IGVC 2011

The 19th Annual Intelligent Ground Vehicle Competition

University of Cincinnati Team 2

Bearcat Cub II

Certification

I certify that the engineering design in the vehicle Bearcat Cub II by the current design team identified in this Design Report has been significant and equivalent to what might be awarded credit in a senior design course.

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Dr. Daniel L Humpert, CEAS-School of Dynamic Systems

Introduction

This year is the 19th year that the University of Cincinnati Robotics Team has participated in the IGVC. This year there are two teams from UC running with two separate robots. This is the report for Team II, which built a new robot from the ground up rather than modifying the existing design. In this case, the robot has a brand new structure and electronics setup, with emphasis on better fitting newer requirements for the IGVC. The following report describes what was done to complete this project and how it will attempt to improve on its predecessor.

Initial Design Rationale

The initial problem that was revealed was that the current design lacked in one principle area: speed. The Bearcat Cub I from the previous year's competition would move at a pace of roughly a couple miles per hour. In this year's competition the requirement was increased to up to 10 miles per hour, so it seemed warranted to increase the operating speed of the robot. Furthermore, it was noticed that the old model had many unnecessary connections and extraneous components, so a new model seemed warranted in order to address these concerns. The team designed a new drive system in hopes that it could be more easily modified to perform based on evolving rules and regulations for the IGVC, and also to allow for better performance in this year's competition than in previous years. In addition, a simpler sensor system was used to allow for smoother operations. Many of the innovations are described in better detail below.

Team Organization

This robot's design was carried out principally by a team of five mechanical engineers. Initially the team decided to come up with drive system concepts involving a continuously-variable transmission or exchangeable-gear system and a new wheel layout, which was followed by the idea of making the robot lighter and more efficient in its use of power. The team consisted principally of the five undergraduate mechanical engineers with support from other members of the team. A Gantt chart is provided below to detail how work was carried out.

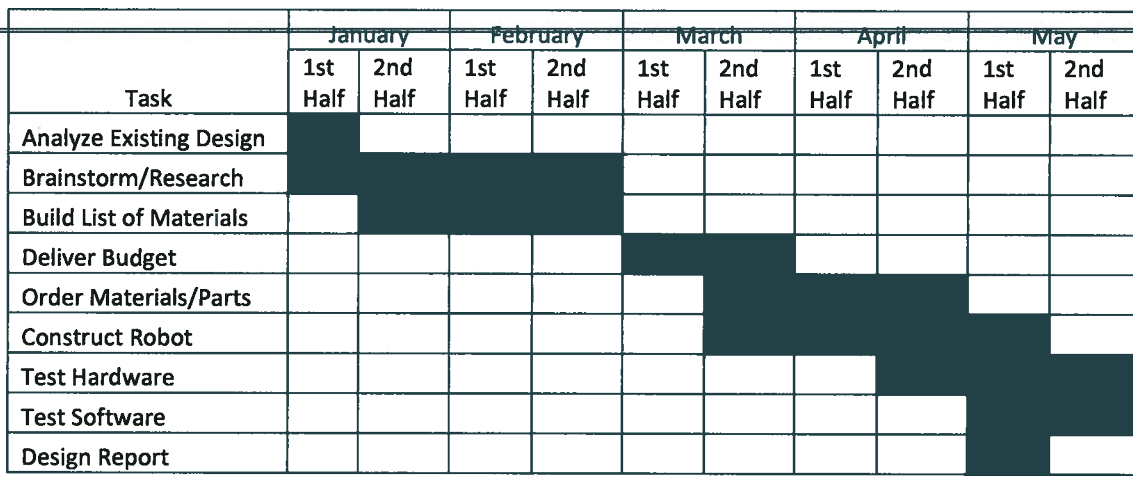

Figure 1: Gantt Chart

This report is divided into sections, each one detailing a different part of the robot's makeup and development.

1. Hardware: details the robot platform itself, including the drivetrain, the power supply system, and our considerations of safety and durability.
2. Electronics: details the hardware of the robot including the computer system and the sensors used.
3. Software: a basic overview of the software and programming of the robot.
4. Expected Performance: some of the expected performance of the robot itself.

Final Design

1. Hardware

a. Frame/Structure

The robot structure itself is as shown below. It is principally composed of extruded 80/20 aluminum which allows for a lightweight yet durable structure that also grants a high degree of modularity so that any changes can be made quickly and easily. The frame was designed to provide the maximum of support for all the components and provide a mounting structure for the drivetrain and power system. The configuration uses three wheels, two for drive mounted in the middle and one for support mounted in the rear. The front will have a skid mounted on it to keep it from hitting the ground hard. In addition to the layout shown, the robot will also have a single mast stretching up from the middle of the vehicle that will hold the sensor system, supported by four tension cables tied to the four corners.

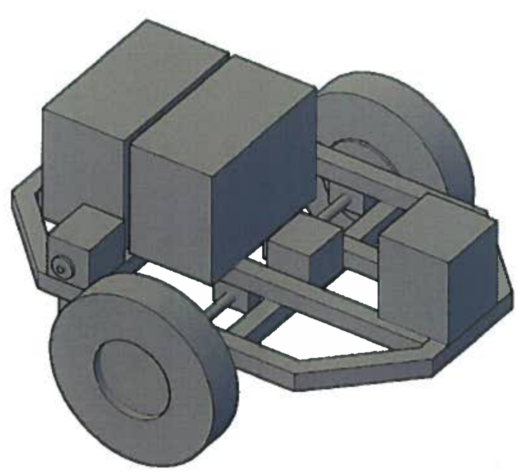

Figure 2: Initial Frame Layout

b. Power System

The robot runs on two 12 Volt batteries connected in parallel to provide 12 Volts of power to the robots electrical components. The drive motors and Sick LiDAR run on 24 Volts and require a DC/DC converter to operate properly. Each motor runs on one separate converter and the LiDAR is connected to one of the converters. All components are connected in parallel at two terminal blocks. All other electronic components are also connected to the power system as well through a serial hub.

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c. Drive System

The robot itself uses one Quicksilver NEMA 34 servomotor per drive wheel, each connected to a SilverNugget N3 motion controller. These motors each drive the 14" diameter wheels (each wheel with approximately 5" wide treads) separately via heavy duty chain-and-gear drive. The gears put the motor's rotation through a 4:1 reduction (the wheel shaft turns four times slower) than the drive shaft, providing a speed of somewhere roughly in the 3-6 mph range (actual top speed is as yet to be tested at the moment of writing this report). The drive system is displayed in the diagram below (generated via AutoCAD), in pink.

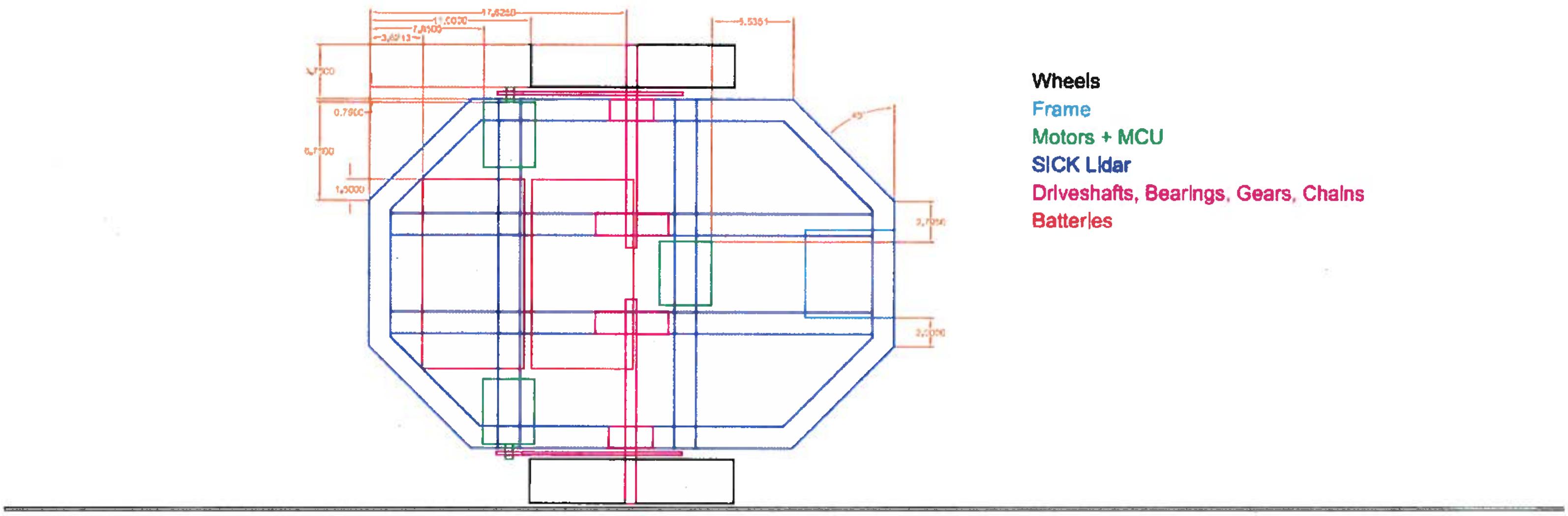

Figure 3: Drive System Layout

d. Safety/Durability Considerations

In building the robot safety and durability were major factors. Two emergency stop measures were implemented (as per competition rules, a manual button is mounted on the frame over two feet above the ground and a remote stop with a range of over 100 feet), and a safety light was built on the structure to signal when the robot is in operation. In addition, to protect the robot itself it is mostly enclosed in a shell made up of aluminum sheets joined together. This shell is design so that it is easy to remove in order that the robot itself is easy to repair and service, yet still durable enough to keep dirt and debris out. In addition, all components have been sized so that the Cub II can withstand the stresses and strains of competition operation.

2. Electronics

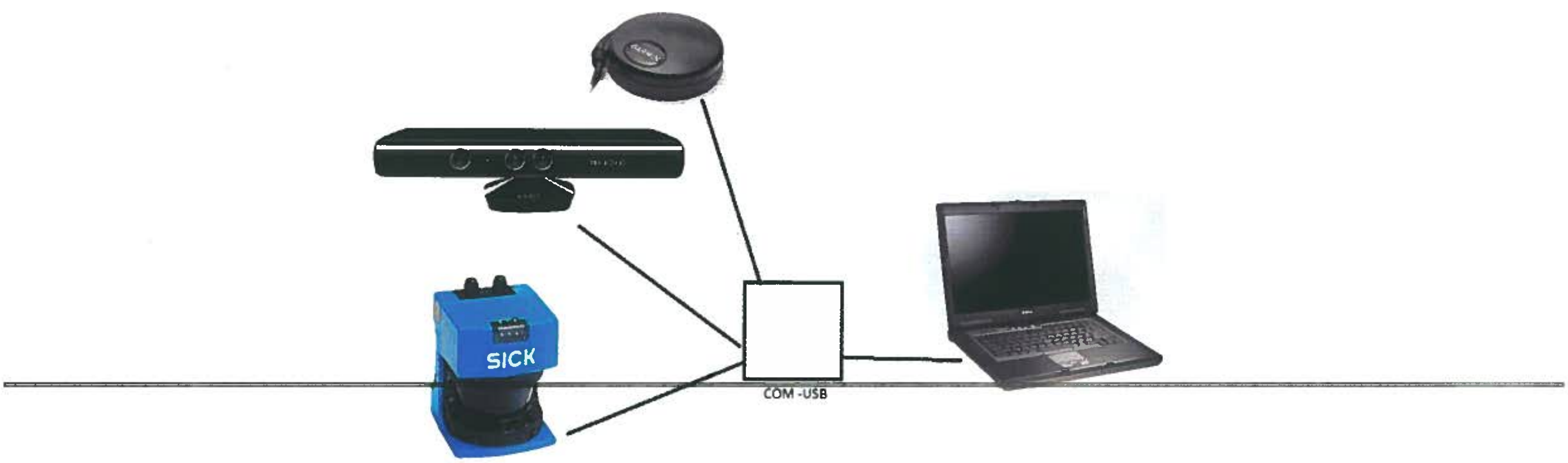

Figure 4: Bearcat Cub II Sensor Diagram

a. Computer

the laptop computer being used to control the robot is a Dell Latitude D830. The computer runs with a 2.6 GHz processor and 3.5 GB of RAM. All data gathered by the sensors is collected and analyzed by the Quick Control and other programs.

b. Cameras

The Xbox Kinect provides the primary sensing capabilities for the robot. The Kinect relies on its two cameras and an IR projector to see. The two cameras are color CMOS sensing and IR sensing and have depth sensing capabilities. The Kinect has a horizontal field of view of 57°, a vertical field of view of 43°, and an operating range of 1.2 – 3.5 meters. The cameras send data via USB at 30 frames per second.

c. Light Detection And Ranging (LiDAR)

The Sick LMS200 LiDAR using laser detection and ranging and is the primary sensor for seeing preventing collisions. It has a 180° field of view with a 75 Hz scanning frequency. It has an operating range of 0 – 80 meters. It interfaces via two serial RS-422 connectors for power and control.

d. Global Positioning System

A Garmin GPS 18x OEM is used for passive navigation and tracking. It is not interfaced to provide steering and guidance for the robot. The GPS receiver has an acquisition time of less than 45 seconds and updates at 1 record per second. The GPS interfaces with the laptop via an RS232 serial connector.

3. Software

a. Mapping

The autonomous program will actively map the course as it goes by plotting GPS coordinates in a log file. This log file will be used in order to make sure that the robot does not turn itself around and finish at the starting point due to a difficult obstacle. Mapping will be used solely for advancing the robot's progress. In the future, this mapping code can be used to have the vehicle autonomously "escape" from the course via the same path, but no plans are made to develop this feature this year as it is not specifically part of the competition.

b. Lane Detection

The lanes will be solid white painted lines on grass. Using the Kinect color camera as raw input, a line detection algorithm is used to separate driveable area from the out-of-bounds area. The robot is not permitted to cross any line at least 1" wide that it detects as a "white line." This width factor assumes error in the Kinect sensor to accurately detect anomalies in the grass which could cause severe problems during the competition.

c. Path Finding

The Bearcat Cub is designed to drive as directly as possible to each waypoint. The program uses an iterative method that constantly checks for lanes and obstacles. If an obstacle or edge line is found, the algorithm actively checks to see if it is on a collision course. If there is no collision course, then there is no change in robot behavior. However, when a collision is imminent, the robot adjusts course in order to prevent a collision or going out-of-bounds. For hazards detected via the LiDAR, the avoidance algorithm has time to respond due to the LiDAR's range. However, when detecting edge lines or obstacles through the Kinect, the robot is designed to slow down much more in order to compensate for the smaller range of the optical sensor. After passing the obstacle or getting out of range of the boundary line, the robot readjusts its course straight to the waypoint. Once a waypoint has been reached (within a margin of error), the next waypoint becomes active and the initial one neglected. Due to our zero-point turning radius, this active priority shifting can work even right next to obstacles without a collision.

Conclusions

The new Bearcat Cub II will hopefully become the flagship vehicle of the UC robotics team in the near future. Its performance is predicted to improve significantly over the last model and its design is much more adjustable and customizable in addition. If successfully tested, the Bearcat Cub II will provide a competitive and powerful force in the IGVC. However, the Bearcat Cub II at very worst provides a great platform which can be modified and reprogrammed to operate even more effectively in the IGVC.

Team Bearcat Cub II for Intelligent Ground Vehicle Competition 2011

- Josh George Mechanical Engineering
- Caleb Gillespie Mechanical Engineering
- Andrew Steele Mechanical Engineering
- Patrick Wilsey Mechanical Engineering
- Clifford Zimmer Mechanical Engineering