The Bob Jones University A-Team Presents

DIONYSIUS

IGVC 2009

Table of Contents

Team Members	1
I. Innovations	2
II. Team Members and Organization	3
III. Hardware and Electronics Design	4
IV. Software Design and Integration	9
V. Predicted Performance	11
VI. Bill of Materials	13

Team Members

Project Manager

Micha Moyer - Post-Graduate Special
Degree: Computer Science

Chris Heindl - Senior
Electrical Engineering
Aaron Hammons - Senior
Electrical Engineering
Adam Swanson - Senior
Electronics and Computer Technology
Ryan Borg - Senior
Computer Engineering

David Frazee - Senior
Electronics and Computer Technology
Justin Mundy - Senior
Electrical Engineering
Dennis Long - Senior
Electronics and Computer Technology
Chris Terre-Blanche – Senior
Electronics and Computer Technology

Total Man Hours Expended: 380

I. Innovations

This year, the Bob Jones University team has created Dionysius, a remodeled version of a robot from a previous year. Many different innovative aspects of Dionysius give it a competitive advantage when navigating the surrounding world. A wide angle lens has been fitted to the camera to provide a more significant range of vision without forcing the camera to rotate on an axis, thereby reducing the number of moving parts. An infrared sensor was designed and fitted onto the front of the robot to prevent it from navigating solely based on the camera. The integration of the camera and the infrared sensors gives Dionysius an edge in obstacle and short-range detection. Dionysius is implementing lane detection rather than white line avoidance to better navigate through sand traps and to stay in bounds when encountering dashed line segments. Two motor controllers drive the steering and drive-train motors independently, providing greater dependability during operation. Simulation software has been improved to provide a more realistic operating environment and to more accurately replicate the robot’s upgraded navigation systems. A wireless controller has been added for easy relocation of Dionysius without an excessive amount of manual labor. In order to eliminate rolling stops and provide additional safety after an e-stop, a mechanical brake has been added by using the built-in handbrake hardware.

II. Team Organization

At the beginning of September, 2008, our team was introduced to Cornelius, the robot entered by Bob Jones University in the 2008 IGVC competition. With a platform to build on, our team began to address many different problems with Cornelius. The very first week, our team divided into two halves: the hardware team and the software team. The first issue addressed by the hardware team concerned the motor controller. Even though it was marketed as able to drive two motors simultaneously in different modes, it was not able to perform this task, thereby hindering the previous team's ability to compete. In previous years, the Bob Jones University robots were simply carried or pushed by hand. In order to purge this primitive practice, a member of the team tackled the problem of Dionysius's mobility when not in autonomous mode. Several small hardware issues were also addressed such as a faulty voltmeter and a broken potentiometer.

The software half of the Dionysius team also had many obstacles left to them by the Cornelius team. First of all, the simulation software had no way to add more than one barrel to a simulation run, thereby hindering our ability to analyze how software improvements affected Dionysius's navigational skills. Secondly, implementing the ability to navigate via the JAUS language was also a priority as it was not successful in previous years. Another important task was the integration of the infrared sensors into the software of Dionysius. Although Cornelius did have the sensors, the previous team did not have any software to read them, rendering them useless. Other assignments included reviewing and editing the navigation and autonomous mode software with several different emphasize, one being the ability of Dionysius to navigate switchbacks.

III. Hardware and Electronics Design

Because Dionysius was entered as Cornelius last year, our team did not have to do any extensive hardware designing. However, the team did have to repair, replace, and add several different pieces of hardware and electronics. These pieces include a voltmeter, potentiometer, wireless remote control, and a motor controller. Because of poor documentation by the Cornelius team, several weeks were spent learning how the old hardware worked and how it needed to be upgraded.

Chassis

One option for the type of steering that can be used for the IGVC competition was Ackerman steering. The challenges presented by Ackerman steering are due to the large turn radius; however, this steering system was chosen in order to more accurately simulate the pre-existing platforms with which embedded systems will be mated, for example United States Armed Forces weapon platforms. The chassis of our robot is a stripped-down version of an electric ATV, complete with an electric drive motor and batteries.

Steering Motor

The steering motor is mounted to the chassis where the ATV’s handle bars were formerly located. A bracket mounted to the chassis gives the motor proper height and angle in relation to the steering shaft. A machined metal plate is bolted onto the steering shaft with a key slot. The key allows for protection of the motor and supporting brackets if the steering turns too far or too fast.

Drive-train Motor Controller

The Cornelius team selected the RoboTeq AX3500 because it has the capability of running one channel in closed loop speed mode while running the other channel in closed loop position mode. However, the controller was not able to live up to its billing. The Dionysius team has relegated this controller to the drive-train only and bought a new controller for the steering motor. The 3500 is capable of 60 Amps, which is more than enough to drive the robot. The controller utilizes speed control mode with closed loop feedback for the drive motor. It also has inputs for feedback devices such as an encoder or potentiometer.

Steering Motor Controller

This motor controller, also a RoboTeq AX3500, was added due to the faulty operation of the other drive-train controller. Configured in position mode, the steering controller outputs an analog signal through a potentiometer and then reads the voltage on an input in the controller. The change in voltage is recognized as a change in position, which is then relayed to software via RS-232.

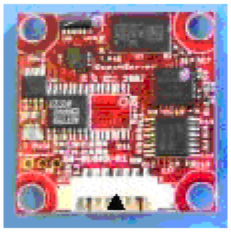
GPS

Because the Cornelius team had a $3,000 budget, a great deal of money was not spent on a differential GPS. Dionysius is equipped with a U-Blox Antaris 4 GPS, which provides greater accuracy than a standard GPS receiver but can be bought for a fraction of the price of a differential receiver. The U-Blox Antaris 4 comes with features that allow us to receive a GPS signal within 1/2 second, and it is designed to be able to receive satellite signals in locations where other receivers have difficulty. The U-blox Antaris 4 is also very efficient in its power usage. In the graph below, one can see that the GPS can be set to different modes that can save power. Sleep mode uses 80uA, and the backup mode only uses 8uA.

Finally, the U-blox Antaris 4 is more accurate than most GPS units, featuring a 16 channel receiver. Since the standard GPS receiver has only 12 channels, four extra channels provide Dionysius with the ability to be accurate within 2.5 meters.

Compass

Dionysius is equipped with an Ocean Server OS5000-US compass. The OS5000-US is a full three axis compass which uses Honeywell anisotropic magneto-resistive sensors to detect the earth's magnetic field. Solid state accelerometers from STM provide pitch and roll information. The data is sent to a 50 MIPS processor which determines bearing to within one degree of accuracy, pitch, and roll. The OS5000-US can be accessed using either USB or serial connections. Power consumption is also very low, only using 20mA at 5V when operating in RS-232 mode. The entire compass module is packaged on a single one inch by one inch circuit board, making the OS5000-US one of the smallest three axis compasses in the world.



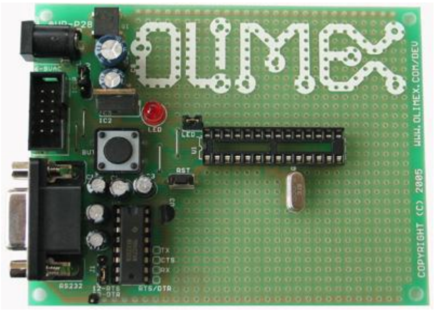
E-stop System

The emergency stop system on Dionysius is fairly straightforward. A keyless entry module, the JC Whitney ZX478506T, is adapted for the wireless component of the emergency stop. Powered by 12V, the module has a range of

200 feet. The relay outputs of the lock and unlock button are configured to allow either button to perform an emergency stop. A wired emergency stop is provided by a simple momentary pushbutton, located on the rear of Dionysius. Both of these systems provide the robot with the ability to safely operate in crowded environments.

Infrared Sensors

The infrared sensors were designed by the Cornelius team; however, Dionysius is the first to integrate them into the navigation and autonomous software. The Sharp GP2Y3A infrared sensors are wired to a pre-built Olimex AVR-P28 microcontroller board that interfaces with the computer via an RS-232 serial port. The sensors and Olimex board are mounted to the front of the robot directly in front of the steering shaft, giving the sensors a clear field of vision. The 5 sensors each have a range of 25 degrees, therefore giving the robot an infrared field of vision of 125 degrees. The range of the sensors is a maximum of 300 centimeters and a minimum of 40 centimeters.



Computer

The heart and soul of Dionysius is an IBM Thinkpad R-31, complete with an Intel Pentium III-M clocking in at 1.07 GHz. A specified battery life of 3.1 hours gives Dionysius adequate runtime on a single battery, and a 30 Giga-byte hard drive provides ample room for program files, hardware drivers, and data storage. The RAM size is 378 mega-bytes. This particular model was chosen by our predecessors because of its light weight of 6.17 lbs. and its small laptop dimensions of $10.01 \times 12.29 \times 1.42$ inches.

IV. Software Design and Integration

One of the many problems that faced the programmers of Dionysius was the testing of written code. In order to deal with this issue, a simulator was developed. The simulation software, which gives the ability to test the autonomous, navigation, and JAUS code in a virtual environment, is specifically designed for Dionysius. With this software, the programmers are able to debug the code without wasting time uploading the code to the Dionysius's CPU and moving the robot to a testing site. The integration of the different aspects of our code is also more easily tested in this virtual environment. The created environment includes an obstacle course complete with movable white lines, barrels, and barrel switchbacks.

The navigation software for Dionysius uses two specific classes for both the compass and the GPS. These classes provide methods which open a serial connection to both the devices, read NMEA messages from the devices, and parse the received messages. Only the GGA information from the GPS is needed, and it includes latitude, longitude, quality of signal, and number of satellites. The code to read and parse the GPS messages is called once every loop and is synchronized with the rest of the robots navigation systems. The difference is then taken from the current position of the robot to its goal, in this case a waypoint. The navigation software uses the same obstacle detection as the autonomous; therefore, the navigation code only moves toward its next waypoint when there are no obstacles to maneuver around. After reaching the designated waypoint, Dionysius will repeat the process to navigate toward the next destination.

The autonomous mode software takes a picture from the camera and makes a copy of it in an array of pixels that is set to the correct red, blue and green characters. After this operation, Dionysius scans the picture for certain colors such as red, white, or orange and removes that space as drivable space. The picture is then smoothed so that black pixels in a white area are converted to black and vice versa to avoid confusion. Before Dionysius chooses a path, the picture is updated with any objects that the IR sensors detect. A path is then selected using the data described above. As the robot moves, it is constantly updating the picture with objects and what the IR sensors perceive.

V. Predicted Performance

Speed

The speed of Dionysius is limited at the driver level to 5 mph. Because the diameter of the wheels was measured to be approximately 13 inches, then the RPM of the wheels at 5 mph is 130. Therefore, because the pulses per revolution of the encoder is known to be 100 and the time base used is 63, then the maximum speed value calculates to be 14 using the derived equation:

$$MSV = \frac{RPM * PPR * (TB + 1)}{58593.75}.$$

Ramp Climbing Ability

Dionysius has a mass of approximately 65.75 kilograms. Using this number, the calculated Watts required to climb a 15% grade is 215. Because the drive motor draws a maximum of 60 Amps at 24 Volts, the maximum output power of the motor is 1,440 Watts, giving Dionysius more than enough power to climb the 15% grade at 5 mph.

Reaction Times

Camera: The frames-per-second of the camera is 15, thereby providing Dionysius with a new picture to analyze every 67 milliseconds.

Infrared: Due to the read time of one infrared beam being 20 milliseconds, the time elapsed during one sweep of the sensors is approximately one-half second.

Steering: After being geared at a ratio of 48.5:1, the steering motor is able to turn the wheels at a rate of 174 RPM. Therefore, the motor is able to turn the wheels one degree in 960 microseconds. Because of hardware limiting, the steering range is +/- 50 degrees. Using these numbers, Dionysius is able to change direction by 100 degrees in approximately 96 milliseconds.

GPS: Although the data can be read at up to 1000 Hz, Dionysius corresponds with the GPS at the same rate as a new picture is analyzed, which is 15 Hertz.

Compass: The compass specifications allow us to access the data at 40 Hz. However, the code only reads the data at the standard 15 Hertz.

Battery Life

Motor Batteries: The batteries supply 7AH and the average current draw during operation is 14.5A, giving an approximate battery life of 30 minutes.

Electronics Batteries: The Ryobi One+ battery supplies 1.7AH and the average current draw during operation is 100mA, giving an estimated battery life of 17 hours.

Distance at Which Obstacles Detected

Camera: The camera is situated at 138 degrees measured down from the z axis, and its viewing angle is measured to be at maximum 100 degrees measured in the same manner. The height of the camera is approximately 143 centimeters, and therefore, using geometry and trigonometry, the maximum distance at which the camera can see an obstacle is 8.1 meters.

Infrared: The specifications give a maximum range of 3 meters.

Dealing with Obstacles

Because of the object detection scheme described above, Dionysius will detect an obstacle at a minimum of three feet. After determining the size and position of the obstacle, Dionysius will take the path with the most “free” space by analyzing each frame of video.

Accuracy of Waypoint Arrival

The specifications of the GPS give accuracy to within 2.5 meters. Therefore, Dionysius should be able to approach this accuracy estimate in arriving at waypoints.

VI. Bill of Materials

Description	Details	Price	Cost to Team
Razor Dirt Quad ATV	http://www.razor-help.com/dirtQuad.html	$300.00	$300.00
Steering Motor Controller	AX3500 RoboTeq	$395.00	$395.00
Drive Motor Controller	AX3500 RoboTeq	$275.00	$275.00
Steering Motor	NPC-41250	$155.00	$155.00
Keyless Entry	JC Whitney ZX478506T	$30.00	$30.00
GPS	UBLOX AEK-4H	$199.00	$199.00
Compass	Ocean Server OS5000-US	$299.00	$299.00
Computer	IBM Thinkpad R31 (Used)	$350.00	$0.00
1394/USB PCMCIA card		$20.00	$0.00
Thinkpad External Charger		$40.00	$40.00
Thinkpad Batteries		$130.00	$130.00
Strobe	Action Electronics HAA110W	$11.00	$11.00
Potentiometer	P3 America R23P-RCWT	$20.00	$20.00
USB to Serial	Edgeport 4	$260.00	$0.00
Rear Encoder	Model 225q www.encoderoutlet.com	$252.00	$252.00

18V Battery	Ryobi One+	$100.00	$100.00
Steering Potentiometer	P3 America R23P-RCWT	$20.00	$20.00
Sheet Metal	Aluminum 1/8"	$100.00	$0.00
Motor Mount	Aluminum 3/8"	$200.00	$200.00
Misc Hardware		$200.00	$200.00
IR Sensor	Sharp GP2Y3A003K0F	$315.00	$315.00
IR Interface	AVR Board and Parts	$50.00	$50.00
DC/DC Converters	TCElectronics SD-15A-5 SD-15A-12	$40.00	$40.00
Panel Meters	Futurlec.com	$40.00	$40.00
Misc Electronics		$100.00	$100.00
Spare Batteries	PowersonicPS-1270	$40.00	$40.00
Xbox Controller	Also With Wireless Dongle	$40.00	$40.00
	TOTAL	**$3,981.00**	**$3,251.00**