UNIVERSITY OF DELHI
DELHI COLLEGE OF ENGINEERING

TEAM YANTRAVID

PRESENTS

SARVAGYA

Theoretically, there is no difference between Theory and Practical,

Practically, there is…

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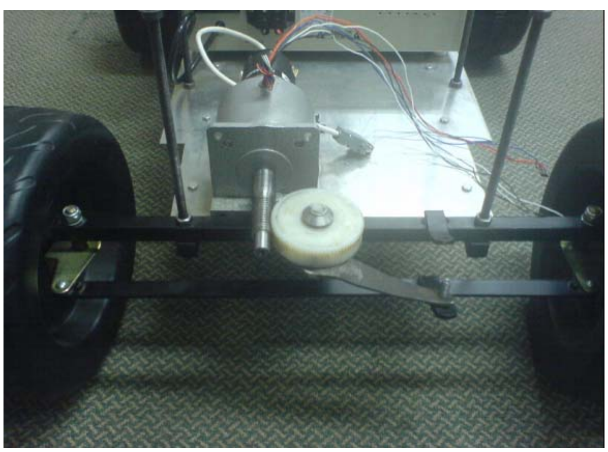
INTRODUCTION:

The Unmanned Ground Vehicle team from Delhi College of Engineering, New Delhi, India "Team Yantravid" is proud to present the first entry from India at the 14th Annual Intelligent Ground Vehicle Competition. In our novel attempt we have striven hard to build an Unmanned Robot, which is proficient in autonomous navigation, is built on a sound mechanical platform and is adept for testing newer technologies and various other algorithms in our future endeavors.

Team Yantravid comprises of under graduate engineering students only who have been working in the field of Robotics for the last 2 years and have come so far already.

INNOVATIONS:



The design is simple and easy to reassemble and makes an effective utilization of the available space. The steering mechanism is very robust and rugged as it is used in normal road cars. All the circuit boards have been fabricated by the team members themselves and the design has been kept as generic as possible.

DESIGN PROCESS:

Constraints on time and resources together with the design requirements stipulated by the IGVC objectives required a rigorous design process. It includes identifying the deliverables and milestones and a very realistic estimate of achievable targets under the very acute constriction of time and particularly resources. The aim was to prepare a robot with all the basic necessities of an intelligent robot and to improve upon it as far as possible in the first attempt.

The team worked on a very systematic process chart which was updated regularly to achieve the desirables in time.

TEAM STRUCTURE:

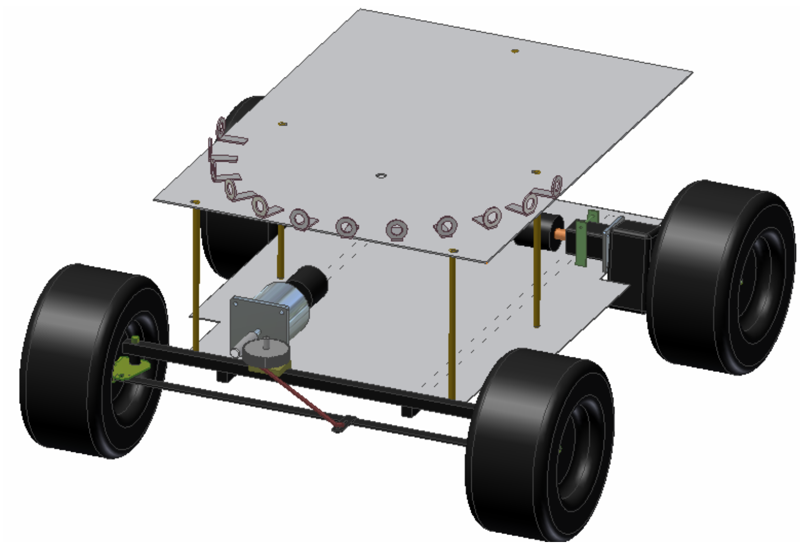
The team of ten was divided into teams of two each. Each team was required to work on a separate module independently. The performance of each team was reviewed periodically and the goal redefined accordingly. The following is the division of the team.

NAME OF TEAM MEMBER	FIELD	QUALIFICATION
ANKIT SATIA	MACHINE VISION AND PROGRAMMING	UNDER GRADUATE, 3RD YEAR
ARUN KUMAR AHLAWAT	MECHANICAL DESIGN AND MATHEMATICAL MODELLING	UNDER GRADUATE, 3RD YEAR
ASHISH	POWER SYSTEMS	UNDER GRADUATE, 3RD YEAR
DEBADEEPTA DEY	MACHINE VISION	UNDER GRADUATE, 3RD YEAR
GAURAV SINGH RANA	EMBEDDED SYSTEMS AND PROGRAMMING	UNDER GRADUATE, 3RD YEAR
GAURAV TAANK	ARTIFICIAL INTELLIGENCE	UNDER GRADUATE, 3RD YEAR
KETAN BHARDWAJ	SENSORS AND EMBEDDED SYSTEMS	UNDER GRADUATE, 3RD YEAR
NAVDEEP DAHIYA	MECHANICAL DESIGN AND MATHEMATICAL MODELLING	UNDER GRADUATE, 3RD YEAR
NEHUL GULLAIYA	EMBEDDED SYSTEMS AND COMMUNICATIONS	UNDER GRADUATE, 3RD YEAR
RAMNIK GARG	CORPORATE AND PUBLIC RELATIONS	UNDER GRADUATE, 2ND YEAR

DESIGN METHODOLOGY:

A holistic approach was employed throughout the design process where the main emphasis was laid on learning and building a skill set to successfully complete the robot. A practical and objective review of the desirables was performed periodically and goals were modified accordingly. Intense reviewing and deliberations led to the decision that incorporating the GPS navigation system was not a feasible option keeping in mind the constraints on time and resources. Hence the team decided making the other system work as best as possible. However it has been kept as the target for next year specifically.

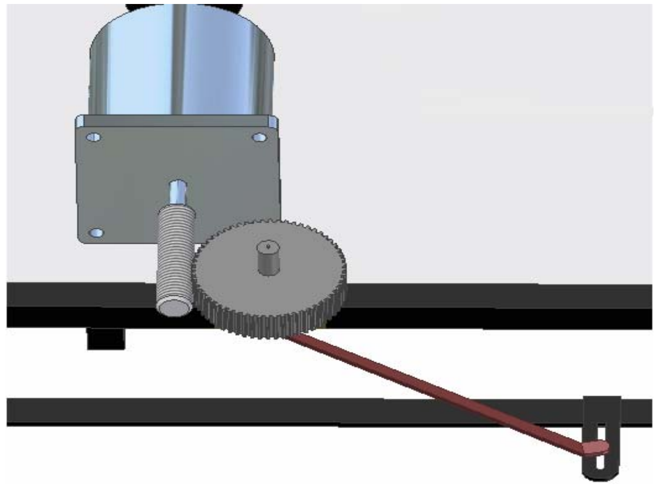
CHASSIS:



The tubular mild steel frame of the *SARVAGYA* is very durable and can carry weight much more than is required even though it is very light. To transform ideas to reality 3 – D models were created in AutoDesk inventor and simulated as well.

Light aluminum sheets were fixed to the base of the chassis to carry the weight of the batteries, inverter and other items. Modular approach was followed to keep separate platform for the CPU and the radars. The batteries were clamped to the base in such away so as to be fixed rigidly while motion and are easy to remove for servicing as well. The inverter was bolted to the frame so that it does not vibrate or fall out during motion.

MOBILITY:



The fundamental design of *SARVAGYA* is a car like Ackerman steering stable on uneven terrain. The four-wheel configuration provides a stable platform for all the components. The functionality of the robot lies in the fact that two separate motors drive each of the rear wheels. Each of the motors provides ample torque so that even if one wheel gets stuck other will move independently. This gets the vehicle out of potholes and since the robot is maneuvered by an intelligent control system it will regain its path.

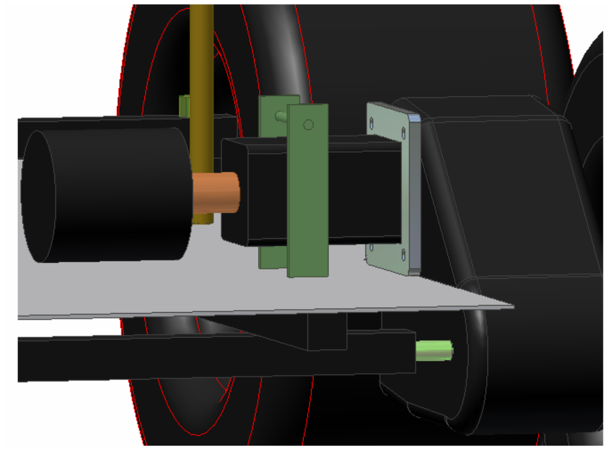
Steering is accomplished by an independent steering motor, which controls the Ackerman steering and makes the vehicle proceed in the right direction as calculated by the software. The specialty of Ackerman steering is that it is the most widely used driving mechanism in all the road vehicles. The front outer wheel turns by a larger angle than the front inner wheel to overcome slip due to larger arc traveled by the outer wheel. The steering motor assembly was designed and manufactured using worm and worm wheel gears to steer the vehicle.

An 80:1 reduction type of gear with efficiency close to 60 percent was used along with 1.89 N-m bifilar stepper motor so that it will steer the vehicle in any form of ground conditions.

CHASSIS RELIABILITY:

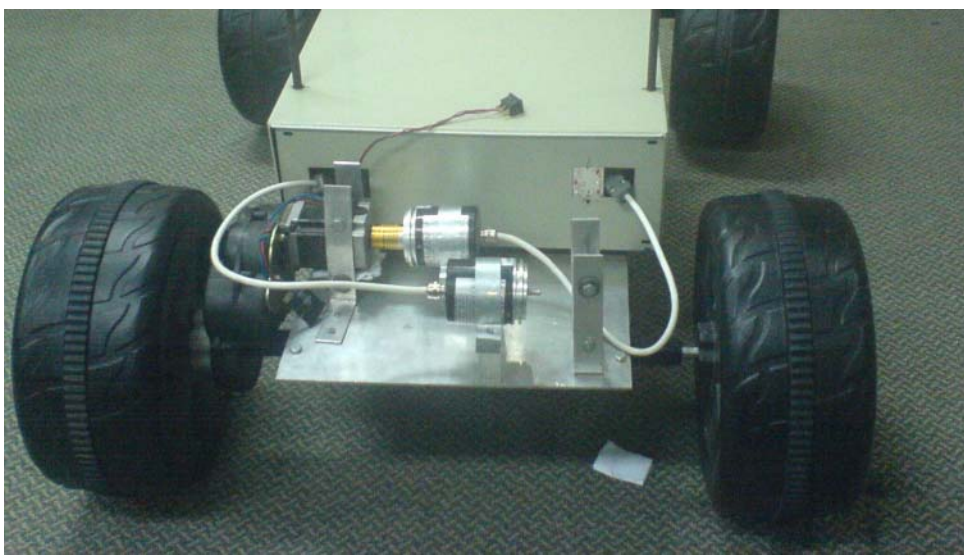
Most of the hardware on top of the vehicle is electronic hence the need for weatherproofing. All the components are rigidly and neatly packed hence the stability in uneven terrain is achieved. The attention to weather proofing allows *SARVAGYA* to compete come rain or shine.

DRIVE GEAR:



Two stepper motors drive *SARVAGYA*. Each motor provides a maximum torque of 1.89 N-m. A 12:1 reduction gearbox has been manufactured to transfer the power from motor to the drive wheels to help move the robot.

ELECTRICAL SYSTEM:



The electrical system on *SARVAGYA* is based upon safety, practicality, and reliability from initial design concept to final implementation. Many problems were encountered in achieving a modular power distribution and control systems but were solved with the help of CAD models developed in AutoDesk Inventor. All the wires are insulated properly to prevent short circuits and safety hazards.

SAFETY:

The electrical system features an emergency stop capability that can be activated via wireless controller, software control, or a large easily visible and accessible button on the vehicle's exterior body. When activated, the emergency stop system stops the motion of the vehicle by effectively cutting the power to the motors. All current carrying components are electrically and physically isolated from the outside environment in order to minimize any possibility of electrical injury. Also the onboard batteries are sealed properly to avoid any accidental leakage during operation.

HARDWARE EXPANDABILITY:

The front part of the vehicle body has the sensor and the camera mountings while the rear part has all the motor controller and power distribution hardware. There are a number of USB ports available onboard the CPU, which allows for quick and easy up gradation of the sensor hardware like extra radar modules, an INS module or stereo vision modules, which will improve the performance of the vehicle in the competition significantly and has been kept in mind for forthcoming competitions.

MOTORS:

The vehicle is driven by two stepper motors providing 1.89 N-m of torque and coupled with 12:1 reduction gearbox. The driver board and power stabilizer board has been designed and fabricated by the electrical design team. The stepper motors are lighter, more powerful, and easily controllable than traditional brushed DC servomotors systems. Precise motor control is inherent to the stepper motors. Furthermore the feedback from the motors is obtained using 200 line encoders, which makes it a closed loop operation. Hence the entire motor control is easy through the USB port. The inherent accuracy of stepper motor combined with feedback from motors makes motor control highly precise, easy and reliable.

POWER SYSTEM:

In contrast to most other vehicles, sealed lead acid batteries power *SARVAGYA*. It is a safe and reliable power source. The use of only batteries was based on the consideration of the inherent complexity associated with other power sources such as generators or other hybrid systems, which would have led to deviation from our primary objectives. Apart from this, battery operation eliminates toxic fumes, vibration and proves to be a clean fuel. In addition it provides an ability to work in hazardous conditions where there is a possibility of accidental spilling of fuel or there is a possibility of fire hazard in case of combustible fuel.

SARVAGYA employs a simple battery system. This system utilizes two sealed lead acid batteries. Each battery weighs 13.8 Kgs and provides 42 amp-hours of deep cycle capacity at 12 volts. When arranged into two battery banks these batteries provide 42 Amp-Hours of capacity at 24 volts. The power provided by the onboard batteries is distributed to the motors, motherboard, and sensors via the power stabilizers and inverter. The batteries are clamped rigidly can be easily charged onboard.

ELECTRICAL BOX:

An electrical box was designed to hold all the electrical circuit boards together at one place. All wires were taken out separately for each circuit board. The wires were color coded for easy identification. The electrical box was placed in such a way so as to experience least amount of vibration and shock to prevent any damage as well as to shield the circuitry from noise. It reduced the number of physical interconnections. It also facilitates easy serviceability and identification of any electrical fault.

SENSORS:

Twelve radars were used in the front of the vehicle to detect obstacles and to map them in an occupancy grid. This data is fed to the obstacle avoidance algorithm to plan the next move of the vehicle. The sensors communicate via serial port to the main router board.

The 12 ultrasonic radars were driven by 3 driver boards, which consist of analog circuitry, digitally controlled micro controllers to fire these radars, collect the echo and make the required calculations for finding out the range of various objects in front of our robot. We have sequentially fired the radars to reduce the effects of cross talk. The 12 radars are at an angle of 15 degrees to each other covering 180 degrees in front of the robot. We have used assembly language to program our controller boards. The radar controller provides the value of ranges in the 12 directions and sends a packet of all values to the router board, which then communicates with the computer via a serial port and provides the software with the required range data.

VISION:

We have used Intel Open CV as the major developmental tool for our vision algorithm. We are using a single Samsung 243-PD CCD camera giving composite output to a BT878A based PCI tuner card which in spite of being a V4L2 device has been adapted for use with Open CV.

We have utilized the information contained in the HSV and Y Cb Cr channels of the input image for detecting lines. With the aid of morphological operators we are weeding out the outliers to the lines such as the bins and people in the field of view and retaining only the lines in the image. We have then calculated the distance to both the left and right lines in the image from the robot position and then pass the information to the decision making algorithm which decides the best direction for movement in combination with the Vector Field Histogram technique keeping in mind the last known line configuration.

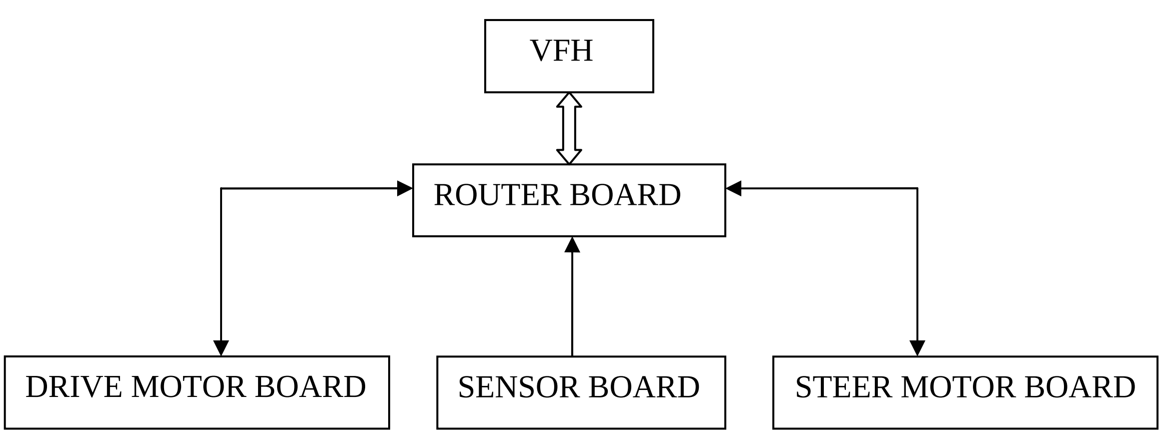
A.I. & SOFTWARE:

Player 1.6.5 was used as the base software and modifications were made to it as required. VFH is the algorithm used for local planning and navigation purposes. We integrated the positions of white lines with the radar data to avoid obstacles and navigate through the obstacle course. Now the white lines were projected as obstacles and then the VFH locally made the Robot navigate around staying inside the white lines and avoid bins detected by radars.

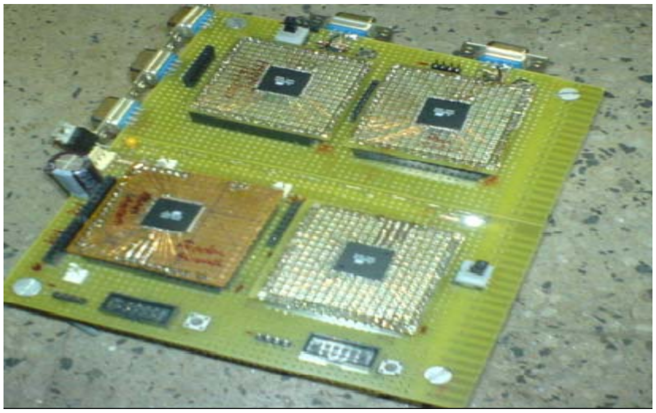
The software communicates via a serial port to the router board to give commands to the motors and to get the 12 radar range values.

PCQ Linux 2005 is the operating system used to run the software.

DEVICE COMMUNICATION:



We have used router board for the communication between the different boards and the VFH obstacle avoidance algorithm. Router board communicates through single RS-232 port with the VFH collecting all the necessary data from motor boards and sensor boards. It also communicates with VFH to issue command to the drive and steer motor to follow the trajectory according to VFH



Use of simple Radio Frequency communication modules has been made for communicating the Wireless E-Stop to the Robot. A single stop bit is communicated to the Robot to stop the robot from moving any further by tripping a relay circuit.

Rest of the devices communicates with each other through serial communication at a prefixed baud rate through serial cables.

VEHICLE PERFORMANCE:

1) Speed:

The stepper motors have a maximum speed of 1000 rpm. It is combined with 12:1 reduction gearing which leads to a final speed of 83.33 rpm at the wheel. With diameter of .33 m for the wheel the speed of the vehicle turns out to be around 1.44 m/s. This speed is desirable because the software performance does not allow a speed greater than this.

2) Ramp Climbing Ability:

The maximum incline specified in the IGVC rules is 15% grade which is 8.5 degrees. It has been verified with dynamic force analysis that the motors provide enough torque to propel the vehicle up an incline of 15 degrees (which is more than that specified in the rules) with a velocity of 1 m/s. The tires have been rubber treaded so as to provide proper grip on the surface even if it is smooth. The weight distribution is in favor of the front tires so that it provides it with an ability to climb over obstacle and navigate uneven terrain easily.

3) Reaction Times:

The processing time for the vision software is 100 ms. The total time to collect sensor data; process it and issue commands to the motors is 50 ms. At a speed of 1.44 m/s it translates into the vehicle moving 0.216 m. This reaction distance is within the sensing distance of the cameras and radars. Hence vehicle can move effectively without hitting obstacles in front.

VEHICLE COST:

S No.	Articles	Qty.	Rate per pc. (Rupees)	Total Cost (Rupees)
1	Chassis (Frame and Tires)	1	15,000	15,000
2	Gear Train (Rear Wheels)	2	2,500	5,000
3	Steering Mounting and Gears	1	10,000	10,000
4	Camera Rig	1	1,500	1,500
5	Ultra Sonic Sensor Mounting and Base	1	2,000	2,000
6	Stepper Motors (Rear)	2	5,000	10,000
7	Stepper Motor (Front)	1	3,900	3,900
8	Encoders with Coupling	3	6,000	18,000
9	Inverter	1	5,000	5,000
10	Batteries (12 V, 42 Amp Hr)	2	2,500	5,000
11	Motor Driving Boards	3	5,000	15,000
12	Motherboard (915 Chipset)	1	7,000	7,000
13	Processor (Intel Pentium Dual Core)	1	10,500	10,500
14	Hard Disk Drive (40 GB)	1	2,000	2,000
15	RAM Chip (512 MB)	1	3,000	3,000
16	Serial and Parallel Ports	2	1,700	3,400
17	CPU Cabinet – Purchased	1	1,500	1,500
18	Wireless Modules	2	6,000	12,000
19	Ultra Sonic Sensors (4 in one)	3	2,500	7,500
20	Camera (Samsung)	1	20,000	20,000
21	Frame Grabbers (PCI card)	1	2,500	2,500
22	Miscellaneous (Electronic Circuits and Fabrication Costs)	-	20,000	20,000
Grand Total				**Rs.1,79,800 ($ 3,910.00)**

Note: The price shown above is in Indian currency (Indian Rupees). The amount equals $ 3,910 if we consider the present exchange rate of $1 = Indian Rupees 46.00

CONCLUSION:

SARVAGYA is a fully autonomous vehicle, designed by III year undergraduate students from Delhi College of Engineering, India. This is a first attempt from any college in India to participate in a competition of such repute. A functional autonomous vehicle is developed despite the acute shortage of resources and lack of availability of components. This project has led us through a very steep learning curve and has exposed us to a very exciting new world of autonomous mobile robotics. It is sincerely hoped that the experience of participating in the 14^{th} Annual Intelligent Ground Vehicle Competition would be an enriching experience and would fuel our desire to better our first attempt and make an improved vehicle.

ACKNOWLEDGEMENT:

It takes us great pleasure to thank our faculty advisors from Delhi College of Engineering, under whose guidance we could complete the mammoth task of designing up a vehicle like this one. We would like to thank…

Prof. Sagar Maji, Head, Dept. of Mechanical Engineering, DCE

Dr. M. Kulkarni, Dept. of Electronics and Communication, DCE

Mr. Ranganath M. Singari, Dept. of Mechanical Engineering, DCE