ECE 492 Special Instruction Final Report

Brehm Robotics Team #2219 FIRST Robotics Competition Report

By: David Gitz

5-May-2009

For: Dr. Farzad Pourboghrat

Background: The FIRST (For Inspiration and Recognition of Science and Technology) Robotics Competition (FRC) is by far the world's largest robotics competition with over 3000 teams participating in 50 Regional and 1 Championship Event every year. Originally founded in 1992, this competition is designed for High School students to learn more about the fields of Science, Technology, Math and Engineering by participating in a 6 week long robotics competition that changes every year, guided by Engineers, Teachers, Parents and College Students. One of the many benefits of being involved in FIRST is a very practical hands-on experience in modern Engineering practices that gives young people the ability to see what the career is really about and to motivate them to do well in college.

Brehm Robotics Team #2219 was founded in 2006 by Joe Viscomi, a teacher at the local Brehm Preparatory School. Brehm is a boarding school located in Carbondale IL that gives students with complex learning disabilities the opportunity to be involved in directed education by world-class instructors. After 3 years of being involved in the FIRST Robotics Competition the Brehm Robotics Team has climbed the ladder to winning 2^{nd} place at their annual St. Louis Regional in April, an astounding feat.

As an Electrical Engineering student at SIU-Carbondale, it is very important for me to not only hone my skills in the Technology field but more importantly to give back to the community and encourage and motivate the younger people to want to become Engineers in the future.

For this year's FRC Competition, we were given the National Instruments Compact Reconfigurable Input/Output Robot Controller that has many advanced and exciting features in a robotics application, including:

- 400 mHz PowerPC Processor with a 2M gate FPGA for digital I/O
- 64 MB DRAM
- 128 MB Flash Memory
- 16 Channel Analog Input 12-bit Resolution with 500 kHz aggregate sampling rate
- 8 12V 1A Solenoid outputs for pneumatic devices
- 64 Channel Digital Input/Outputs , which include:
    - 20 PWM Outputs for Motor Controls, with 6V selectable output level
    - 16 Forward/Reverse Relay outputs
    - 28 GPIO Channels, for encoders, limit switches, etc.
- System is capable of being programmed in either LabView or C++

Clearly, this is a very advanced system that vastly exceeds most robot controllers currently in use, and as such I felt this would be a fitting project for ECE 492.

Objectives: To develop an effective traction control system using the necessary sensors to provide a competitive edge over other teams in the FRC Competition, develop an effective tracking system utilizing color and possibly shape recognition, and more importantly to be able to teach these control system techniques to the students on the FIRST team to increase their knowledge in the fields of embedded controllers and feedback control.

Robot Description:

The Robot was built according to the FRC 2009 Competition Rules. It was designed to be a 4 Wheel-Drive vehicle (See Figure 1) that would have a ball pickup mechanism (See Figure 2), a ball storage mechanism (See Figure 3), and a ball shooter mechanism (See Figure 4). The Ball pickup mechanism consisted of 2 small diameter rollers that were spaced appropriately to suck the balls into the ball storage mechanism, assisted by the bottom and side ramps. The ball storage mechanism was a vertical helix structure with a large diameter vertical roller that would roll the balls up into the ball shooter. The Ball shooter featured a kicker wheel that would place the balls into the shooter, and the shooter itself had wheels again that moved with enough speed to propel the balls up to about 10 feet forward with a good angle. Also, the Shooter was on a rotating turret that allowed one of the Operators to more precisely position the ball where they wanted it to go.

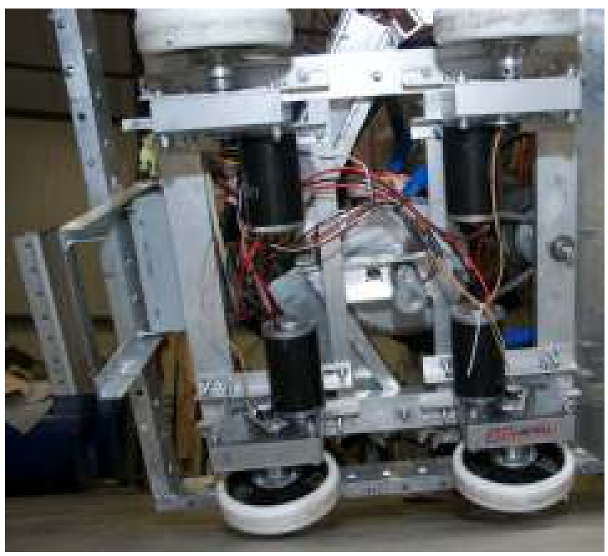

Figure 1 – 4 Wheel Drive

Figure 2 – Ball Pickup

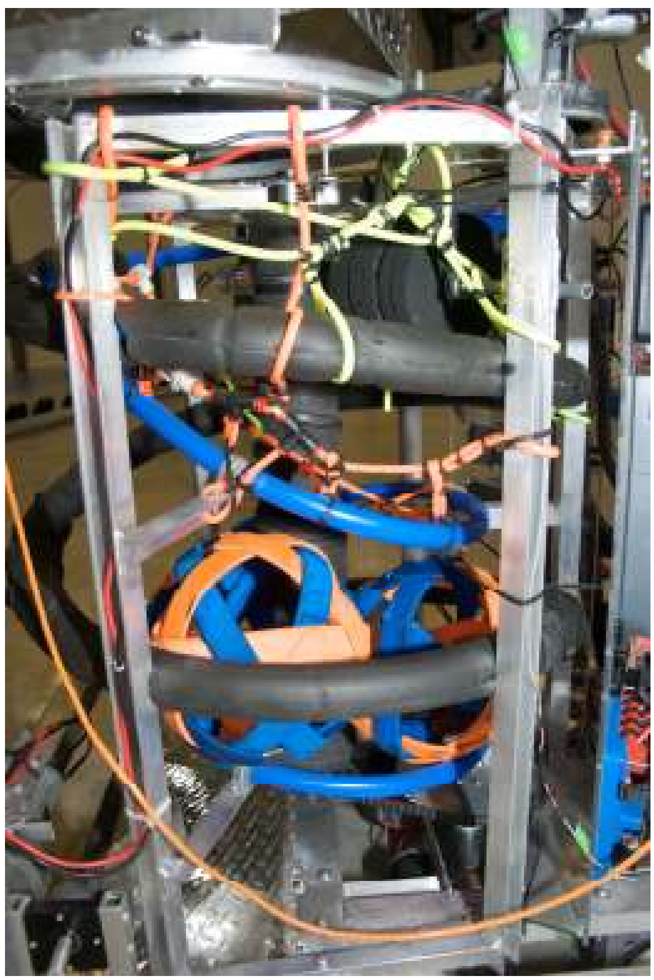

Figure 3 – Ball Storage

Figure 4 – Ball Shooter

Implementation:

Due to the constraints of the FRC Competition, the Robot must be designed, built and tested completely in a 6 week period, and also follow a large amount of very strict rules provided by the FIRST Organization. Normally this is a fairly complicated process but there is some experience learned from year to year by having a similar control system. This year, this was not true. We were required (and given) a completely new control system that was superior in many ways to the previous controllers but required a higher degree of sophistication to implement effectively. Also, due to the time constraint proper testing and reproducibility is hardly ever possible and as such “best guesses” must be employed often. Besides the basic running of the machine, the 2 advanced methods that were introduced were an image tracking algorithm and a traction control algorithm.

Traction Control

The Traction Control system was implemented using a 2 axis accelerometer, a 1-axis gyroscope(See Figure 5) and 4 Quadrature Encoders (See Figure 6). An aspect of the FRC 2009 Competition was a game floor made of “Regolith”, a common wall covering material in homes that features a very low coefficient of friction. Coupled with the required “Slick Wheels” a Robot with any drive system would have a hard time of driving without slipping, which was the motivation for a Traction Control System.

Obviously there are many ways to implement this kind of system. The method used for our Robot consisted of driving the Robot on a similar surface and watching the encoder values for each wheel during different drive tests. When an encoder value would “spike”, i.e. reaching a value that was much higher than the rest of the wheels, the accelerometer and/or the gyroscope values were read. This would give the maximum acceleration that the Robot could undergo before slipping. For the actual driving tests, first the robot was accelerated on a straight line and the accelerometer values were read. Secondly, the robot was rotated rapidly and the gyroscope values were read. After these maximum values were obtained, it was a simple manner to limit the Robot to drive under these values, as seen in

Figure 7 and Figure 8. After this system was implemented the Robot was much easier to control on the test field playing surface.

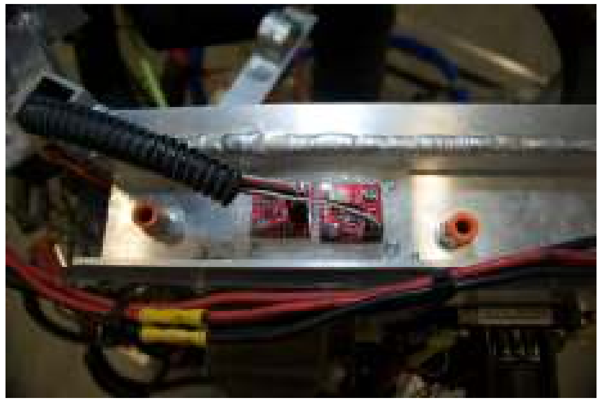

Figure 5 – Accelerometer and Gyroscope

Figure 6 – Wheel Encoder

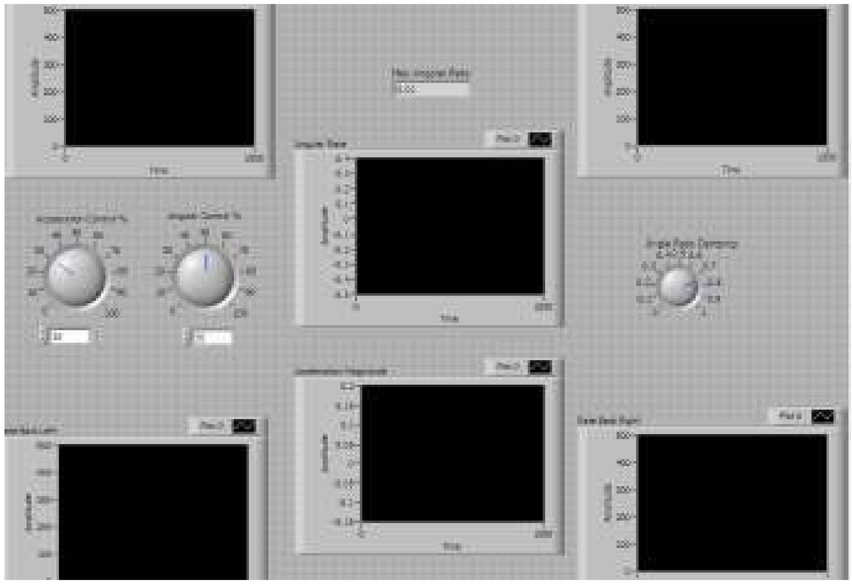

Figure 7 – Traction Control Panel Display

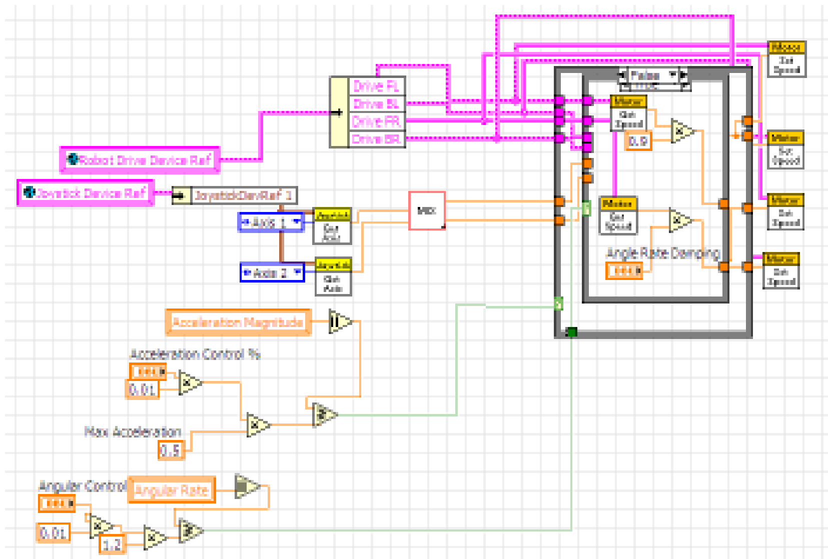

Figure 8 – Traction Control Functional Diagram

Image Tracking

The Image Tracking System was designed to allow an Operator to automatically steer the Turret (See Figure 4) to the correct destination based on the video data acquired from a digital webcam. For the FRC 2009 Competition all robots that were competing towed behind them a “Trailer” that had a light in the center of it, either Pink or Green. Based on this it is possible to design a system that is capable of steering some implement of the Robot towards this light and increase the scoring capability of the Robot. Due to mechanical stresses and friction, the Turret was steered using PID control to reduce the amount of time required to target the opposing team’s trailer. Because of other issues with the Robot, this system was not fully tested before the actual Regional Event. See Figure 9 and Figure 10 for the Image Tracking algorithm and Figure 11 for the Turret State Machine Diagram.

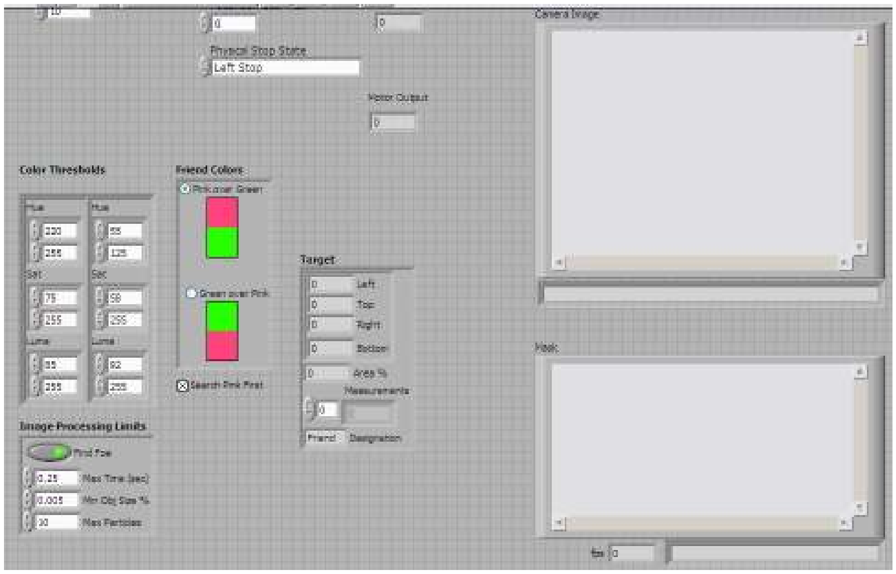

Figure 9 – Image Tracking Display Panel

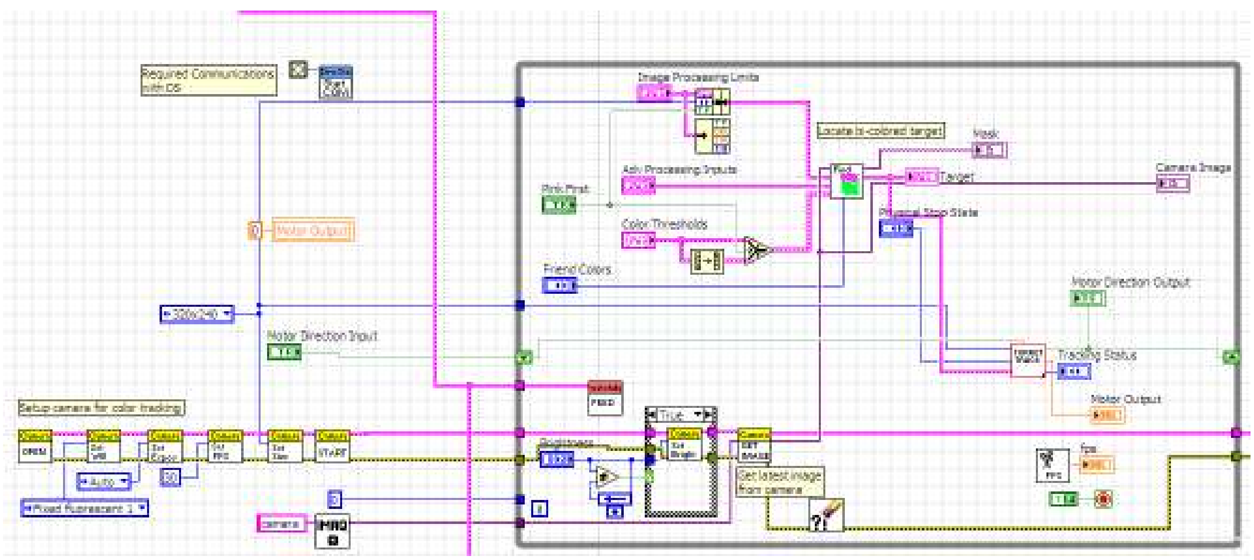

Figure 10 – Image Tracking Functional Diagram

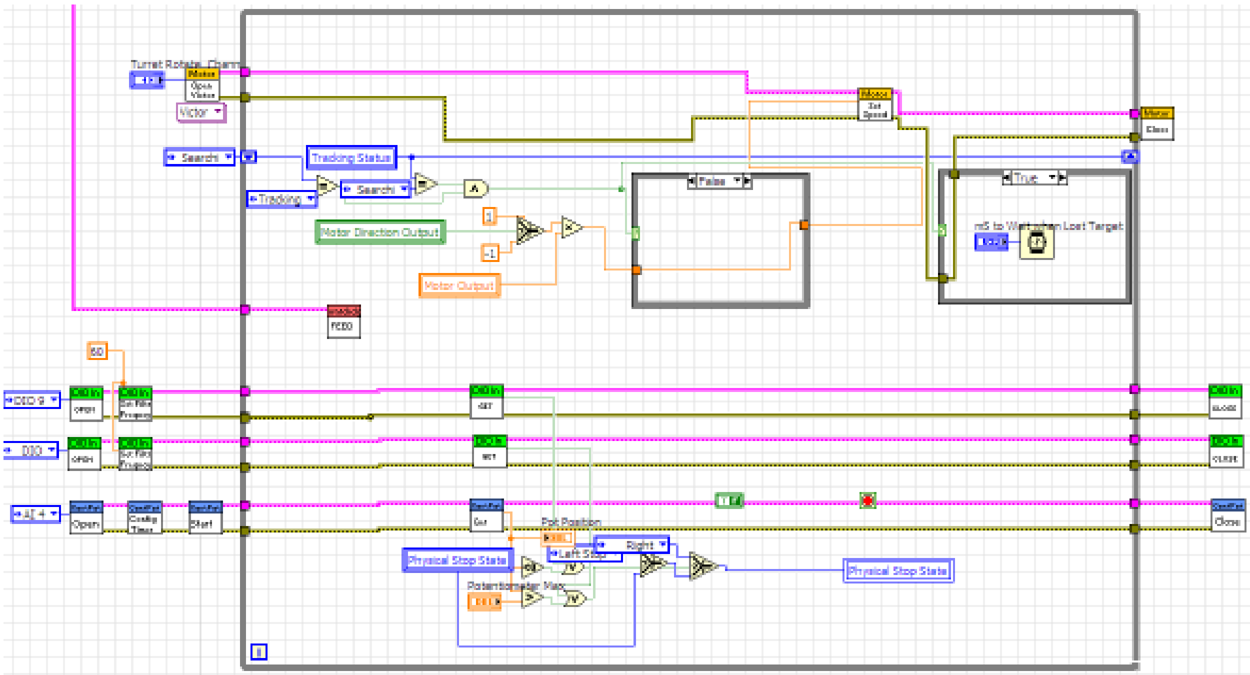

Figure 11 – Turret State Machine State Diagram

Results

Tracking Control

Due to differences between the actual playing field and the test field that was used, along with considering the large amount of collisions between robots and trailers, the Traction Control system as implemented was deemed ineffective to control the motion of the Robot, and more importantly reduced the capability of the Robot because it limited the acceleration of the system too much. It should be noted that, with better calibration parameters this system should have performed better but due to time constraints at the Regional it was not deemed a priority and was removed from the Robot program.

Image Tracking

As was stated above, the Image Tracking system was not fully tested before the Regional. During the Regional, between the continuous matches the Image Tracking system was fine tuned and on the 2nd day of the Regional was working flawlessly. However, after about 10 minutes the camera stopped working completely and could not be repaired. Due to the frequent and harsh collisions between robots this was deemed to be the cause of this problem.

However, it should be noted that the Brehm Robotics Team was still very successful at the Regional, earning a 2nd place medal. There were many contributing factors for this, including diligent team effort, an advanced control system that allowed the mechanical building of the robot to proceed unobstructed.

More importantly, after spending 3 years mentoring the Brehm Robotics Team I feel that I have encouraged and motivated many of the members of the team to desire careers in Engineering. One of the students will be pursuing an Engineering degree at Cal-Tech and another of the students will be pursuing an Engineering degree at Washington University in St. Louis.

More Information

The Brehm Robotics Team website can be found at:

http://www.megahurts2219.com/

Video can be found at the following website:

http://www.thebluealliance.net/tbatv/team/2219