Abel

The Autonomous Vehicle

Bob Jones University

2008

1. Introduction

This year for IGVC Bob Jones is returning with an improvement of last year's robot. The name Abel is taken from the son of the original man, Adam, as Abel is rebuilt from the hardware of our first IGVC robot Adam. Abel has many improvements over Adam in both software and hardware.

2. Philosophy and Design Process

The redesign of Abel began with an analysis of the weaknesses of the previous design. Based on this analysis, several significant alterations were planned as detailed on the report below. The various alterations were assigned to various team members as listed in Section 5. An online wiki and discussion forum were the primary means of team coordination and communication.

3. Changes

This year's team has made changes to the robot in both hardware and software.

3.1 Hardware

The hardware of Abel has undergone many significant changes which are detailed below.

3.1.1 Caster Wheel

In 2007 Bob Jones took a vehicle to competition that had a ball instead of the normal caster wheel. This solved the problem of directional changes with the caster wheel, but presented the additional problem of trying to keep the bearings clean which proved to be not worth the trouble. For this year we have returned back to a caster wheel. This was relocated to keep the body level. Most importantly, the direction of travel was reversed so the caster wheel now leads rather than trails the body. This places the camera over the wheels instead of three feet behind the wheels.

3.1.2 Visually pleasing body

From the beginning, the body of Abel has been a boring rectangle that has long needed attention. For this year we have constructed rounded panels that are still easy to remove for troubleshooting the electronics.

3.1.3 Shorter body

In past years the body has been long and turning produced a wide swinging of the rear end that was unaccounted for in software. We found it easiest to reduce the length to just barely fit within the confines of the rules.

3.1.4 Sonar

While last year the robot had a sonar array, it had broken before this year. Originally we had planned to go with a scanning IR but after consideration have found that scanning sonar is much easier to implement. The sonar array was removed and replaced with a single sonar mounted on a servo that scans it through 180 degrees.

3.1.5 Batteries

In the past three batteries were employed with two of them in series to meet the 24 volt needs of the motors. The one that was left over was to power all of the electronics. That one battery worked fine but when it was completely discharged all testing had to stop while it could be charged back up again. This problem was solved by the use of two smaller batteries that can be quickly removed so that while one is being used the other can be on the charger.

3.2 Software

This year we have improved much upon the software of previous years.

3.2.1 Hough Transform

In the past we have viewed lines simply as obstacles to be avoided. Our attempts at more sophisticated line detection have nt been successful. This year we are detecting them using the standard Hough transform and using them for directional guidance, doing true lane following in addition to obstacle avoidance. In the absence of obstacles, the robot attempts to drive parallel to the lines. In the absence of lines, the robot attempts to continue the current course. This strategy deals quite well with gaps in the lines.

By using the Hough Transformation, we are now able to find the y=mx+b form of the painted white lines on the course. Because computers ultimately use math to make decisions it becomes imperative that information about the lines on the course be in a mathematical form. The Hough Transformation puts the lines into a form the computer can use and thereby helps the robot navigate otherwise impossible situations.

3.2.1 Simulation

While working on ways to improve the autonomous mode of the robot, it became apparent that we needed a way to test ideas without actually taking the robot out and testing it. A engineering student in the past had written a simulation environment of a virtual course using OpenGL. The simulation was used extensively in order to test the robot for ways of navigating switchbacks and sand traps.

3.2.2 Strategy

In navigation mode, the GPS and compass are used to determine the present position and orientation. The direction to the target waypoint is calculated. The robot begins to drive and steer towards the target direction, with a simple proportional control of the steering. If obstacles are detected, the robot goes into obstacle avoidance mode until the path is again clear, at which point is resumes driving towards the target.

In autonomous mode, the robot detects lines in the image and attempts to steer parallel to them. The camera detects obstacles by color and texture. Sonar detected obstacles are added to this image. If any obstacles are in the immediate path of the robot, the robot steers away from them.

4. Electronics

We have stayed with most of the electronics from previous years to stay within budget constraints.

4.1 Motors

We are utilizing two wheelchair motors, from NPC robotics, for differential steering from the back end of our robot. Both of the motors are equipped with encoders that provide feedback to the motor controller.

4.2 Motor Controller

The motor controller of choice is from Roboteq and is rated at 120 amps for two channels. The motor controller communicates via RS-232 to the computer.

4.3 Computer

Abel has a single board computer from Ampro (LittleBoard P5V PC-104) that is designed to be diskless and fanless and uses very little power.

4.4 GPS

Abel receives his position through Garmin's GPS 18 PC which communicates through the industry standard NEMA format at one update per second.

4.5 Compass

The PNI-TCM2 is used to figure out what way we are pointing. This a very sophisticated compass with a 3-axis sensor to give not only direction but pitch and roll.

4.6 E-Stop

The wireless e-stop device is a standard aftermarket door unlocker for a car. This has been found to work in excess of 100'.

5. General

5.1 Robot Performance

Table 1 - Performance Details

Parameter	Prediction	Actual
Top Speed	8.38 mph	5 mph*
Weight	185 lb	190 lb
Power (level)	90 watts	96 watts
Power (15% slope)	351 watts	360 watts
Current (24v battery pack)	3.76 amps	4 amps
Current (12v battery)	2.67 amps	1.4 amps
Weight Distribution (front/rear)	70/30	67/33 **
Battery Life (level Ground)	4.5hr	>2 hours ***
Reaction time	67ms	143 ms****
Distance of Obstacle Detection	9m	8.5m
Waypoint accuracy	1.5 m	Varies with GPS conditions

* The drive train is capable of >8 mph on level ground but the closed loop speed controller limits the maximum speed to 5 mph.
** With two wheels on the front, this represents a distribution of almost exactly 33% per wheel.
*** Not tested all the way to dead batteries
**** Hardware is capable of 67ms frame period (15 Hz) but software has only achieved 7 Hz so far.

5.2 Component costs

Components	Quantity	Retail Price	Cost to Team
PS12180 18Ah batteries	3	$144	$144
Ampo Littleboard Pv5 single board computer	1	$995	$995
NPC-R82 motors	2	$570	$570
Hubs	2	$40	$40
NPC-AX2550 motor controller	1	$94	$94
Wheels and tires	2	$495	$495

GPS receiver	1	$89	$89
PNI-TCM2-20 Digital Compass	1	$699	$0
PC-104 4-port serial board	1	$149	$19
T-slot and angle bracket frame	N/A	$180	$180
Emergency stop system components	N/A	$70	$70
CM7326ER PC/104 video capture card	1	$455	$455
NTSC video camera	1	$15	$15
Firewire camera	1	$120	$120
Thinkpad computer	1	$1,500	$0
Stereo Camera (research project)	1	N/A	$220
IR System	1	N/A	$100
WiPORT wireless module	1	$199	$99
Ball mount	1	$350	$350
Miscellaneous	N/A	$170	$170
Total		**$6,335**	**$4,316**

5.3 Team Contributions

Below are estimated contributions from each of the team members:

Anthony Garland, software, 60 hours
Zach Richards, software, 40 Hours
Derick Kopp, hardware, 40 Hours
Philip Campbell, hardware and software, 100 hours
Ian Wagner, software, 40 hours
Ben Still, sonar, 40 hours
Nino Palazzolo, body, 40 hours
Chris Jankovic, hardware, 40 hours

Total: 400 hours

Certification of design work performed by the Bob Jones University design team

I, Dr. Bill Lovegrove, Professor of Electrical Engineering at Bob Jones University, certify that the members of this engineering design have done significant engineering design work on the robot that is equivalent to the work that is awarded credit in a senior design course.

Signed:

Date: