The Bob Jones University B-Team Presents

Eran

IGVC 2010

Design Report

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Team Members

Nathan Moorehead – Sophomore
Engineering Science
Isaac Lloyd – Freshman
Electrical Engineering

David Frazee – Graduate Assistant
Electronics and Computer Technology
Andrew Gieger – Junior
Premed/Predent

Total Man Hours Expended: 150

Bill Lovegrove and **Patrick McGary**
Faculty Advisors

I. Innovations

This year, the Bob Jones University team has created Eran, a remodeled version of Dionysius from last year's competition (2009). Many different innovative aspects of Eran 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. Eran 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. Simulation software has been improved to provide a more realistic operating environment and to more accurately replicate the robot's upgraded navigation systems.

II. Team Organization

At the beginning of September, 2009, our team was introduced to Dionysius, the robot entered by Bob Jones University in the 2009 IGVC competition. With a partially built robot our team began to address many different problems with Dionysius. We renamed the robot to Eran. The first major issue addressed concerned a computer upgrade from a Pentium III 1.1 GHz to a Pentium 4 running at 2.6 GHz with increased memory from 384 MB to 512 MB. All of this was to increase image processing frame rates. The second issue was to address the rapid battery discharging due to USB powered accessories by adding an inverter to power the laptop from the main drive batteries. The third major issue was replacing the steering mechanism. The existing direct-drive steering mechanism had resulted in turning torques that put much strain on the steering motor which burned out 2 motors previously. This year's transformation was to change the mechanism to a chain drive giving the motor the ability to provide enough torque for turning at much less current. Third, the existing UNIBRAIN Fire-i camera was replaced with a Chameleon USB 2.0 camera with a new wide-angle lens which improved image quality and enabled use of the vendor's Software Development Kit (SDK). The power system was simplified by adding an inverter on to the main drive batteries to allow them to power the USB-powered accessories. The faulty IR detection and the unnecessary mechanical brake were also eliminated. Finally, the last major improvement was integrating new software originally developed for Euroclydon, BJU's other entry to this year's competition. This included significantly reworked image processing, controls for the new camera architecture, and better threading. Other improvements to the software included reviewing and editing the navigation and autonomous mode software with several different emphases, one being the ability of Eran to navigate switchbacks. Minor work included repositioning the power distribution box and designing a new cowl.

III. Hardware and Electronics Design

Because Eran was entered as Dionysius last year, our team did not have to do any extensive hardware designing. However, the team did have to redesign the steering mechanism and add several different pieces of hardware and electronics.

Chassis

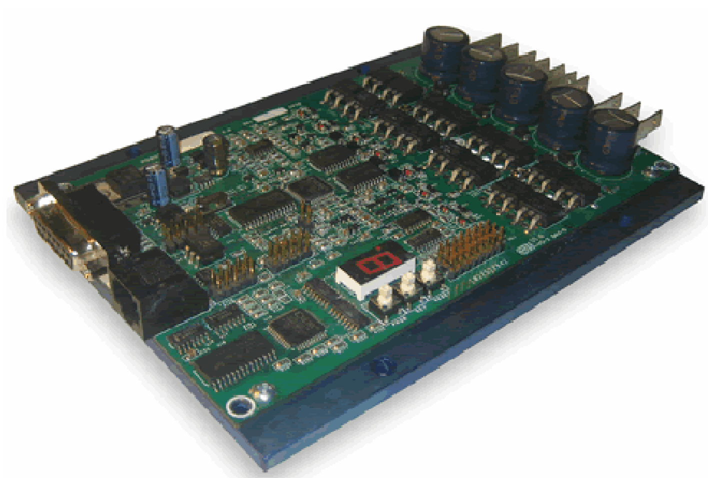
One option for the type of steering that can be used for the IGVC competition was Ackerman steering. The main disadvantage presented by Ackerman steering is large turning radius; however, this steering system was chosen in order to more accurately simulate the pre-existing platforms with which embedded 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 All Terrain Vehicle (ATV), complete with an electric drive motor and batteries.

Steering Motor

The original steering mechanism from 2009 was by direct drive from a motor mounted to the chassis where the ATV's handle bars were formerly located. However, the 34:1 direct-drive system lacked enough torque to turn the wheels on some terrain resulting in stalls that burned out 2 steering motors. Eran's new chain driven mechanism gives higher torque on the wheels per unit current in the motor. A bracket mounted to the chassis gives the motor sprocket (14 teeth) the proper height and angle in relation to the shaft sprocket (60 teeth). The wheels turn more slowly but with less current in the motor.

Drive-train Motor Controller

The Dionysius team (2009) had chosen the RoboTeq AX3500 controller to be for 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

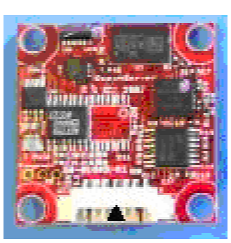
This motor controller, also a RoboTeq AX3500, was added due to the faulty operation of the other drive-train controller. Configured in position mode, the steering controller outputs an analog signal through a potentiometer and then reads the voltage on an input in the controller. The change in voltage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

GPS

GPS. Eran 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 fix at 2 Hz, 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 80 µA, and the backup mode only uses 8 µA. 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 Eran with the ability to be accurate within 2.5 meters.

Compass

Eran 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 Eran is 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 Eran. Both of these systems provide the robot with the ability to safely operate in crowded environments.

Chameleon Digital Camera

Our vehicle is outfitted with a USB 2.0 digital video camera. The Chameleon's tiny casing is only 25.5 mm x 41 mm x 44 mm, and is positioned at the pinnacle of the wooden frame. Mounted on the camera is a 2.8 mm lens to give it a wide field of view. The camera is the only means of boundary line and obstacle detection. The camera transmits the captured video to the computer at rates up to 18 frames per second.

Infrared Sensors

The infrared sensors were designed by the Cornelius team; Dionysius was the first to integrate them into the navigation and autonomous software. However, the results were unreliable and **the IR system was jettisoned from the Eran design** with reliance on improved image processing algorithms to compensate.

Computer

The brain of Eran is an IBM Thinkpad® G40, complete with an Intel Pentium 4® running at 2.6 GHz. The previous design's battery life was quite small due to the USB power requirements of the electronic accessories. For Eran, an inverter was added to allow the laptop and all of the USB-powered accessories to be powered directly from the drive batteries. A 16 Giga-byte hard drive provides ample room for program files, hardware drivers, and data storage. The RAM size is 512 mega-bytes.

IV. Software Design and Integration

One of the many problems that faced the programmers of Eran was the testing of written code. In order to deal with this issue, a simulator had been developed. The simulation software, which gives the ability to test the autonomous, navigation, and JAUS code in a virtual environment, was specifically designed for Dionysius (2009). With this software, the programmers are able to debug the code without wasting time moving the robot to a testing site for each test. 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.

Image Processing

Primarily, to avoid lines, we employ a line detection algorithm which includes a Hough transform. The transform has proven helpful to fill in the gaps for dotted/ dashed lines. We also run a simple smoothing algorithm to help eliminate spurious single point obstacles; after possible obstacle pixels have been identified, if not enough of those pixels occur in a box around a possible obstacle pixel, then it is not treated as an obstacle.

Obstacle and Line Detection

There are three main parts to the obstacle detection. First, we attempt to identify various obstacles based on color -- orange, red, black, grey, etc. We then use the smoothing algorithm as referenced above to eliminate spurious points. Second, we also attempt to identify obstacles based on texture. Since barrels, cones, and similar obstacles tend to be smooth, as opposed to grass, which is more varied in color, we split the picture into small bins and calculate the range of red, blue, and green in that bin. If the bin exceeds a certain intensity range (texture is rough), we mark that area as not an obstacle; however, if the bin is within the range (texture is smooth), then we mark that area as an obstacle.

Navigation

In autonomous mode, Eran takes the processed image and finds the trajectory in the image with the most free space in front and makes a steering decision to go there. As the robot moves, it is constantly updating the picture. Obstacle detection is only real-time and Eran has no memory of where he has been. In navigation mode, the compass direction is compared to the GPS heading to the waypoint from Eran's current position fix. Eran makes a decision to turn toward the waypoint from the compass direction. All obstacle detection algorithms other than white line detection are functioning during autonomous operation.

V. Predicted Performance

Speed

The speed of Eran 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

Eran 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 Eran more than enough power to climb the 15% grade at 5 mph.

Reaction Times

Camera: The frames-per-second of the camera is 17, thereby providing Eran with a new picture to analyze every 59 milliseconds.

Steering: After being geared at a ratio of 34:1 with a gearbox and an additional 4:1 chain drive reduction, the steering motor is able to turn the wheels at a rate of 40.6 RPM. Therefore, the motor is able to turn the wheels one degree in 4.1 ms. Because of hardware limitations, the steering range is +/- 50 degrees. Using these numbers, Eran is able to change direction by 100 degrees in approximately 410 ms. This is, of course, 4 times slower than the direct-drive scheme, but the torque at the wheels per unit current is also 4 times as great.

GPS: The position fix is only updated at 2 Hz. However, Eran polls the GPS at the same rate as a new picture is analyzed.

Compass: The compass specifications allow us to access the data at 40 Hz. However, the code only reads the data with each new image.

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 4 meters.

Dealing with Obstacles

After determining the size and position of the obstacle, Eran 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, Eran 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 G40 (Used)	$220.00	$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
Camera and Lens	USB Chameleon Camera	$395.00	$395.00
Chain Drive	Sprockets and Chain	$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	**$3,976.00**	**$3,331.00**