BuzzBot

Robojackets

Georgia Institute of Technology

2003

A. ABSTRACT

This goal of this project was to build a robot that would score as many points as possible in the AUVSI ground competition. The robot has integrated cameras, sonar range finders, and differential GPS with an on-board laptop computer to autonomously navigate the various obstacle courses. This report describes the design created using sketches of important design features and provides analysis of several of the robot's capabilities that have been tested as of this writing.

B.   OVERVIEW OF DESIGN

Mechanical System

The robot utilizes a former bomb-disposal robot's chassis as its mechanical base. Originally a six-wheeled design, the front wheels were removed to lighten the robot so that it could be more easily transported. The resulting 4-wheeled robot received new batteries, 3 sonar range finders, 3 cameras, an emergency E-stop, and storage capacity for a laptop and the required payload. Figure 1 shows an AutoCAD drawing of the robot. The cameras, sonar, E-stop, and storage boxes are all labeled in Figure 1.
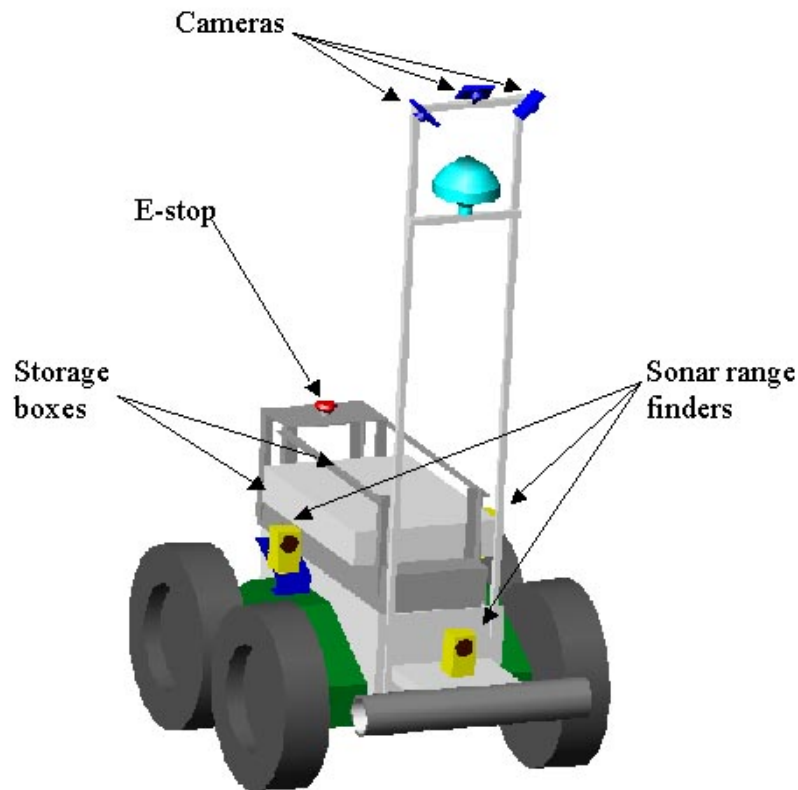

Figure 1: Mechanical overview of the robot.

Electrical System

Three 12V batteries power the electrical systems on the robot. Two of these batteries are wired in series to provide 24V for the motors, sonar sensors, the laptop, and the GPS receiver. The third battery provides 12V for the microcontroller and other low-power components.

All high-level control functions are performed by a laptop running Linux with a 400MHz Intel Celeron processor and 64MB RAM. The laptop connects to sub systems via USB and

serial ports. The laptop is powered by the robot's 24V supply. It also has a wireless LAN card to facilitate remote development, debugging, and monitoring.

An Atmel ATMEGA103 microcontroller development board is used to interface between the laptop and several control and sensor systems. The analog interface board conditions input/output signals for the microcontroller board so that the signal levels fall within the required ranges. The microcontroller has eight built-in analog-to-digital converter channels, which are used to monitor battery voltages, the E-stop inhibit signal, and the three sonar inputs. The laptop communicates with the microcontroller board using a text-based protocol over a serial port.

The robot uses one drive motor for each wheel. Both drive motors on each side are wired in parallel and are controlled by a single motor driver board. Each motor driver is controlled by a PWM output from the microcontroller board, which is filtered and offset by the analog interface board. Each motor driver also has an inhibit input which is generated by the emergency stop system.

The emergency stop system consists of a receiver, the emergency stop button, and two relays. The remote E-stop receiver is a commercial garage door opener receiver, which operates from the 24V supply. Detection of a remote E-stop signal is latched so human intervention is required at the robot to restart after a remote E-stop. The E-stop system will send an inhibit signal to both motor drivers for the following conditions: if the button is pressed, the receiver detects a remote E-stop signal, or the 12V supply fails. Failure of the 12V must be detected because the microcontroller and analog interface boards require 12V to operate and loss of this supply may lead to uncontrolled speed inputs to the motor drivers. The motor drivers will automatically shut down if the 24V supply falls below a safe operating level.

Sensors

Vision

There are three cameras mounted on the vehicle. They are UC110 web cams from Hawkeye. All three are mounted on the top of the camera stand near the front of the robot. There are two cameras pointing to either side of the vehicle angled towards the ground a few feet away from the vehicle's base. The third camera is angled towards the ground a few feet towards the front of the vehicle. The outputs from each camera are sent straight to the laptop through a USB interface.

Sonar

There are three sonar units on the robot. They are ULTRA-BEAM units from Banner. These were salvaged off of two different bomb disposal robots. There is one sonar facing forward positioned on either side of the robot above the center of each wheel system. The third sonar is mounted on a platform on the front of the vehicle and is allowed to pivot left and right. A standard R/C servo is attached to the front sonar and can turn it almost 180 degrees from left to right. The analog outputs from each sonar unit are sent to the controller board, which then passes a digital reading to the laptop.

GPS

The GPS unit that is being used in this robot is capable of receiving differential signals for a higher accuracy in positioning. It is interfaced via a RS232 port.

<u>Software</u>

Vision

A relatively simple algorithm is used to detect lines and potholes that appear in the camera images. A typical image from one of the side-pointing cameras is shown in Figure 2. First, the color image is converted to a gray scale image. Then, the gray scale image is changed into a binary image using thresholding as shown in Figure 3. The threshold is set to 1.5 times the average pixel intensity. A binary image is an image where every pixel is either black (off) or white (on). The remaining white pixels in the image are then fit to a line using a least-squares fit as shown in Figure 4. The R^2 value for the fit and the standard deviation of each point's distance from the line are calculated. A choice is then made as to weather this image is a line, a pothole, a line and a pothole in the same image, or nothing. Table 1 lists the thresholds used to make this decision. The coordinates for the line/pothole are then translated from the image coordinates to the world space coordinates.

Table 1: Decision criteria for determining lines and potholes.

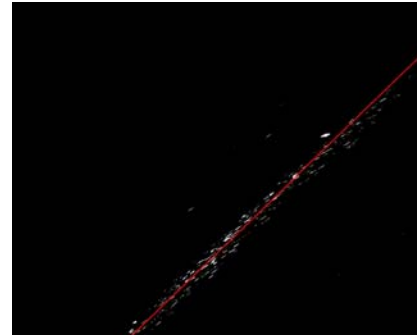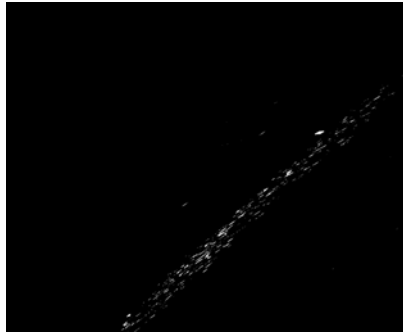| If	And	Then the object is a
$R^2 > 0.01$	$\sigma_y > 175$	Line and a pothole
$R^2 > 0.01$	$\sigma_y \leq 175$	Line
$R^2 \leq 0.01$	$\sigma_y \leq 175$	Pothole
Any other combination		Noise

Figure 2: Typical image from side-facing camera

Figure 3: Binary image of Figure 2.
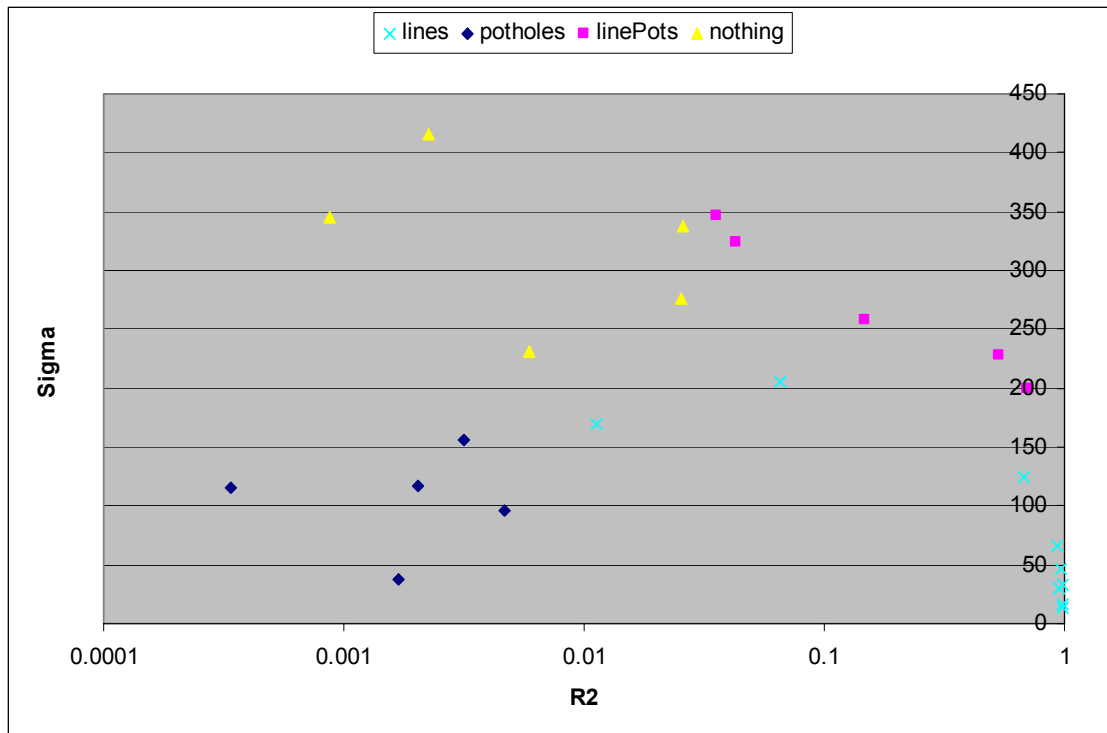

Figure 4: A line fit to the binary image.

Figure 5: Plot of σ_y vs. R^2 for several test images. Notice the general grouping by object type.

All of the numbers used in Table 1 should be calibrated to the grass and lines of the actual competition field. For testing, several images of each category (line, line and pothole, pothole, nothing) were used. Each image was passed through the algorithm and the R^2 and σ_y values were calculated as shown in . These data points were then used to determine what values to place the limits at.

Sonar

The sonar is read by the hardware, and translated into ranges by the software. The sonar is used by the software to determine the placement of obstacles both during driving and when the robot gets stuck.

<u>System Integration</u>

All high-level control functions are performed by a laptop running Linux. An Atmel microcontroller development board is used to interface between the laptop and several control and sensor systems, as shown in Figure 5: Electrical system overview. The microcontroller has eight built-in analog-to-digital converter channels that are used to monitor battery voltages, the E-stop inhibit signal, and the three sonar inputs. The laptop communicates with the microcontroller board using a text-based protocol over a serial port. Each motor driver is controlled by a PWM output from the microcontroller board, which is filtered and offset by the analog interface board. Each motor driver also has an inhibit input which is generated by the emergency stop system.
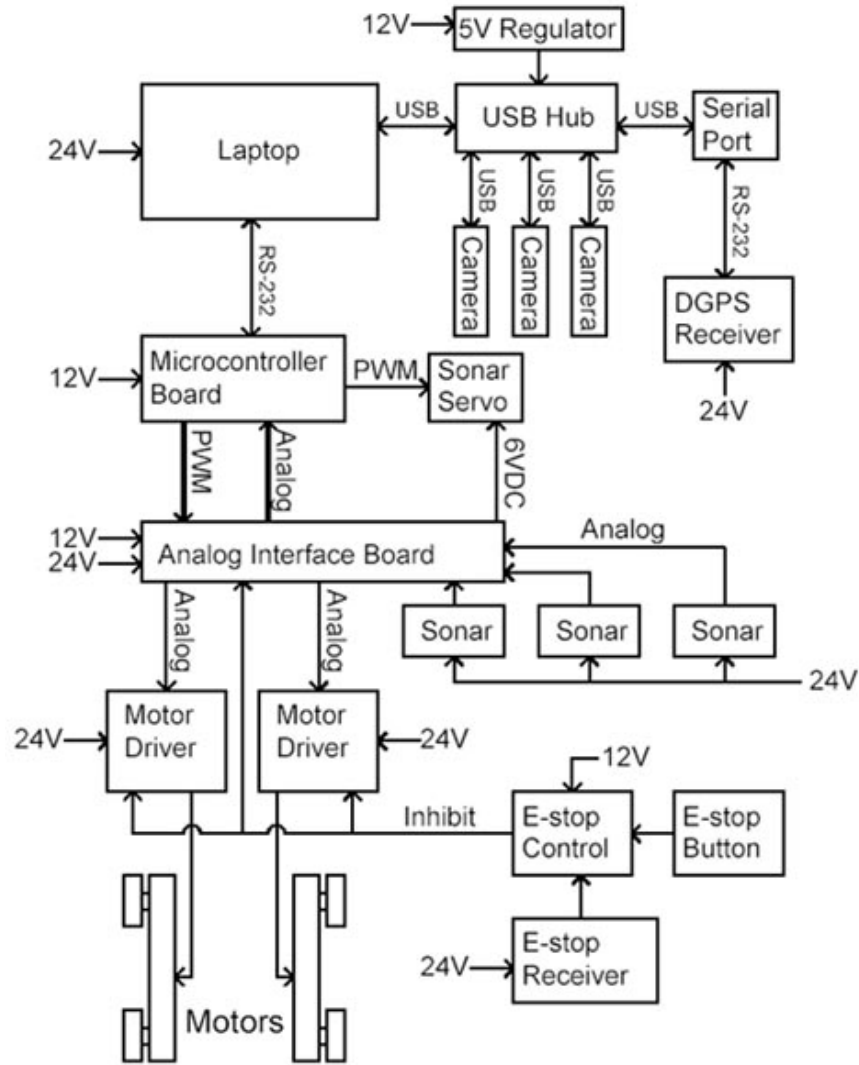
Figure 5: Electrical system overview

C. DESIGN METHODOLOGY

Design Methodology Overview

Because this was the first year of competition, a completely new robot had to be designed and developed. This large and non-trivial task required an organized and systematic approach in order for it to be completed in a timely manner while also satisfying the set design requirements. The design method outlined by Pahl and Beitz in Engineering Design: A Systematic Approach and shown in Figure 6 was used as a systematic design guide for this design task.
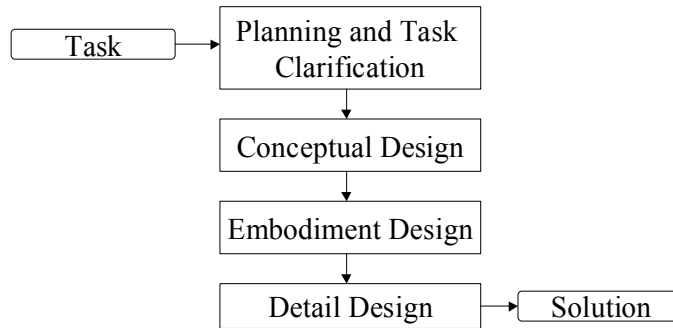
Figure 6: Design methodology.

The task was to design a robust fully autonomous system to compete in the autonomous, navigation, and follow the leader challenges of the IGVC. A list of specifications was developed and continuously updated throughout the duration of the project. However, the constraints of this report limit the detail of the description of these design steps. Design decisions and alternatives were evaluated against these listed design specifications and selected accordingly.

Team Organization

The project team was composed of undergraduates and graduates from various backgrounds, as shown in Table 2. The estimated total number of person-hours expended on this project is 800 hours. The cost estimate is listed in Table 3. The total estimated cost to replicate the robot is $9220.

Table 2: Team organization
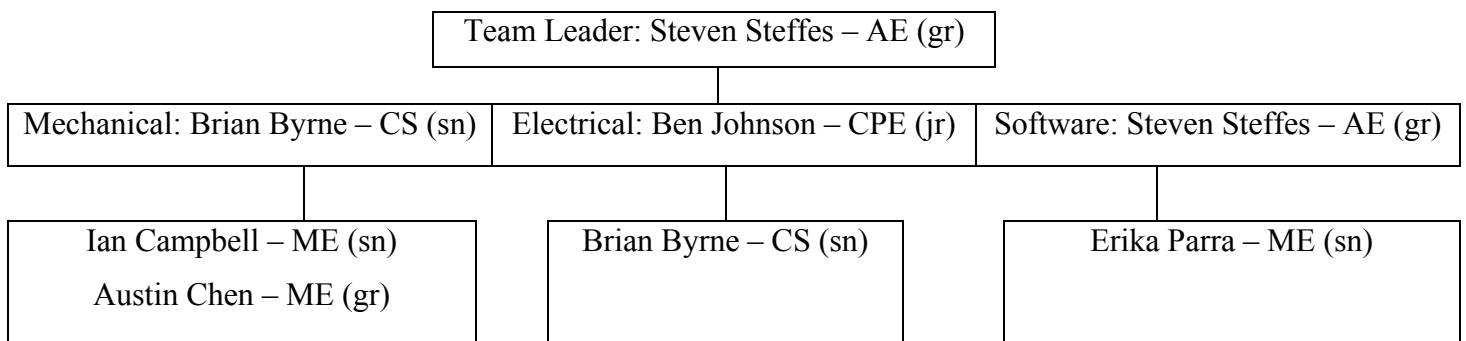
AE = Aeronautical Engineering	gr = graduate student
CS = Computer Science	sn = senior
CPE = Computer Engineering	jr = junior
ME = Mechanical Engineering	so = sophmore

Table 3: Cost estimation

Part	Cost
Bomb Bot Chassis*	$4,000.00
Differential GPS Reciever*	$4,000.00
Batteries	$600.00
Motor Drivers	$400.00
Atmel Control Board	$100.00
Wireless Card	$50.00
Webcams	$70.00
Total	$9,220.00

*Denotes a donated or lent product

Lane Planning and Obstacle Detection

The software for this portion of the competition will be based on a hybrid reactive / deliberative control system. The reactive system will take in sensor data and use potential field navigation techniques to guide the robot around the course. However, this course is designed so that potential field navigation techniques can lead to a robot getting stuck in one of the barrel traps that wedge the robot to the side, as shown in Figure 8. Therefore we introduce a deliberative portion to watch the output of the potential field navigation. When the potential field navigation fails to output a suggestion of where to move, which would suggest that it was trapped, then the deliberative portion takes over. The deliberative portion also gets access to the sensors, and determines from them what kind of trap the robot is in. The deliberative portion then changes the definitions of what the potential fields are, and hands control back to the potential field navigation portion as shown in Figure 9. After a fixed time interval, the deliberative portion changes the definitions of the potential fields back to the original state.
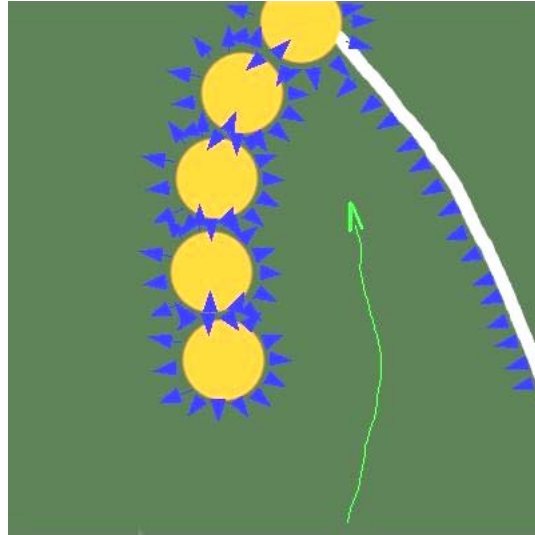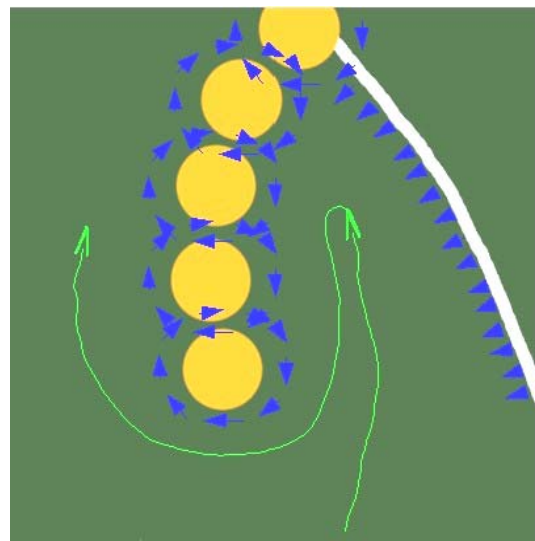
Figure 8: Default Potential Field definitions.

Figure 9: Adjusted Potential Field definitions.

Navigation Challenge

Many techniques have been developed for the trajectory planning of unmanned autonomous vehicles. However, most of these are off-line methods that use graphs and are computational intensive. The problem at hand requires real-time path development as the vehicle negotiates through the obstacle course.

A promising method that satisfies these requirements is the Potential Field method. The method consists of a potential function, similar to the electrostatic potential, which

is assigned to the obstacles and the goal, creating a topological map. However, several modifications had to be implemented to resolve the Potential Field Method shortcomings and to accommodate for the Intelligent Ground Vehicle Competition obstacle arrangements. The modifications included detecting and avoiding the barricades by steering the vehicle accordingly and accounting for the lane markers as obstacles.

D.   ANALYSIS AND EVALUATION

<u>Mechanical System</u>

The robot's chassis presents a very reliable and robust solution to the IGVC competition. Tested in environments where it mastered tree roots, street curbs, and thirty degree slopes, as well as surfaces such as sand, gravel, grass, and pavement, we feel that the robot will perform well on the course provided by the IGVC competition. From the robot's top speed of X, the robot is able to come to a complete stop within one foot, even on a fifteen degree incline.

<u>Electrical System</u>

With a variety of integrated failsafe systems, our robot presents a very robust and safe platform to work on. The wireless E-Stop will stop the robot at a range of at least one hundred feet, with typical ranges from one hundred and fifty feet to two hundred and fifty feet. This presents a very large margin of safety over the required minimum of fifty feet. Integrated failsafes in the control electronics will stop the robot in case of any form of power loss, as well as any form of control signal loss.

E.   CONCLUSION

An autonomous robot has been created to utilize cameras, sonar, and differential GPS to navigate the various courses of the AUVSI ground competition. A hybrid reactive / deliberative control system will be used to navigate through the autonomous challenge course.

F.   COURSE EQUIVELENCY

        I, _____, certify that the engineering design in the vehicle
(original or changes) by the current student team has been significant and equivalent to what
might be awarded credit in a senior design course.

Professor:_____   Date:_____