Design Report for

Proteus

Oakland University

12th International Ground Vehicle Competition

I, Ka C Cheok, hereby certify that the engineering design in this entry by the current student team is original and has been significant to be counted as credit in a senior design course.

Ka C Cheok
Faculty Adviser, Oakland University

Introduction

The team from Oakland University is proud to submit the report for *Proteus,* our entry into the 2004 IGVC competition. We have made numerous improvements over the past year in our organization, design and construction, and are very pleased to present them in this report.

Team Organization

Our team took a very structured approach towards organization when planning for the 2004 IGVC tournament. All of our team members are part of the OU student organization *Association for Unmanned Vehicle Systems.* This is an official organization of our University, and as such has officers for managing the relations between the organization and the university.

Brian Clark – President
Christopher Cook – Vice President
Kevin Hayes – Treasurer
Bill Clements – Secretary

Within the group, additional groups were made to facilitate the four major aspects of the project. After consulting with all of our members, we determined that four distinct groups were needed to logically organize everybody and allow for the efficient delegation of tasks and projects.

- Software

  Responsible for all programming aspects of the robot. To include communications between different robotic components, movement algorithms, path planning and obstacle avoidance.

- Electrical

  Responsible for all electrical subsystems of the robot. To include electrical wiring between all components, electrical load balancing, emergency stop system and motor controller installation.

- Mechanical

  Responsible for the mechanical structure of the robot. To include the design and construction of the robot, as well as a fiberglass cover.

- Management

  Responsible for the coordination of the robotic project. To include project management, budgeting, upkeep of work areas, purchasing and delegation of assignments.

Team members were then assigned to their respective groups based on their knowledge and areas of expertise.

Software	**Electrical**	**Mechanical**	**Management**
Brian Clark	Jason Finch	Tomasz Zielonka	Kevin Hayes
Bill Clements	Corey Wideman	Adam Ladensack	Christopher Cook
Phil Stene	Eddie Schwartz		
	Brian Vitale		

Design Process

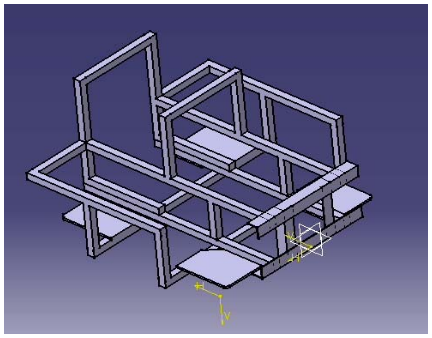
Our current entry, *Proteus*, is a major improvement over last year's entry, *Grizzly*. Our design process consisted of identifying major areas of improvement on our old robot, creating a solution for that problem, and then implementing that solution back into the robot. We identified several key areas for improvement which when combined provided for almost a complete overhaul on our old design. Problems which were addressed included:

- Unreliable electrical wiring
- Troublesome E-STOP system
- Power loads not distributed properly
- Frame takes up too much space
- Not water resistant
- Complex motor controller system
- Buggy software modules

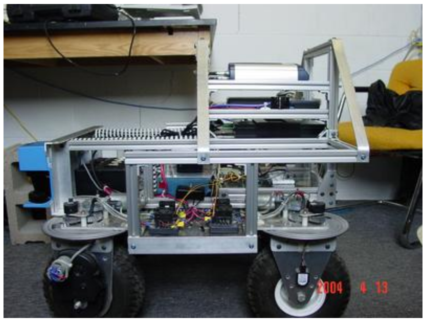
These major problems were brought up early in the design process, and were then formulated into projects to be completed by the different groups, as will be demonstrated in the remainder of this report. While team members were responsible for implementing any changes for their particular responsibility, all members of the team regularly held meetings to discuss algorithms, designs and processes which would affect every system of the robot. By doing this, ideas were implemented which were not necessarily obvious to their soon-to-be implementers.

Robot Construction

Proteus is constructed on an aluminum frame. The frame has a footprint of 3 feet in width by 3 feet in length. It is supported by approximately 8 inches of ground clearance by 4 Power-Wheels toy car tires.



The mechanical design for the robot was similar in that we are building the robot in “layers” to compartmentalize the various components which will reside in the robot at completion. The bottom layer is used for the motors and motor controller subsystem of the robot, including:



- 4 Power Window Motors for Steering
- 4 Power Wheels Drive Motors for Velocity
- 8 Victor 883 Motor Controllers for Voltage Regulation
- 4 Potentiometers for Steering Feedback
- 4 Encoder Sensors for Velocity Feedback
- Pico-Servio Motor Controller Coordinator

In our current design, all 8 Victor 883 motor controllers, as well as the 8 Feedback sensors are connected to the Pico-Servio Motor Controller Coordinator. This device coordinates the servo outputs for the Victor controllers, as well as the digital inputs for the sensors. This information can then be accessed or manipulated thru a single COM port on our PC, as described below.

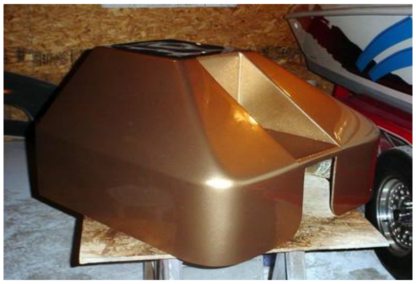
The next 3 “layers” are held in the tower portion of the robot in the rear of the vehicle, as shown above. These layers contain the vital portions of our robot, including:

- Stealth Mini-PC
- USB to COM port breakout box
- 802.11b Wireless Network Bridge
- GPS Unit

Each of these components is mounted on a Plexiglas panel, which is able to easily slide in and out of the tower section when needed. Cable runners along the side of the tower allow for clean and efficient wire management. All electrical wires run thru these runners into a centralized fuse box at the front of the unit, where individual motors and components can be turned on and off individually. Power is supplied by 2 Lead 9V batteries in the center of the vehicle, as well as a 12V to 24V converter located next to the fuse box.

In addition to the frame of the robot, we also constructed a fiberglass cover to hold the payload, as well as provide resistance from rain and moisture. This cover was created by first shaping a Styrofoam mold. This was chosen because it was lightweight, easy to shape, and provided the ability to create complex angles. Measurements were doublechecked, edges were rounded smooth, and the entire mold was covered in plastic for protection.

4 layers of fiberglass covering were then applied to the mold, with Bondo used to smooth the entire cover and fill cracks. After sanding and coating the cover in primer, it was painted with the school colors, and spray-in bedliner was used in the payload section for extra grip. For finishing touches, clear coat was applied for a glossy finish, and school stickers were applied to finish off the cover.



Electronic Design

One of the major problems which was encountered at the previous competition was the lack of a dependable electrical system. This year, the entire electrical system was removed and rebuild using the expertise of four Electrical Engineers. In doing this, the following tasks were completed:

- Proper grounding of all devices

  All electrical devices are now grounded to the frame in either one of two places on the chassis. These 2 places are on either side of the battery, and are covered with a black cover to minimize cable clutter and improve aesthetics.

- Rewiring all devices to a centralized fuse box

  All electrical circuits were run back with the proper gauge wire to a fuse box in the front of the robot. In addition to providing overload protection, switches on the top of the fuse box allowed for the independent engagement or disengagement of the 9 electrical circuits;

    - Motor Controller Unit
    - Stealth PC
    - GPS / IMU
    - SICK Laser Rangefinder
    - Auxiliary Circuit
    - Front Right Steering and Movement Motors
    - Front Left Steering and Movement Motors
    - Back Right Steering and Movement Motors
    - Back Left Steering and Movement Motors

- Installation of Advanced E-STOP system

  The E-STOP system was redesigned to provide for a fail-safe system in the case of an emergency. The current for the motor circuits passes thru the E-STOP system. When either the wireless button or the local button is activated, that signal is immediately dropped, halting the motors from moving while still allowing all the onboard equipment to remain functional. In addition, this sends a signal to the host PC alerting it of the E-STOP condition so that proper measures can take place in software.

Software Strategy

All software is written and run on the Stealth PC, which is located on the robot. Obstacle avoidance and lane recognition are the key aspects of the autonomous challenge.

Obstacle avoidance is handled by a process called vector addition. All obstacles in the robot's environment are represented by a vector. The details of this vector are determined by the distance and direction to any individual obstacle. An obstacle's individual strength in the vector is reduced when there are numerous other obstacles in close proximity. In addition to the vectors represented by obstacles, there is one other vector produced: the target point vector. This vector is the representation of the destination point or goal of the robot. By adding up all of the obstacle vectors as well as the target point vector, a final vector is produced which will govern the final movement of the robot.

There are many problems which must be addressed in the topic of lane following. The main problems which we face are:

- Line color varies.
- Background color varies.
- View of lines can be obstructed.
- Lines can be dashed.
- Potholes inside the lanes.

For our first problem, changing line colors, we use an algorithm to evaluate an image capture from our cameras, searching for the given line colors of white and yellow.

Histogram analysis is then used to determine a threshold, and the image is then split into lane and background categories. Our second problem, varying background colors, can affect this process. To reduce this detrimental effect, we can reduce the size of the analyzed picture to obtain a reduced sample. Since the view of the lines can be obstructed, or the lines be dashed, it is possible to be unable to locate the line. To best solve this problem in a simple way, we attempt to follow one of the two lines. If we lose view of this individual line, and are unable to obtain view again, we will switch sides and find the other line to work off of.

Waypoint navigation is a critical aspect of the navigational challenge. Our robot treats it as a special case of the autonomous challenge, with the extra requirement that it must move to specific points on a field. In this regard, we have removed lane following from the decision algorithms and greatly enhanced the obstacle avoidance. First, an algorithm is run which plots the shortest path between the points while remaining clear of the origin. Each of the paths between these points is treated independently, with the goal of the robot being to move from point to point. The “target point vector” is represented by the location if the desired GPS coordinate to go to in relationship to where the robot currently lies on the field. As the robot moves towards the point, obstacle vectors are introduced and dealt with as described above. As the robot nears its destination, it slows down allowing for greater GPS accuracy. When the robot reaches its acceptable tolerance of closeness to the GPS point, it repeats this same process over by positioning itself towards the next point to travel to and doing the same steps which were just listed.

With the last point in the robot's memory being the origin, the unit will move itself back into the starting area when all GPS coordinates have been determined to be reached.

Systems Integration

The critical portion of any large project, especially for the IGVC tournament, is the successful combination and integration of all hardware and software systems into a final functioning product. Combined systems will include:

- SICK Laser rangefinder

  The SICK Laser Ranger is on loan to us from the US Government. This unit, mounted at the front of the vehicle, has a 180-degree detection range of around 10 meters, with readings every half-degree and a resolution of 5 cm. This is our main sensor for obstacles, and communicates via a standard serial port.

- Inertial Momentum Unit

  The inertial momentum unit is mounted in the center of gravity in the middle of the robot. This device monitors acceleration for movement and rotation in each of the 3 major axis. It is used for error correction in the GPS system, as well as for verification of movement. It communicates via a standard serial port.

- Global Positioning System

  A NovAtel GPS system is installed on the robot to facilitate the accurate completion of the navigational challenge. With WAAS technology enabled, we are able to achieve a resolution of 1 meter for both latitude and longitude. As does all NMEA-compatible devices, our GPS system communications via a standard serial port.

- Avoidance Cameras

  Two Logitech QuickCam webcams are used for line detection in the autonomous challenge. These cameras are able to capture color images at resolutions of 640 by 480 in real-time for processing by the host PC. These cameras are mounted on the front corners of the robot cover, and connect to the host PC via a high-speed Universal Serial Bus(USB) connection.

- Pico Servio Motor Controller Manager

  The Pico Servio Motor Controller Manager is the device which all of our devices not able to be hooked up to a PC are connected to. This includes 8 motors for use in robot movement, as well as 8 sensors to confirm correct robotic movement. This device communicates with the host PC via a standard serial port.

- Wireless Network

  An 802.11b wireless network bridge is installed on the robot in order to efficiently operate the robot. In our current configuration, the program VNC is sun on the host PC inside the robot. This program allows other computers to connect to it via the network and see the desktop, as well as use the keyboard and mouse. When we are out in the field we use a second computer, a laptop with a wireless card, to connect to *Proteus* using this VNC program. This device connects to the host PC using a standard Ethernet cable.

- Drive System

  The drive system consists of the motors, gears, sensors, and controllers used in order to efficiently and effectively move the robot. As mentioned in the *Robot Construction* section above, this consists of 8 independent motors capable of turning and moving each wheel independently. This allows for true 4-wheel drive, where our robot can not only strafe side-to-side, but move in any direction while facing in any direction. The motors are connected to Victor 883 motor controllers which regulate the voltage to produce the desired speed for each motor. These motor controllers, as well as the 4 potentiometers and 4 encoders are connected to controller pins on the Pico Servio Board.

The top five systems are connected to a Stealth PC running Windows 2000. It is on this PC where the main program runs, controlling not only the five systems listed above, but image analysis and path planning as well.

Unit Reliability & Performance

We have tested the performance of the robot in various areas to ensure the reliability and durability of the robot during the competition. While the maximum speed for the competition is 5 MPH, and we have coded this into our software to ensure safety, the motors are able to handle speeds well over 10 miles per hour. In addition to being fast, *Proteus* is able to handle ramps with a grade over 30 degrees, and is able to climb over the roadside curbs on campus. The reaction times are also extremely impressive, with the path planning module running over 30 cycles a second, and all 8 motors are able to be manipulated over 8 times a second.

With our current battery capability, the robot can handle over an hour of full-load usage. This translates to over 60 minutes of every single component on the robot drawing current at the same time. However, as not all devices draw their maximum current while running, actual runtime is even longer, with our testing sessions lasting longer than 2 hours. Standby time is even longer. Without the motors running, we have achieved over 8 hours of working time without charging the batteries.

Obstacles are detected by the SICK unit reliably at 10 meters, and are detected with increasing resolution as they get closer. Lines can be detected at a distance of 1 meter. All laser and visual detection is done in a 180-degree arc in the front of the robot. If the robot encounters a trap, it stops, does an extensive analysis of its surroundings, and when it determines a proper path, will easily maneuver itself using its 4-wheel drive system to its intended location. If necessary, it will reverse itself slowly using its short term memory of where it has been (compiled with information from the IMU). Finally, with WAAS enabled, we were able to achieve a 1-meter accuracy with our Global Positioning System on an open field.

Cost Breakdown

The following is a breakdown of the costs needed to reduplicate or current configuration:

Crossbow IMU	$300
NovAtel OEM Euro4	$3000
Stealth PC	$695
SICK LMS200-6	$6,000
Sealevel USB to Serial Converter	$200
PicoServio Motor Controller Board	$300
QuickCam webcams	$200
Victor 883 Motor Controllers	$600
Linksys Wireless Bridge	$100
Metal Components	$800
Electrical Components	$1400
Construction Components	$300
TOTAL	**$13,895**

Conclusion

Our team feels very confident that the drastic improvements made during the past year will allow our entry to perform remarkable in the autonomous and navigational challenges. With complete overhauls of the frame and electrical systems, as well as a fiberglass cover, *Proteus* can physically withstand what we require of it. Improved software modules can now take advantage of the hardware, resulting in superior performance. The knowledge and insight gained during the past year is priceless; any additional accomplishments we can achieve in the competitions against the other teams will be supplemental to our already large sense of accomplishment.