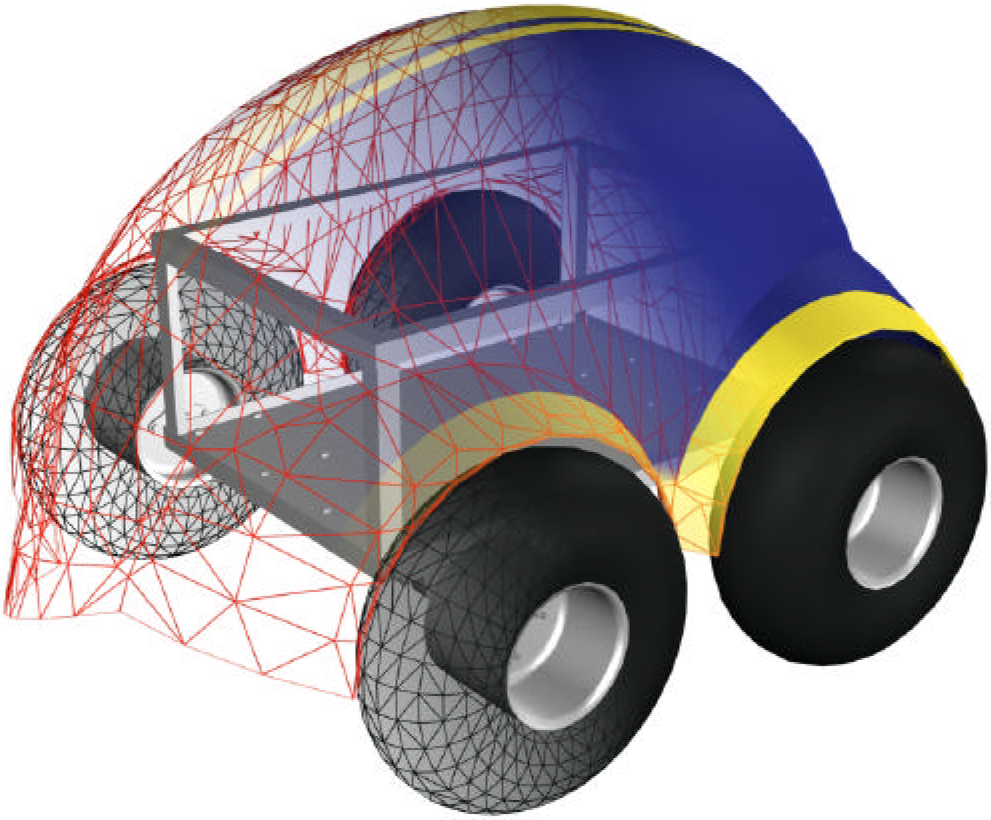
Embry Riddle Aeronautical University

Embry-Riddle Robotics Association

"*Talon One*"



Complied By:

Danny Kent

Presented to:

William G. Agnew

Chair, Design Judging Panel

8th International Ground Robotics Competition

Involvement and Sponsors

Team Members:

Borja Carballo, Joshua Cole, Hardy Delay, Tom Galluzzo, Andy Garcia, David Ingram, Jeff Johnson, Danny Kent, Jason Lamb, Eduardo Sanz-Martin, Patrick McDermott, Holger Pfaender, Joel Reese, Sam Septembre, Charles Shank, Brian Sharrer, Ed Springer, Bill Steiner, Matt Stoll

Faculty Advisor

Dr. Sathya N. Gangadharan, Engineering Technology Program

Special Thanks

Dr. Michael C. Nechyba, University of Florida
Mr. Don Boiver, Machinist, Embry-Riddle Aeronautical University

Sponsors

» Engineering Technology Department
» Leeson Electric
» Precision Navigation
» Precision MicroControl
» Amtel
» Embry-Riddle Laboratories
» Rocky Mountain Instruments
» Grove Gear
» Diamond Chain
» Fujitsu
» Kennedy Space Center
» Alacron
» Chic-Fil-A
» EZ-Go Golf Carts
» Daytona Micro
» Machine Intelligence Laboratory
» Bryson Industrial Equipment
» Powertron Batteries
» Karl Edminster of Foster-Miller
» Embry-Riddle Student Government Association
» Embry-Riddle Student Chapter of the Society of Automotive Engineers

Table of Contents

Table of Figures

Abstract

Due to the recent growth in the robotics field in both autonomous and tele-operated platforms, the growth in the control systems for these platforms has been exponential. This report describes the Talon One project built for the 2000 International Ground Vehicle Competition. The competition sets forth a variety of challenges to the vehicle, all to be address autonomously by the control system. These challenges include: autonomous navigation through the use of sensors, vision guided navigation, and an autonomous control system.

Introduction

Talon One is an autonomous unmanned ground vehicle capable of performing a variety of given tasks. The primary objective of the vehicle is to navigate a course autonomously between two white lines while avoiding road obstacles such as cones, buckets and potholes. Talon One carries out its primary objective by employing the use of several sensors and a central control algorithm. When coupled with the drivetrain and motors, this platform is readily able to accomplish the variety of tasks presented to it.

The primary sensor data that Talon One uses is vision. Visual data of the area directly in front of Talon One is analyzed and used to determine where Talon One should navigate. This data is cross-referenced using ultrasonic sonar, producing a check and balance system.
What follows is an analysis of the Talon One vehicle’s subsystems in order to evaluate Talon One as a whole. The structural components are analyzed using analysis by part, while the computer and electrical components are followed in an analysis by process.

This overview of Talon One allows the reader to familiarize themselves with the design criteria and objectives imposed by the primary objective, the competition rules and the design team’s desires.

Structure

Twin Leeson 1 HP motors drive the Talon One to a top speed of approximately 3 mph. Turning is accomplish through the use of a differential steering system. Such a drive configuration gives Talon One the ability to turn about its own midpoint should the need to reconfigure its orientation without forward motion be required. This is especially useful in a vehicle presented with the design challenges of Talon One. However, to recognize the HP potential of the vehicle, a gear-down ratio was needed to produce the available HP into available torque.

Grove Gear and their 40:1 gearboxes, which mated to the Leeson motors gives Talon One a rugged and aggressive towing and carrying capacity, answered the need for gear reduction. This created a rugged and powerful combination. At 1670 RPM, each motor produces 40 lb-in of torque. The Grove gearbox reduces this to 41.75 RPM and 1430 lb-in of torque. This gives Talon a max speed of 2.75 MPH and a total max force output, over all wheels, of 260 lb. Calculating the maximum weight Talon One can carry at this speed up a 20° incline results in 500 lb at 2.75 MPH.

However, the strength and power of the Grove Gear/Leeson Motor combination is much more apparent at low RPM. At a motor speed of 274 RPM, each motor creates 243 lb-in of torque. Routing that through the gearbox results in 8500 lb-in of torque at 6.85 RPM. At this speed Talon One is sustaining a max velocity of .45 MPH, however it has 1520 lb of force over all wheels. This results in Talon One being capable of carrying/pulling 3200 lb up a 20° incline at .45 MPH. That is approximately 8 times the vehicle’s weight.

The massive amount power available from this motor/gear combination meant Talon One would need a rugged a drive system. To this end, the chosen configuration consisted of #50 sprockets by Martin Sprocket and Gear and #50 chain from Diamond Chain. Configured in a bowtie, giving equal tension on the gearbox between axels; the chains drive the 4 independent axels on Talon One.

Each axel is 1" Stainless Steel, cut to length and then a keyway was cut into the length. Each axel is connected to the chassis by two pillow blocks, then connected to custom-made hubs and 11" wheels, complimenting the overall rugged design motif. The chassis of Talon One consists primarily of aluminum angle, welded into the simplistic box shape and reinforced as needed. The bottom is constructed from a single piece of high-grade aluminum honeycomb. The honeycomb provides Talon One with a very large weight carrying capacity at a fraction of the weight of a solid sheet of metal.

The fiberglass exterior shell was custom-made by team members. Construction was done by first creating the mold from a cardboard skeleton. This skeletal mold was covered in chicken wire as a foundation for cheesecloth and plaster-of-paris. The final mold was sanded and smoothed to shape prior to laying in the fiberglass and resin.

Powering Talon One's many subsystems is no small task. Each 1 HP motor is rated at 24V and can draw up to 39 amps. Choices of batteries were limited only by imagination, however the decision was made to run the system on two 12V batteries in series to yield 24V. The deep-cycle sealed lead batteries by Powertron were chosen for their 35 AMP hour rating and size qualities. This would give Talon One approximately 1 hour of running time under full load, a condition not expected to exist in normal operation. Team designers also determined that should Talon One deplete its battery reserve, it would be best for the computer systems not to be eliminated also. Therefore, the computer systems are run through a separate circuit and a third 12V battery. Estimated battery life for the computer systems off a battery charge is 2 hours, well above the estimated duty cycle of the vehicle.

Finally, the sensors and electronics required sturdy yet easily accessible attachment to the vehicle. The camera boom is constructed of a split pole, ending in a tripod mount. The tripod mount gives flexibility to fine-tune the angle and height of the camera on the pole. The pole will also pivot from 90° to approximately 60° from the ground normal. The electronics are self-contained within Talon One's "black box." This design was chosen for its ease in installation and removal, turning the "brains" of Talon One into a removable and transferable system onto itself.

A secondary task given to Talon One was the facilitation of carrying a 20 lb payload, approximately the size of a cinderblock. The top layer on the skeletal box was covered and designed as a payload compartment, providing ample room for the given payload. As previously discussed, the weight was of little to no added concern, as Talon One has an extra capacity to carry or tow weight.

A final concern structurally was safety. From the beginning of the design process, the knowledge that no human would be in direct control of the robot at all times heightened the design team's concern over safety. First, the design requirements called for both a remote and a hard-wired emergency kill switch. Both switches are wired into the amplifiers that push the signal from the computer to the motors. The amplifiers are designed with an inhibit channel that, when grounded, shuts off the signal to the motors. The inhibit switch is then wired to a circuit with two possible grounds, one for the hard switch and one from the servo actuator controlled by the remote switch.

Secondly in the safety department was the physical power of Talon One. During initial testing, it was realize that the previously calculated torque and power of the 40:1 gear ration and the motors were more than a human body could withstand, especially at low speeds. To this end, the sprockets and chains were protected from probing fingers by chain guards.

Input

Figure 1

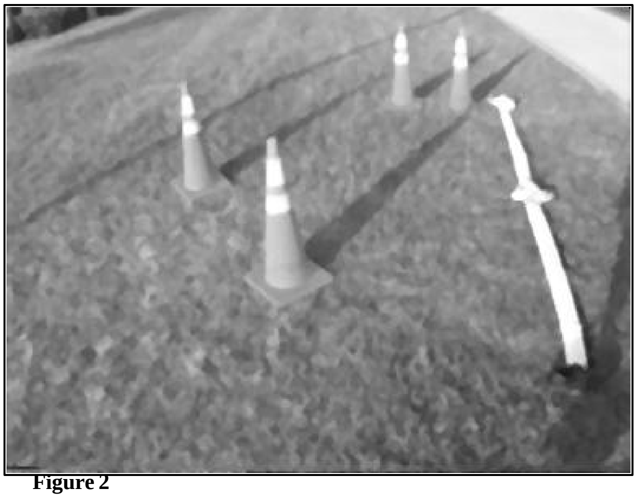


Figure 2

Figure 3

The primary source of input for Talon One is a live video feed. The video comes from a Sony Handicam 8mm camera mounted on the camera boom. The camera provides not only a live video feed through a wide-angle 24mm lens, but also records the feed for post-sortie analysis.

The video is feed through an RCA port into a PCI TV Tuner card. The image analysis code pulls an image from the frame buffer on the TV Tuner card at 2Hz. The image grabbed is a 24-bit RGB image which is then converted to a weighted 8-bit grayscale image. (Figure 1) The 8-bit image is weighted differently for each color channel to help eliminate noise in the image.

Grass is a very noisy medium and thus it was required for a median filter to be applied to reduce the grass to a relatively homogeneous surface. This is done four times prior to running the edge determination filter through the image. (Figure 2) The edge filter produces a simple black and white image showing the desired edges and a little remaining noise. (Figure 3)

The secondary and redundant detection system on Talon One is ultrasonic sonar. Three sonar units are mount fore and one is mounted aft of the vehicle. Each sonar unit is mounted on a servo which sweeps 180°; each unit moves in unison from left to right. The front mounted sonar units are always pointed 45° apart, thus in one full cycle, the immediate front of Talon One is checked for obstacle 6 times, by three independent units.

Each sonar unit operates at 10Hz and has a spread angle of 15°. The sonar on Talon One are calibrated to return a maximum range of 12 feet. The output is 0 volts if the object is 6 inches or less and 5 volts if the detected object is at 12 feet. The relationship between voltage and distance is linear, however it differs for each sonar unit. The design team determined that the divergence between the statistical line digressions between the sonar units were not significant up to 12 feet out; beyond 12 feet, the divergence would require separate equations for each unit.

Shaft Encoders mounted to the read drive shafts provide the final form of input from the surroundings to the control program onboard Talon One. The shaft encoders provide a closed loop on velocity of the vehicle, allowing the Proportional Integral Derivative (PID) to evaluate its performance and maintain a constant speed. The shaft encoders also provide data on RPM and therefore a method by which to calculate the vehicle displacement.

Processing

The input into the path-planning and determination algorithm consists mainly of a 2-bit image as previously stated. (Figure 3) This consists of an array of row by column fill values representing how occupied a sector of the image is. The higher the number, the less occupied that sector of the given image is.

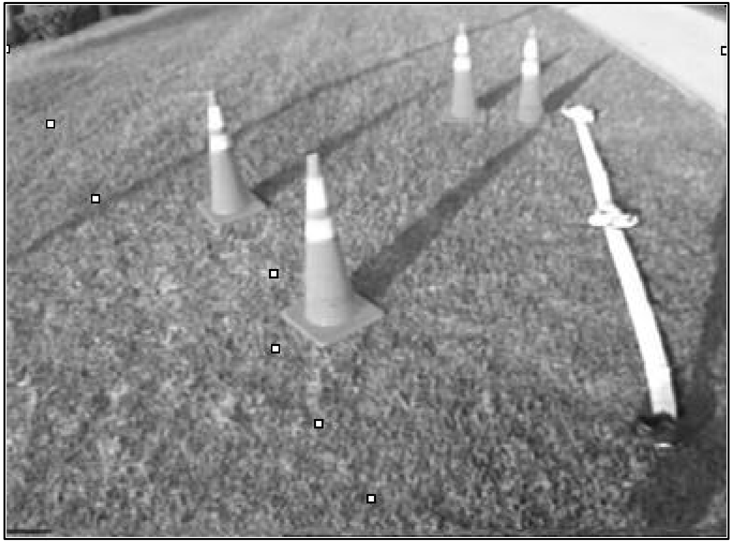


Figure 4

The lowest numbers in the given array represent the areas most fully occupied, and therefore should be avoided. Theses sectors are marked as completely full and therefore must be avoided. These results in a grid of rows and columns where each sector has a value, except those previously marked as avoids.

Taking the fully evaluated image array, sector is checked against the data from the sonar input. If sonar indicates an obstacle in a sector, it too can mark that sector as an avoid. This reduces the image down to only drivable sectors that pass a drivability test through both video and sonar comparison.

From this point, the path-planning can begin. Starting with the bottom row, the array is worked across left to right, searching for groups of sectors that are connected and have numbers indicating that they may be drivable. If a particular row only has one group of drivable sectors, then the decision is made to drive through the center of gravity of the fill values of the group for that row. If a row has two or more groups of drivable area, the determination of which group to drive through is based on two key values. One, how close the center of gravity of that drivable region is to the point chosen in the previous row. Secondly, stressing the importance of large drivable areas, the “mass” of drivable area is used as a decision factor. This results in the desired path for Talon One. (Figure 4)

Output

Once the above desired path is determined (Figure 4), the desired path must be translated to the proper motion of Talon One. The central control mechanism for output is the Precision MicroControl motion control card. The motion control card has an onboard PID loop to control vehicle velocity and 4 analogue/digital ports for various input data.

The card does have the ability to function on a standalone basis, however the design team for Talon One opted to use the card as an integrated PCI card in the computer system. The proper motion portion of the requirement is determined by evaluating the heading needed and the distance to travel. The motion control card is programmed using a Motion Control API provided by Precision MicroControl to determine which engine to turn on and how long.

Once that is known, the motion card generates a +/-10V signal that runs into the signal amplifiers. The amplifiers then in turn pull a full 24V from the batteries in series, thus driving the motors. The output voltage from the amplifiers is always 24V, as the amplifiers are run in current mode. This means the input voltage to the amplifiers determines how much current the amplifiers allow to run through to the motors. This gives us control over the speed of each motor.

Lastly the most important use for the motion control card is the onboard PID loop. This PID loop takes input back from the shaft encoders and determines how fast the vehicle is actually going vs. how fast the control card thinks the vehicle is going. Thus the loop on velocity is considered closed and regulated, allowing Talon One to know exactly how far it has moved on a given command, neglecting any loss of traction.

Conclusion

In conclusion, Talon One is a complex vehicle capable of autonomous navigation of a given course. The tasks presented to the design team have been addressed and overcome through research, design and testing. The structure of Talon One gives it the capability to go beyond the competition requirements and apply itself to future objectives. The control system makes decisions based on assumptions made by the design team and allows it to sufficiently navigate any number of known conditions and to evaluate and decide how to navigate any unknown condition. The vision analysis system also makes Talon One capable to compete in the Follow-the-Leader portion of the event. Overall, Talon One has been built with two words in mind, rugged and reliable. Through the combination of a strong, dependable drive train and the flexible, double-checked path-planning algorithm, Talon One has fulfilled the vision of its designers.

Appendix

During the months following the initial buildup and testing of the Talon One chassis and drive train, it became apparent to the team that design changes would have to occur. What is described herein is a brief overview of the challenges discovered with Talon One and the solutions chosen for the given task.

After building Talon One, and hooking up a very simplistic manual drive control, the design team was very impressed with the ruggedness and strength of Talon One. As shown previously in section 1, the total low-end torque was in the neighborhood of 8500 lb-in of torque per gearbox. This meant Talon One was less likely to lose traction with any surface than it was to destroy the surface while attempting to turn.

Interestingly, turning became the primary issue throughout the team's initial testing period. Turning also proved very difficult for the motion control card to control, and it was known at that time that something had to change. While changing the wheelbase ratio was a possibility and would decrease the problem, the destroying of the surface would still be an issue.

For Talon One's given task, destruction of the grass course was not an option and could lead to disqualification of the vehicle – this in mind, the Talon One team came up with another, more viable solution. As a cost of all wheel drive and some of the available torque, the drive configuration was changed. Talon One is now only powered by two wheels and has front-wheel drive. The rear wheels were still and issue when free spinning, so the option to remove them was exercised. Rather, the rear set of wheels is now two pneumatic casters. This sufficiently decreased the problems turning, stopped the destruction of the driving surface and increased Talon One's maneuverability.

However, some features were lost or lessoned as a result:

- Full reverse is now very difficult for Talon One; while not important to the current task, future design revisions and tasks may require it.

- Going from four-wheel drive to two-wheel drive has significantly lessoned the power of Talon One. Previously it was tested and successfully managed to climb a flight of stairs, however this is no longer the case.

- The previously designed and built chain guards no longer fit the role they were designed for. The time constraints leading to competition limited the teams ability to design and build a replacement. Therefore, side effects of the changes were a lessoning of the overall safety of the vehicle.