the vehicle

## Designing:

The CAD model of the vehicle was designed and simulated on Solidworks of the Dassault Systems. The analysis and altering of the design was done according to the requirements of the various departments after discussion with all the team members before the fabrication of the chassis. This led to detecting and rectifying of several problems even before fabricating the actual chassis. The base and the secondary electronic bay have been made of wooden plank making it even more cost effective.

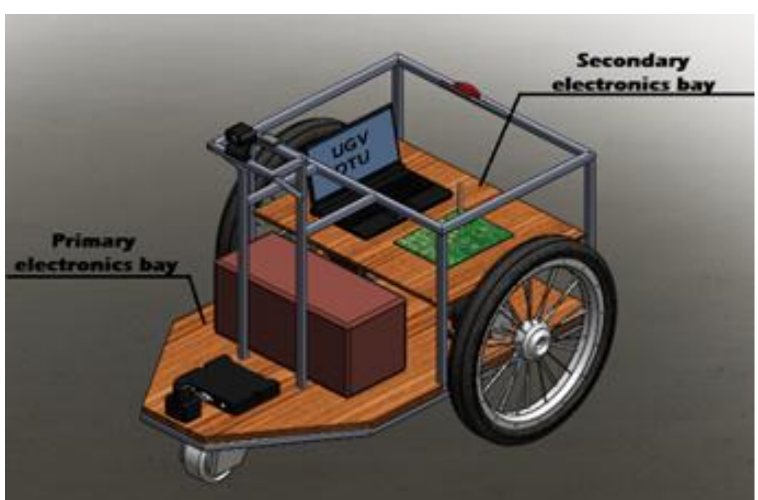



**Fig: CAD model of Lakshya 2**

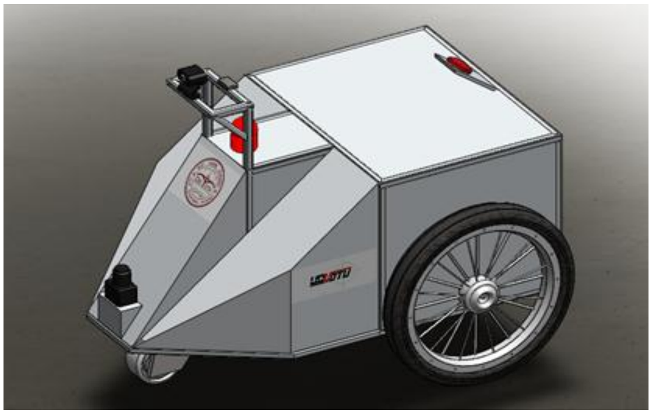



**Fig: CAD model of final look of the vehicle.**

**Fig: Vehicle during 1st Manual testing**

## Drivetrain and performance:

For Lakshya II's drive train, a differential drive has been used for steering the vehicle, the two rear wheels are powered using dc geared motors. The wheels are coupled with motor's shaft using mild steel couplers. A castor wheel is bolted to the front segment of the chassis.

The motors are rated at 144 rpm after using the gearbox and wheels of 25 cm radius have been used. So theoretically, the vehicle is capable of traversing at a speed of,

$$\mathbf{2*pi*(.25)*144*60 = 13.566\ km/h = 8.429\ mph.} \qquad \text{---- eq.(i)}$$

The weight of the loaded vehicle (along with the payload) will be about 35 kg at max.
So, torque rating needed for each motor is:

$$\mathbf{t = m*\sin\theta*r/2} \qquad \text{---- eq.(ii)}$$

The rated stall torque of the motor used in the vehicle at 24V is = 1.2kg-m

So,

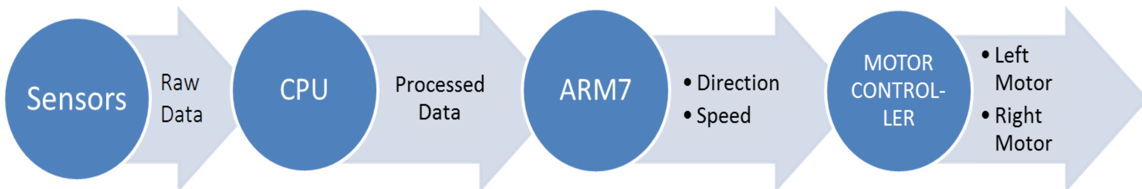
$$1.2 = 35*\sin\theta*(0.25)/2$$
$$\sin\theta = 0.2742$$
$$\mathbf{\Theta = 16^\circ}$$

Hence theoretically, the vehicle can climb an incline of 16$^\circ$.

## Electronic Components

Microcontrollers used are ARM7 and atmega32. A pair of X-bees has been used for RF communication. Remote control is also custom made. It contains many user friendly sensors making it quite easy to use. Software's used for developing the UGV are Proteus ISIS and ARES, AVR studio 4, AvrDude, Hyperterminal, keil (uvision4).

The data flow channel is shown in the figure below:




### Microcontroller

The LPC2148 is based on a 16/32 bit ARM7TDMI-STM CPU with real-time emulation and embedded trace support, together with 128/256 kilobytes (KB) of embedded high speed flash memory. A 128-bit wide internal memory interface and a unique accelerator architecture enable 32-bit code execution at maximum clock rate. For critical code size applications, the alternative 16-bit Thumb Mode reduces code by more than 30% with minimal performance penalty. With their compact 64 and 144 pin packages, low power consumption, various 32-bit timers, combination of 4-channel 10-bit ADC and 2/4 advanced CAN channels or 8-channel 10-bit ADC and 2/4 advanced CAN channels (64 and 144 pin packages respectively), and up to 9 external interrupt pins these microcontrollers are particularly suitable for industrial control, medical systems, access control and point-of-sale. Number of available GPIOs goes up to 46 in 64 pin package. In 144 pin packages number of available GPIOs tops 76 (with external memory in use) through 112 (single-chip application). Being equipped wide range of serial communications interfaces, they are also very well suited for communication gateways, protocol converters and embedded soft modems as well as many other general-purpose applications.

### Motor Controllers

To control speed of dc motors H-bridge based motor controllers are designed. Motor controllers have been designed with high power n channel mosfets driven by a high side and low side mosfet driver. A single driver has a maximum rating of 30v/115 amps. The driver is controlled using pwm pulses which is provided by the microcontroller. A fan has also been provided to cool the heated mosfets. Driver is efficient and provides a flexible control over dc motors.

## Power System

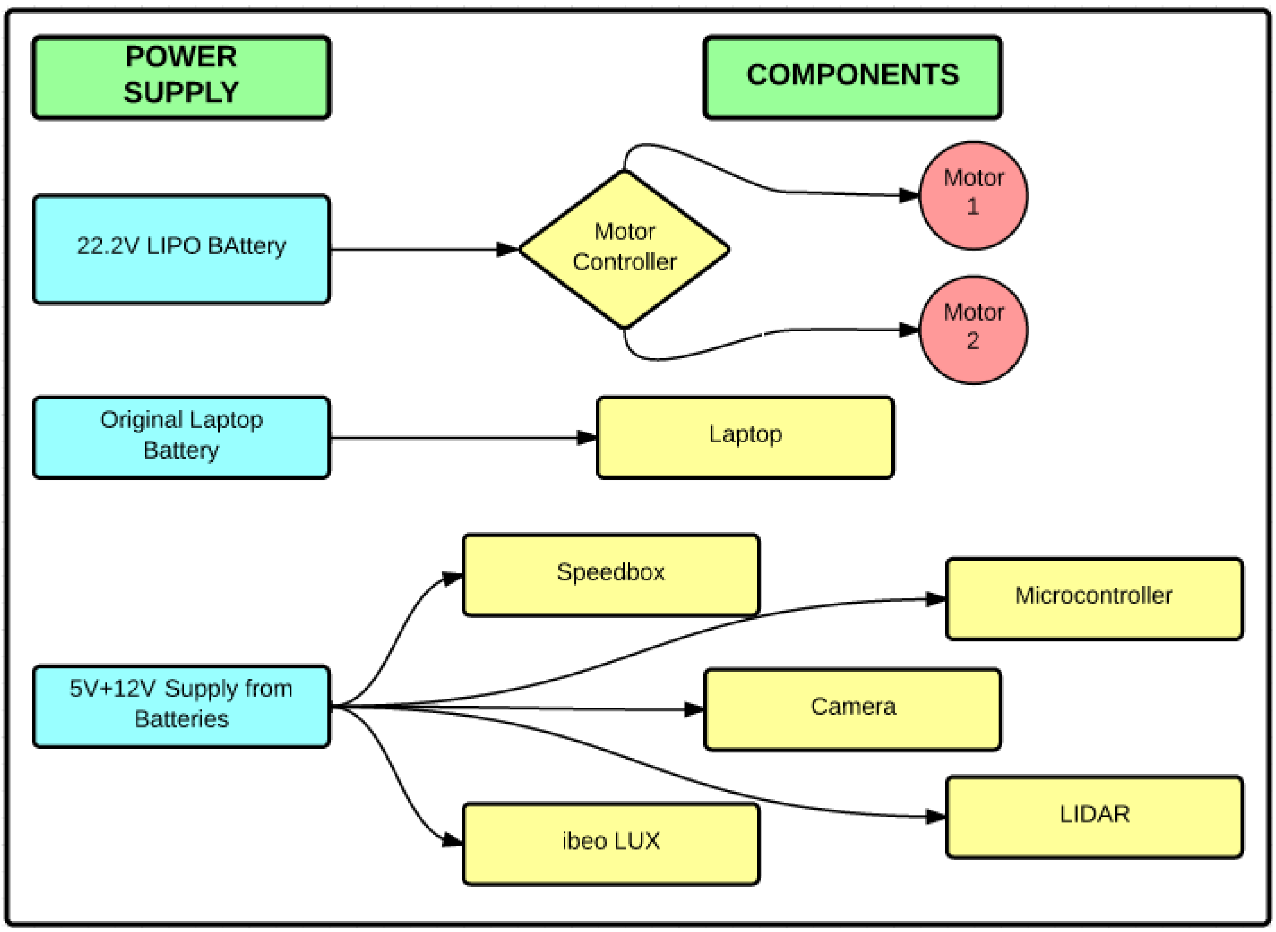
A separate system for power management has been designed for UGV.

It uses a 22V 5AH Lithium Polymer battery for the two motors. With such high power batteries, a fuse is used so that the exceeding current does not damage the components. Battery life is: 2.5 Hours (with load)

With these 2 additional batteries are used for providing 5V and 12V separately. Both the batteries are lithium polymer batteries of 2 cells and 3 cells each. Having a battery life of 5 hours (under complete load). Here 5 Volt is used for powering the microcontroller circuit and 12 volts for powering the speed box and lidar.

Also the Kill switch is installed in the power system which stops the power supply to all the electronic and electrical components except from those powered by laptop. This acts as the **Emergency Stop**.

The system has large conducting free space for common ground which is handy in case of heat dissipation.



# Remote Control

The remote uses x-bee for wireless communications, communicating with the micro-controller. It can be operated on 2 modes manual and autonomous. In manual mode the operator has the power to control the UGV whereas in autonomous mode the UGV takes its own decision on the path to follow.
The remote also has an Emergency Stop which can completely stop the UGV in case of an emergency.

### E-Stop

UGV is provided with a dependable Emergency Stop. The Physical button on the vehicle is red in colour and easily identifiable. Whereas the wireless E-Stop makes the use of relay system.
Both these switches are in series with the batteries input. Thus, closing any 1 of the switches will cut off the power supply to the bot (except for the laptop). Hence completely stopping it

## Computer Systems and Software

### Navigation

Using LIDAR and image processing techniques, we get positions of the obstacles and lanes, using these, we plot them on a global map, thus creating and updating the track many times. The Global map as very large is made by dynamically allocating memory to a 2 dimensional array. Plus there is also a local map which presents the present situation fully.

### Algorithm for Navigation (GPS)

Navigation involves first making a map, which is done via dynamic allocation of memory to create an array which could house the entire map of the obstacle course with a resolution of square dm.
The next step is localizing the vehicle, which would be done using the GPS as using any other localizing technique such as particle filters fail without any prior map.
The corners of our virtual map must be assigned GPS values of themselves to make this work.
Finally with a map, starting and ending coordinates, we employ the A* algorithm to reach our destination via shortest path.

## Algorithm for Obstacle Avoidance

### Obstacle feature detection using Camera

For the obstacle avoidance using logitechC310 HD camera, UGV implements various algorithms like **edge detection**, **line detection**, **circle detection**, **noise reduction filters**, **colour detection** to detect different features of lane and obstacles, and then club altogether the data thus completely detecting the features of the obstacle.

## Edge detection

Edge detection in an image is done on the basis of calculation of pixel values of the neighboring pixels of a pixel. Edge detection is possible for a black and white image. In a black and white image, if there is change in the pixel value(i.e; 1 or 0) in the nearest neighboring pixel then we know that there is occuring a good change in the intensity of the pixels or to put it simply there is an edge to be detected. So in the final image the change in the pixel is defined by a fixed pixel value (1 or 0, which so ever will be significant ), thus clearly detecting the edges in an image.

The only flaw in this technique is that the technique is dependent on the **Threshold** value of the image in the grayscale mode. while converting an image from grayscale form to black and white we need to take care of threshold, i.e; level below which all pixel intensities will be considered to as black and all pixel intensities above this will be considered to be as white. This is adversely affected by different types of noises. To avoid this problem we use,
noise reduction techniques like sharpening filters, histogram equalization.

## Noise reduction filters

In an image there can be different type noises, pepper noise, gaussian noise and others. These can be dealt with simple noise removing filters if needed, however we use top of the line equipment to avoid such noise.

Be as it may, there is still the issue of adaptability, different parts of the day have images of different brightness, and thus the thresholds we fix could be useless against it. We thus employ histogram equalization to counter this effect.

## Colour detection

In real world obstacle avoidance is done based on the decision making using different features of an object like, shape, size, colour and other secondary features. Out of the mentioned above, colour detection has a very unique role. Let's consider two apples one of which is red and the other is green. now we need to pick the right choice let it be the red one. Human perceive data from their eyes and detect the colour of those apples thus making the right choice to select the red apples. Now the same case is with our vehicle, we need to pick up the right flag out of two possibilities ( red or blue), flags detected can only be separated on the basis of colour detection.

For this job we can use the RGB format of image that contains all the 3 basic colour pixels that can be used to define an image that are, R = Red; G= Green; B = Blue. And different colors are just combination of different values of R,G,B.

So to detect a particular colour we need to put some strict conditions on these levels.

example: pure RED has an RGB value = (255,0,0)

Whereas, pure BLUE = (0,0,255)

so giving a condition that if the R component of an image is more than 245 and (G,B)<20, the colour detected will be RED, we can detect different colours,

But again the technique again is interfered by noises, so we needed a different way to put the conditions on the image pixels. To solve this purpose we use the HSV format for representation of RGB values. HSV is a cylindrical representation of RGB values. HSV stands for "Hue", "Saturation", "Value".

Hue is the angle around the central vertical axis.

Saturation is the distance from the central axis.

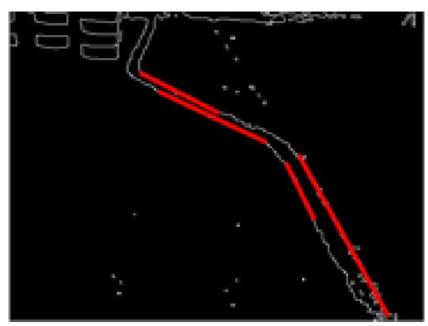
Value is the distance along the vertical axis.

## Line detection

It is achieved using simple edge detection and afterwards employing Hough lines transform, all this is done via using OpenCV libraries, these help establish the lanes and plot them on the map.

On the basis of human perception, lanes can be distinguished from obstacles defining the fact that lanes are the defining boundaries of the window showing the lane and obstacles both.

**RGB image of path**



**Lanes detected clearly**

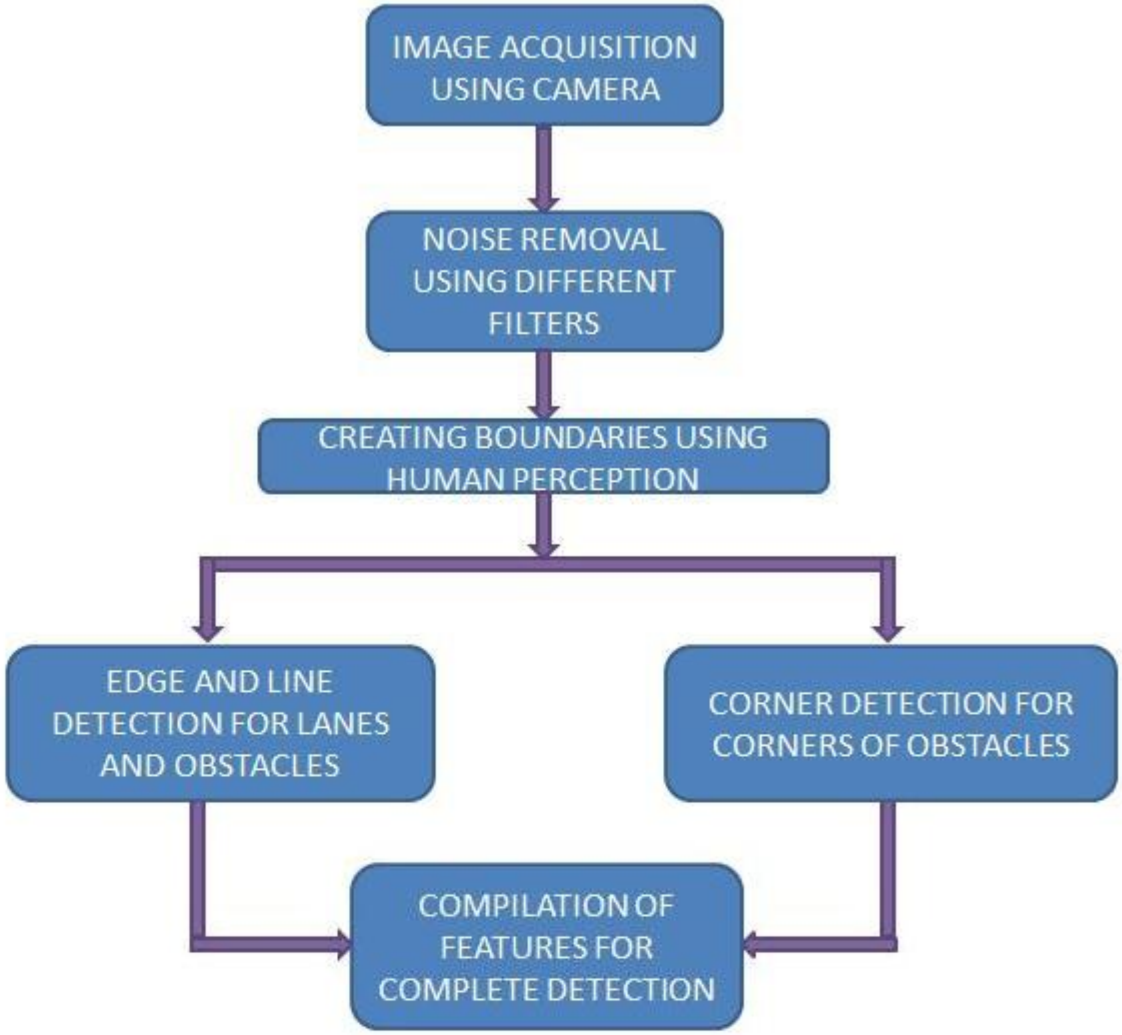
## Corner detection

Corners are image locations having large change in intensity in all directions.

There are few common corner detection algorithms present in the libraries of OpenCV.

One of them is HARRIS CORNER DETECTION algorithm and the other is SHI-TOMASI CORNER DETECTION algorithm.

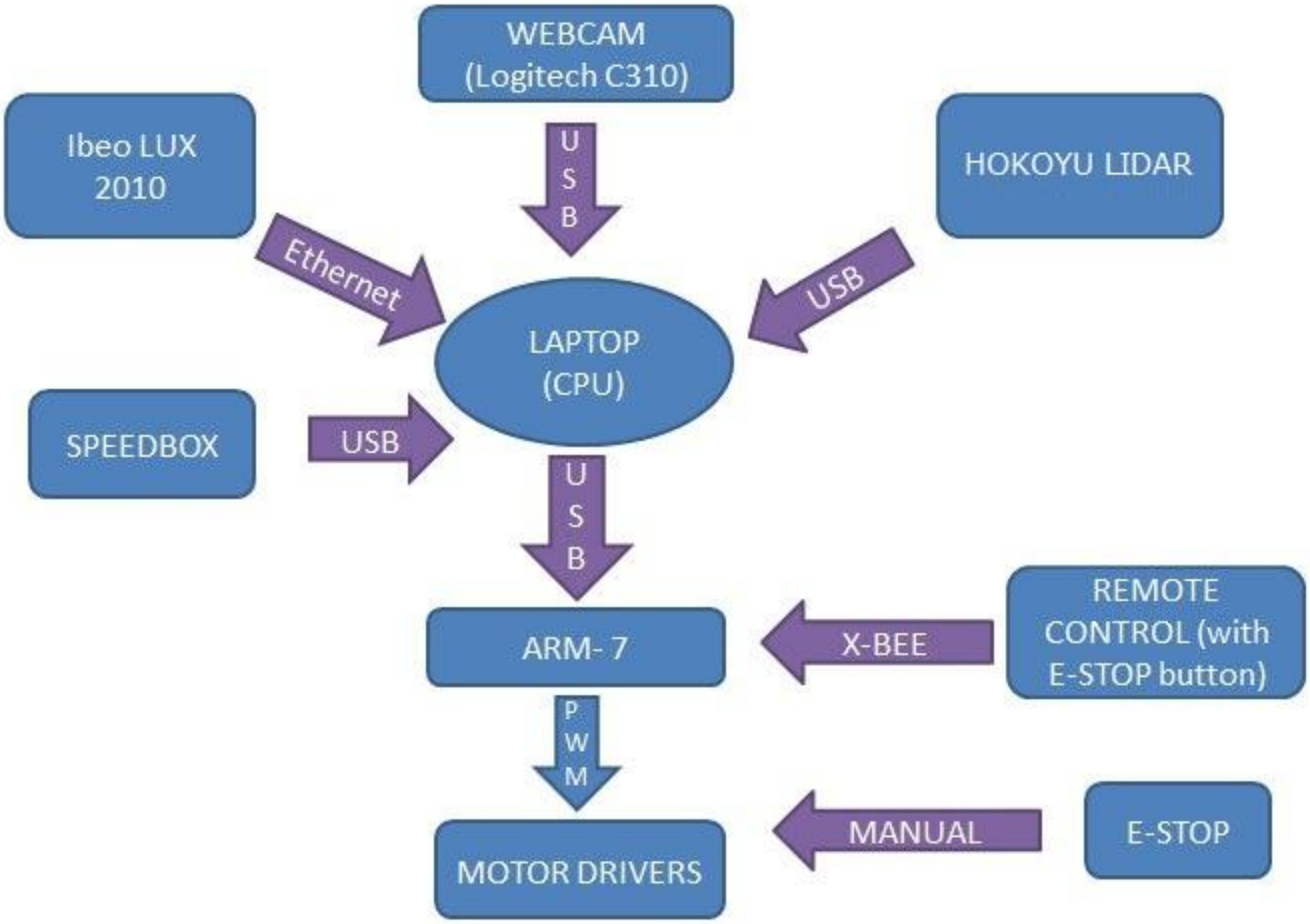
The above provided algorithms work on the basic properties of corners, as stated above and the output given is in the form of pixel locations of the corners found. Direct application of these algorithms is not effective on an image as the image contains different unwanted features that we needed to remove. So before applying the function we use blurring filters to smoothen the image to reduce the number of unwanted corners and then calculate the location and numbers of useful corners in the image.




## Obstacle feature detection using LIDAR sensor

Hokuyo LIDAR outputs a depth map of area. Our Lidar can sense up to 5 metres with 2-3 cm accuracy. It helps us detect obstacles in the nearest, it's viewing angle is 240 degrees and using this we get our boundaries which we plot in our virtual map so we can run A* algorithm on it and get our optimal path.

## System Integration




System integration is one of the important task for any unmanned project. UGV-DTU implements this task keeping in mind that the vehicle need to be autonomous and so any kind of jerk or any weather condition or any kind of fault in one system should not effect the whole vehicle system and interiors.
So we took all kind of safety measures. Normal connections were done using wires with PVC coating avoiding any kind of short circuiting. To avoid the bad weather condition we covered the whole body of the vehicle using flex. To avoid the confusion in the two major part of working of vehicle system, we divided the main base of the vehicle in two storeys keeping the laptop and vision based components on the upper storey and the lower storey contained the microcontroller and the motor controllers and the battery.

## Innovation ibeo Lux

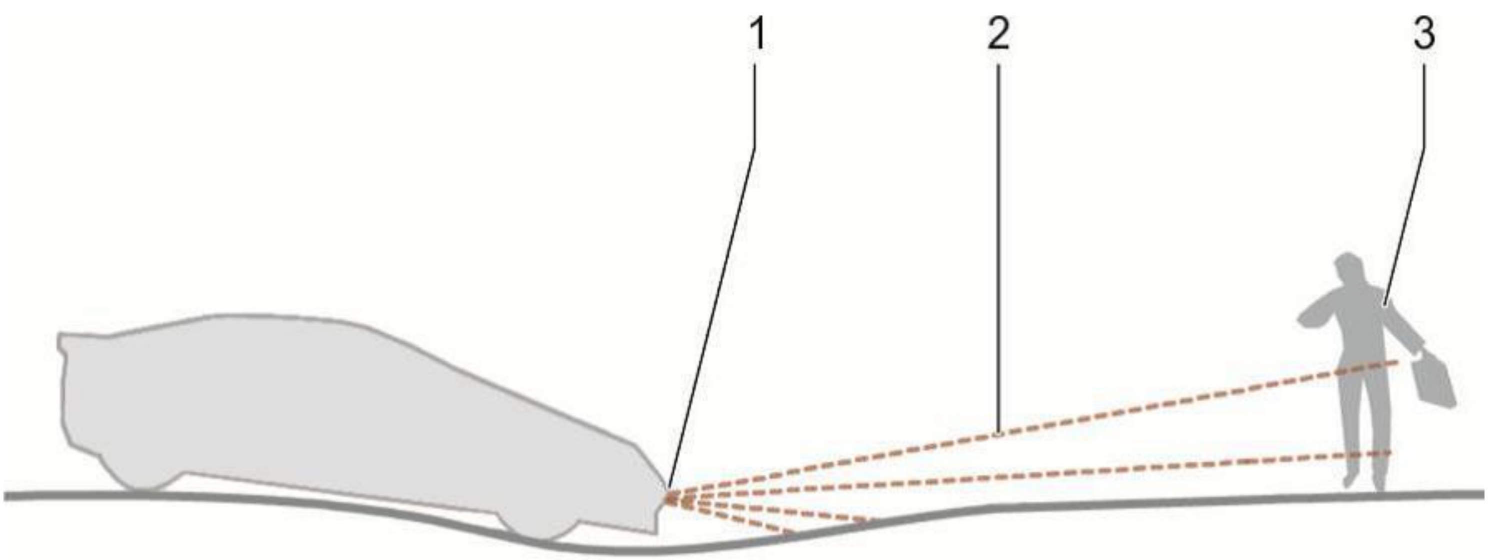
"To make the vehicle first class, state of art technology "ibeo LUX" is implemented in the vehicle UGV-DTU. The ibeo LUX is a real all-rounder for use in urban traffic and on the motorway. ibeo LUX sensors work accurately and reliably even at high speeds, in poor weather conditions and heavy traffic.
Maintaining high field of vision and all weather capabilities ibeo LUX provides object tracking and wide horizontal field of area.

We have been sponsored by ibeo Automotive who have given us this excellent LIDAR, Ibeo Lux. Never used by any team in IGVC.

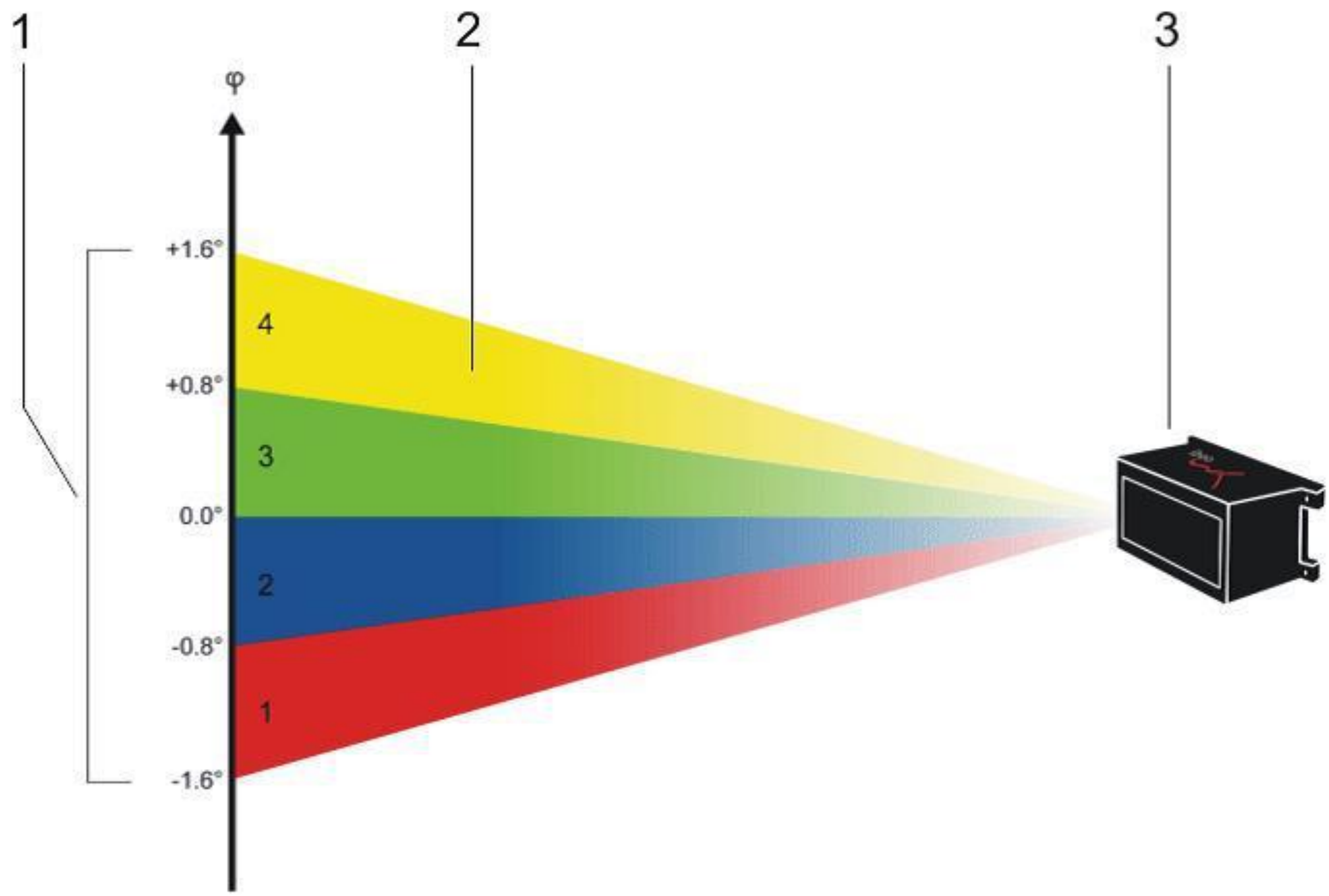
The function of the ibeo LUX 2010® bases on a process to detect the surrounding of the sensor and/or the objects located within the field of view.

For this purpose, laser beams are sent from the ibeo LUX 2010® over four levels and measure the distance and the direction (the angle in relation to the ibeo LUX 2010®) of the objects.
This yields the position of the object in the sensor or vehicle coordinate system.
The resulting profiles of the different levels are called scans, see chapter 4 Scan and object data.
The ibeo LUX 2010® provides two different kinds of information:
Scan data (for all scan frequencies)
Object data (for the scan frequency of 12.5 Hz)
The scan data are the initial information, i. e. information in which area of the field of view of the ibeo LUX 2010® the transmitted pulse has been reflected. The data contain exact angle information (horizontal and vertical), a distance value and information about the pulse width of the reflected pulse.
Scan data are only provided via Ethernet because of their details representation and thus the very extensive amount of data.

It has 4 layers as opposed to Hokuyo which helps it detect even in situations as in image below.




IB-LUX-006

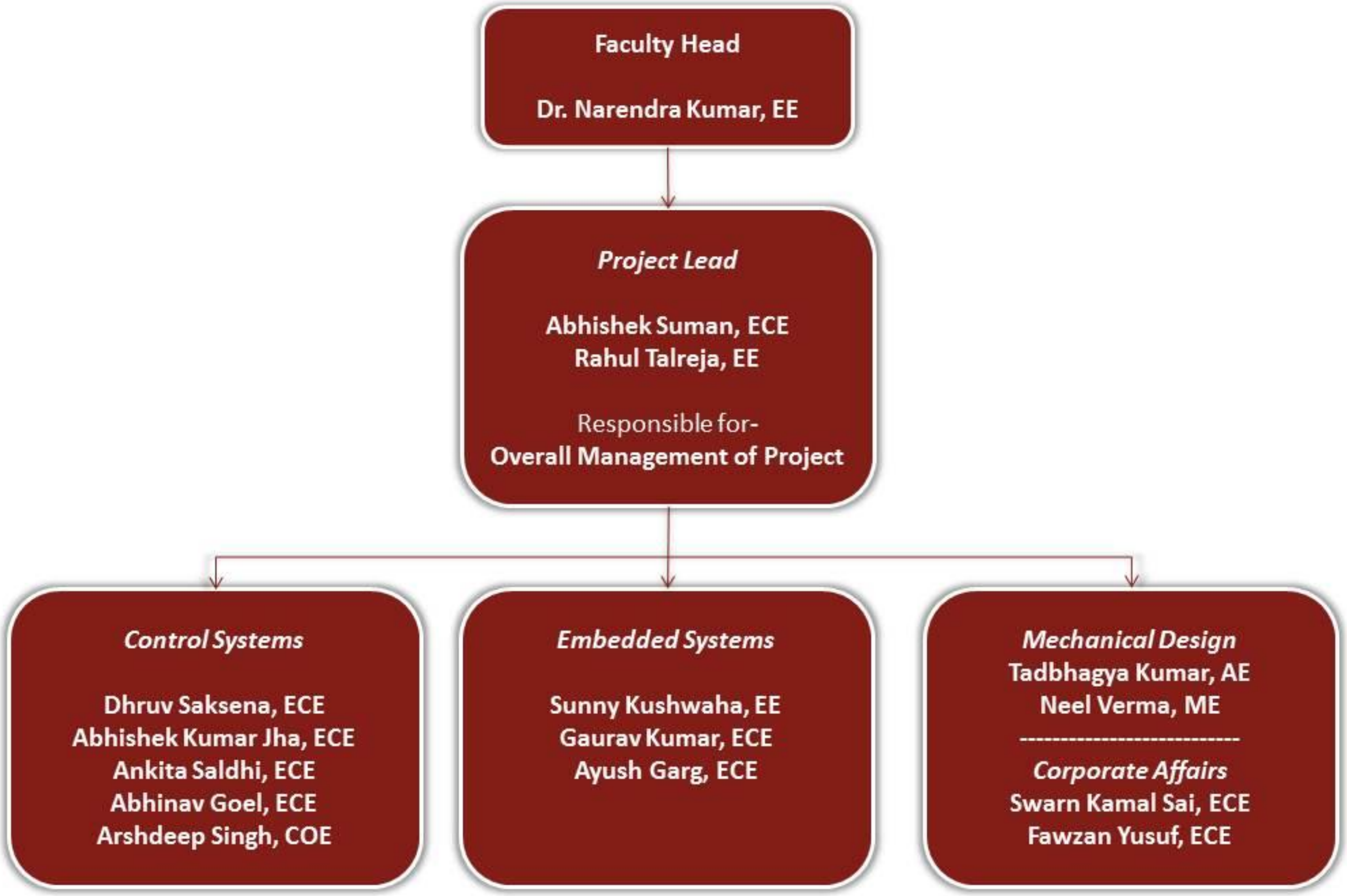



It gives the vehicle gives ramp detection capability, as ramps can be confused with obstacles, but this helps differentiate between the two by using its 4 layers.

## Team Organization

The team focuses greatly on organization and structure. The team structure that developed is comprised of three unique divisions, each with their own challenges.

1) ***Mechanical Design***– the Mechanical team is responsible for creating a lightweight frame that supports an electric motor platform.
2) ***Control Systems*** – The Control systems team is responsible for Design of algorithms responsible for autonomous obstacle avoidance, lane following and internal system communications
3) ***Embedded Systems*** – This team is responsible for Sensor and computer integration, power systems, and remote vehicle operation.
4) ***Corporate Affairs***– The corporate division is responsible for fundraising events and handles the team's media relations.




**AE-** *Automobile Engineering*, **COE-** *Computer Engineering*, **ECE-** *Electronics & Communication Engineering*, **EE-** *Electrical Engineering*, **ME-** *Mechanical Engineering*

## Acknowledgments

The UGV-DTU Team would like to pay special tribute to our supporters and sponsors. First and foremost, we would like to extend our appreciation to the Delhi Technological University for monetary support. We would like to thank our faculty advisor Dr. Narendra Kumar of the Department of Electrical Engineering, under whose guidance we could complete the task of designing up a vehicle like this one. We would like to thank Asst. Professor Mr. Jeebananda Panda of Department of Electronics and Communication for Lab Space & guiding us for the project.

Thanks to ATS, IBEO Automotive Systems GmbH for Parts Support.

# Cost Summary

| Description | Retail Price (USD) | Cost to Team (USD) |
|---|---|---|
| Aluminium frame (including all necessary material) | 136 | 136 |
| Wheel(*2)+ Caster Wheel | 15 | 15 |
| Motors (*2) | 84 | 84 |
| Motor Driver (x2) | 236 | 236 |
| Turnigy Lipo Battery (22.2 V, 5000mah) | 49.5 | 49.5 |
| IMAX B6 Charger+ Adaptor | 49.3 | 49.3 |
| Batteries (11.1 V, 1 A Hr) | 18 | 18 |
| Batteries (7.4 V, 1.6 A Hr) | 18 | 18 |
| Lipo Protector | 2.6 | 2.6 |
| X-Bee Pro Long Wireless Modules | 88 | 88 |
| Camera (Logitech) | 30 | 30 |
| Miscellaneous (Electronic Circuits and Fabrication Costs) | 75 | 75 |
| Hokuyo URG Laser Range Finder | 1525 | 1525 |
| IMU Digital Combo Board-6DOF | 75 | 75 |
| ATS Speed box (for GPS,YAW rate) | 6225 | 0 |
| IBEO LUX (IB-LUX-006) | 8390 | 0 |
| **Grand Total** | $ 17016.4 | $ 2401.4 |

1 Dollar=53.8 Rupees

| | |
|---|---|
| **Total Man Hours:** | **1050 Hours** |

# Faculty Statement

I, Dr. Narendra Kumar, Professor in the Department of Electrical Engineering at the Delhi Technological University, do hereby certify that the engineering design of the unmanned ground vehicle Lakshya-II is fully developed by UGV-DTU team members. (No part of Lakshya vehicle which participated in IGVC 2009 was used). That is significant and equivalent to what might be awarded credit in a senior design course.

Date- 3rd May 2013

Dr. Narendra Kumar

Faculty Head

UGV-DTU