TENTH ANNUAL
INTERNATIONAL GROUND VEHICLE COMPETITION

Design Report

ALVIN III

Trinity College

Hartford, Connecticut

STATEMENT FROM FACULTY

This is to certify that ALVIN III has undergone significant redesign in both hardware and software from last year's IGVC entry. The Alvin team members worked on the robot as an Independent Study project and received 1.0 credit (3 credit hours) per semester. This project is significant and has led to many senior design projects in both Computer Science and Engineering.

Dr. David J. Ahlgren,

Professor of Engineering, Trinity College

1 INTRODUCTION

This report presents the redesign and reconstruction of a third generation unmanned ground vehicle ALVIN-III at Trinity College. After a careful design study and performance evaluations of past robots, the team developed a lightweight, intelligent, safe and a technically superior robot in the form of ALVIN-III.

The complete redesign of the drive system is the main feature of the new improved ALVIN. The use of lighter weight high torque motors with an innovative wheel system module gives it an extra edge in navigation through the thick Orlando grass. The new camera system, the navigation system and the mechanical body together with a new sub-meter accuracy differential GPS system makes the robot capable of performing well in both the navigation challenge and the autonomous vehicle challenge.

2 TEAM ORGANIZATION AND DESIGN PROCEDURE

Five members of the Trinity College Robot Study Team were assigned to the ALVIN Redesign Project with valuable research and suggestion provided by the entire

Robot Study Team. Table 1 shows the names, class level and responsibilities of each member of the ALVIN Sub-Team.

Name	Class	Responsibility
Kundan Nepal	Senior	Chief Engineer, Electrical System, Vision System, CAD
Nhon Trinh	Sophomore	Project Leader, Mechanical System, Vision System
Michelle Bovard	Sophomore	GPS Navigation System, Software
Trishan deLanerolle	Sophomore	Mechanical System, GPS Navigation System, Software
Matt Gillette	Freshman	Vision System, GPS Navigation, Simulator, Software
Robot Team Members	--	Miscellaneous Research and Support

Table 1 ALVIN Team Members and Responsibilities

The team members met every Tuesday afternoons as a sub-team and every Thursday afternoons with the rest of the Robot Study Team to report progress and generate ideas.

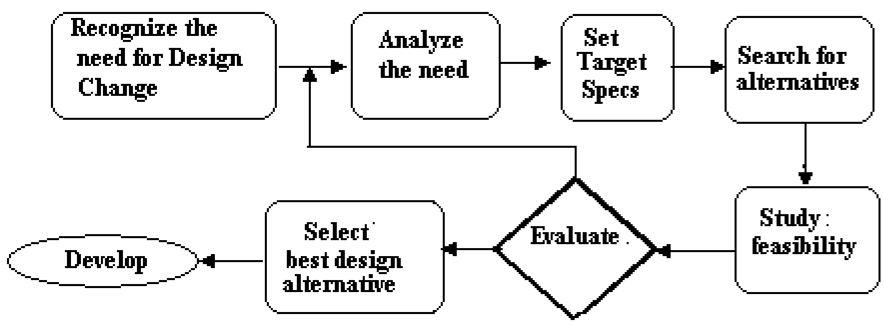

Figure 1 Redesign cycle for ALVIN-III

Since ALVIN-III was a redesign vehicle the first thing that was necessary was to identify the need for a design change. Vehicle performance and personal experiences at the 2000 and 2001 IGVC competitions together with communications with a few other IGVC teams formed a major guideline for the design changes. Based on our past experiences, the following design changes were deemed necessary:

- The weight of the vehicle must be minimized.
- The drive system must be capable of generating more torque to overcome thick St. Augustine grass in Florida.

- The wheels of the vehicle must be light and wide to minimize pressure on the surface of contact so as to easily ride over the grass.
- The computer system must be replaced with a laptop to eliminate the need for external power supply, external monitor and the extra weight.
- The camera system must be able to adapt to the variation in the lighting condition during a run.
- The camera system must be able to auto-calibrate.
- The remote E-stop device must not be triggered by other wireless sources operating at the same frequency.
- The casing on the robot must be made of light material and should prevent the internal vehicle temperature from increasing even when exposed to extreme summer heat.
- The GPS navigation system must be a differential system and must have sub-meter accuracy.
- The speed control unit and the navigation software must be changed to detect motor torque out and to pass over speeds that cause a high motor resonance.

With the major design changes identified, a target specification for the vehicle was developed. The rules of the IGVC and the design changes deemed necessary formed a basis for the target specification. The initial target specifications were carefully considered with alternative implementations considered for each specification generated. After careful feasibility study that considered factors such as design time, design feasibility and cost the following specifications were drawn and the following materials selected.

Weight: 99lbs including 20lb Payload

Dimensions: 3ft x 1.5ft x 2 ft

Drive System:

Motors: M2-3424 Stepper Motors

Motor Controller: IM1007 Microstepping Controllers

Gearbox: NE34-01 10:1 Gearbox

Wheels: Bicycle Wheels in front and Pneumatic Caster on the back

Control System:

Primary: DELL Latitude PIII 750MHz Laptop

Secondary: VESTA SBC2000-332 processor

Sensory System:

Camera: Logitech Pro 3000 Webcam

Vision Software: MVTOOLS Vision Library

GPS: Ashtech BR2G-S GPS receiver

Power System:

Drive Battery: 5 x 12V Lead Acid Cells

Processor Battery: 9.6V NiCd battery pack

Vehicle Frame and Cover:

Frame: light weight aluminum tube.

Cover: Reflective covers to minimize internal temperature increase.

Vehicle Performance:

Maximum Speed: 3mph

Normal Speed: 1mph

Remote Stop capability: 1000ft

Minimum Stop Distance: 3 ft at a speed of 3mph at an incline of 25 degrees

The use of SOLIDWORKS 2000, a 3D modeling package, was made for mechanical design changes. The CAD tool was used for object packaging, weight distribution in the vehicle, stress point analysis and for the calculation of the center of gravity of the vehicle. The CAD tool also enabled the team in understanding the impact of mechanical changes and its usefulness before having to do it in hardware.

3 ELECTRICAL SYSTEM

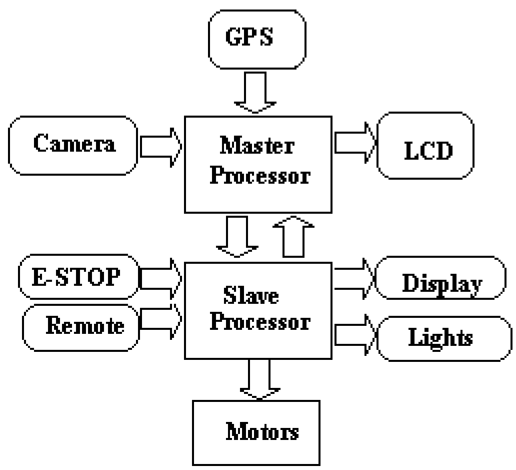

Figure 2 The overall Electrical System Block Diagram

The vehicle uses the master-slave concept. A DELL Latitude C600 750 MHz PIII processor laptop running WINDOWS 98 makes the master processor for the system. The master processor receives its main input from the USB camera system and performs image processing at 20fps using a software frame grabber module. It also receives Differential GPS data during the navigation challenge through the serial port. Based on the image and GPS data processing results, the navigational decisions made by the master processor are passed onto the slave via RS232 communication protocol. A VESTA SB2000-332 board running a VESTA BASIC operating system acts as a slave processor. This processor receives data from the remote E-Stop on a TPU (Timer Processing Unit) channel, the mechanical E-Stop and a control signal from the master processor. Based on the decision made by the master, the slave then sends out appropriate control signals to the motor controllers, the LCD display and the strobe lights. The master processor features Wireless Ethernet card and runs WINVNC virtual neighborhood software for easy debugging purposes. The master processor is operated with a built-in hot swappable rechargeable battery system while the slave uses a 9.6V NiCd battery pack. The normal operating life of the batteries with full electrical load is 1hr.

4 DRIVE SYSTEM

The modified drive system on ALVIN consists of a pair of 16inch bicycle tires, a pair of IM1007 microstepping drives together with the IM3424 34 frame high torque stepper motors and a new light weight gearbox system. The older IM3450 motors together with the Superior electric 5:1 gearboxes were replaced with the IM3424 and Bayside Motion Systems 10:1 gearbox. The new drive system now has an addition 131 percent increase in torque on the drive wheels. The drive module had an added advantage of being lightweight removing an unnecessary 16 lbs off the total body weight. Table 2 shows the comparison of the two drive systems and Fig. 3 shows the operating torque curve at the wheels of the robot.

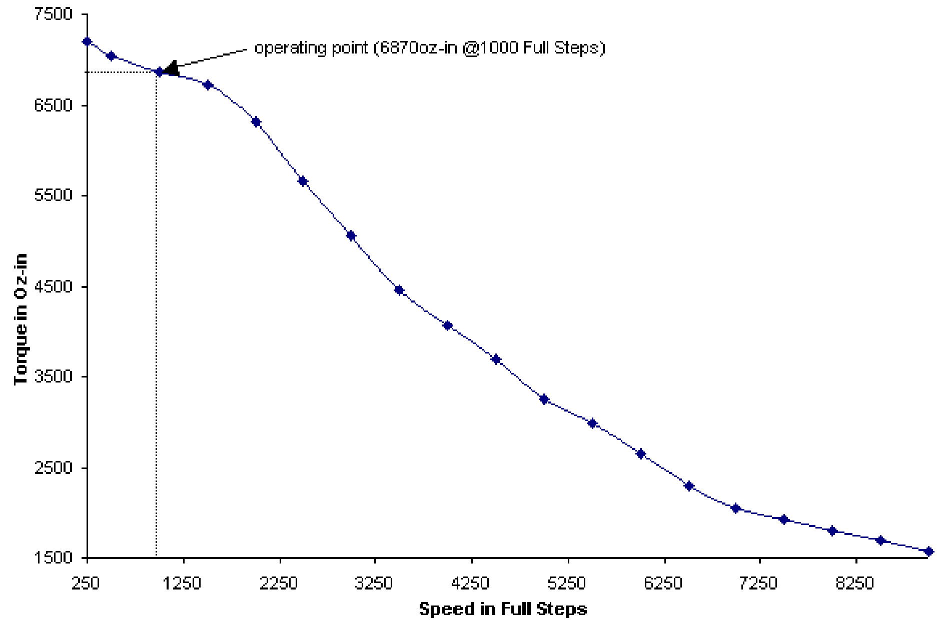

Figure 3 Torque curve at the wheels of ALVIN @ 7Amps and 60V

	Old Drive System	New Drive System
Overall Gear Ratio	9.4:1	18.9:1
Operating Voltage	48V	60V
Operating Current	7.0A	7.0A
Operating Full Step	1000	1000
Overall weight	28 lbs	12 lbs
Operating Torque at wheels	2987 oz-in	6870 oz-in

Table 2 Comparative look at the two drive systems

5 SENSORY SYSTEM

The sensory system on ALVIN-III consists of the vision system and the GPS navigation system. The vision system is the sole sensor system used for lane following as well as object detection and path planning.

5.1 Vision System

The old monochrome progressive scan camera and frame grabber were replaced with a USB color camera. The camera selected for this purpose was a cheap Logitech QC Pro 3000. The new camera features an automatic gain control, which helps the navigation system adapt very easily to the changing lighting conditions during an individual run. The colors obtained from the camera help in isolating certain bright objects in the field of view and in recognizing them as obstacles. The camera is housed at the center front of the robot and is mounted at an angle such that the minimum view is 1 meter with a 110-degree field of view.

5.2 GPS Navigation System

The GPS navigation system is a new addition to the vehicle. ALVIN III is equipped with the Ashtech BR2G-S GPS receiver that provides differential GPS position accuracy and reliable user-friendly operation for the navigation challenge portion of the competition. It combines the latest dual-channel beacon receiver technology with the industry-leading Ashtech 12-channel precision GPS, integrated in a single, easy-to-use product that provides sub-meter position accuracy. Current work is being done to integrate the GPS navigation system with the vision system.

6 MECHANICAL BODY

The frame designed using 6061-T6 Aluminum extruded square tubing was retained because of its lightweight, strength, and stability. The external body design was however removed and is currently being completed. The new outer body is made of weatherproof reflecting material. The material will reflect most of the heat in the hot summer and prevent the internal temperature of the vehicle from rising. A double lining of the material with an insulating layer in between will be very helpful for this purpose. The system will ensure that the electrical components will not fail under extreme summer heat in Florida.

7 SOFTWARE SYSTEM

The major work on the software system came from the change in the camera system. The progressive scan camera and the PCI frame grabber card from ALVIN-II was replaced with a USB camera. This new camera gave rise to the requirement of a custom frame grabber that would work with the MVTOOLS Visual Basic Library. MVTOOLS is an image-processing package used in the ALVIN family of unmanned vehicles and is sponsored by Coreco Imaging. The software also features the development of an auto-camera calibrator that defines the various camera parameters based on 2D-3D transformations. Other changes and improvements in software include new algorithms for vehicle navigation.

7.1 Frame Grabber

The customized frame grabber is a translation of a Microsoft Visual C++ SDK class "avicap" to Visual Basic. This conversion provides tools to acquire an image buffer from USB camera using existing USB driver. This buffer is then processed and converted to the image format compatible with MVTOOLS vision package.

7.2 Kinematics Simulator

The ALVIN kinematics simulator was improved from its previous version. The new version allows users to change the grass texture from a database of real grass images to reflect a more realistic navigation environment. It also includes navigation challenge simulator whose major job is to incorporate the GPS system and obstacle avoidance.

7.3 Camera Calibrator

In order for the image processing to be used for vehicle navigation, the camera parameters have to be determined very accurately. The camera parameters define the angle of tilt of the camera and the location of the image plane. Although, the camera angle can be manually determined by measuring the physical angle, it was desired that an auto calibration algorithm be developed. This algorithm would take an object it the field of view and determine the parameters from it.

The algorithm developed uses a rectangle in the field of view. The rectangle need not be on the ground but it is required that the rectangle be at an angle to the viewer. The camera calibrator uses the principle of vanishing points that has been used by artists for a long time. A vanishing point is the point of intersection of two parallel lines in an image. Using 2D-3D transformations, a set of equations associated with the camera parameters is developed from the coordinates of the vanishing points of the rectangle as illustrated in Fig. 4.

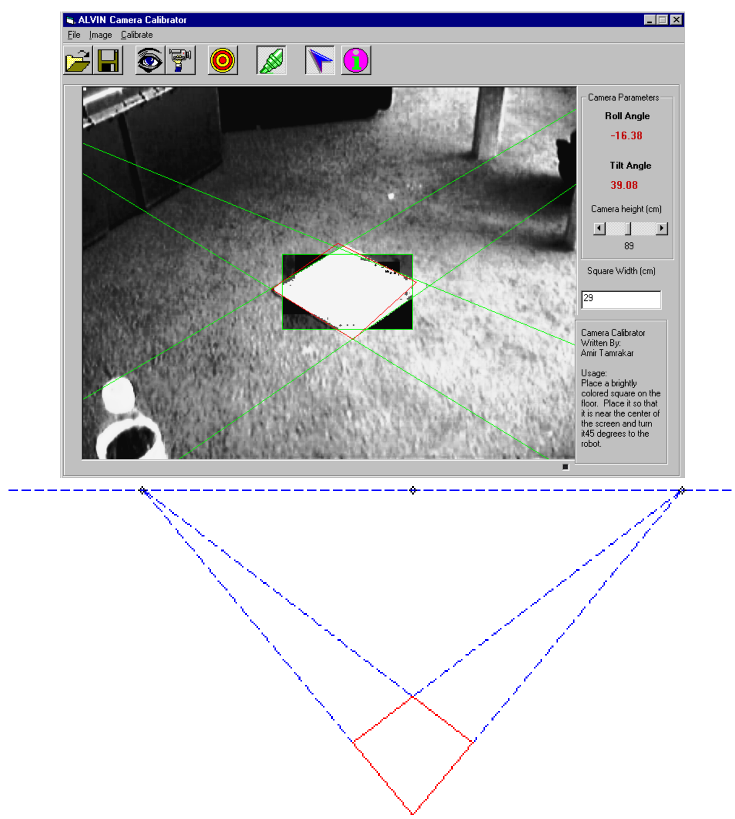

Fig. 4a. Snapshot of the Calibrator. b The vanishing points of a rectangle in the field of view.

8 CONTROL STRATEGY

The control strategies are solely based on vision system for the autonomous challenge and a combination of vision and GPS for navigation challenge.

8.1 Lane Following

For the purpose of lane following only a section of the entire frame captured by the buffer was used. The lower one-third of the image buffer was preprocessed using various imaging algorithms such as image thresholding equalizing. The lane markers are then detected on the region of interest (ROI). The widths of the lines were compared to the ones stored in the database to make sure objects or potholes detected on the ground were not interpreted as lanes. With the basic notion that the vehicle has to move parallel to the road in order for it to successfully stay within the track, the line was projected out into the horizon. The intersection of this line with the horizon has to occur at the same place as the intersection of the line through the center of the robot. Since the line through the center of the robot, is always the line in the center of the image, the intersection has to happen close to the center of the screen. Failure to do this would signal a vehicle going off track and corrective measures would have to be applied to bring the vehicle back on track. If both lines of the track cannot be seen at some point, it is ok to rely on just one line with the argument above. When both lane markers are invisible, it is wise to hold the bearing until the tracks become visible again.

8.2 Object Detection

The texture of the construction barrels form the basis for their distinction as objects in the field of view. The potholes are detected using the fact that they have the same threshold value as the lane markers but produce a bigger white blob in the image than allowed by the navigation controller.

8.3 GPS Navigation

The GPS navigation strategies are currently being developed in conjunction with the vision system for obstacle avoidance during movement from one way point to the other.

9 PREDICTED PERFORMANCE

9.1 Speed

The maximum speed of the vehicle was calculated to be 3mph. However the optimal speed of the vehicle for maximum torque was found to be just under 1mph. Acceleration from zero speed causes a motor resonance at very early speeds requiring great care to be taken during acceleration.

9.2 Ramp Climbing Ability

ALVIN-III with its new high torque motor was able to easily climb a ramp placed at an angle of 20 degrees to the horizontal ground. Climbing a 15% incline should not be a problem for the vehicle.

9.3 Stopping Distance

The stopping distance for ALVIN-III at an incline of 25 degrees was found to be 3ft at its maximum speed of 3mph. The high holding torque at the wheels of the robot (6870oz-in @ 1000 full steps) allows the vehicle to be stopped quickly and at a very short distance.

9.4 Battery Life

The Dell Latitude batteries last a total of 1hr with full electrical load. The lead acid cells used for the motor power are rated at 4.5Aph. The current required by the motors is 7A but due to the use of IM1007 Microstepping controllers the maximum current draw was measured at 3A. Hence the motor batteries have a life of at least one hour.

10 SAFETY CONSIDERATIONS

The use of the mechanical e-stop placed at the rear center of the robot and the remote e-stop that can be used from a distance as far as 1000ft makes the vehicle safe.

11 SPONSORS

- Intelligent Motion Systems Inc.
- Bayside Motion Group
- Coreco Imaging
- Thales Navigation
- Trinity College
- Travelers Insurance
- Teknicircuits Inc.