ME 597 Lab #1:

Motion Control of a Four-Wheeled Ground Robot

Introduction:

This lab has two main goals, first to familiarize your team with the development environment for the robotic platform used in this course, and second, to implement some of the controllers described in the lecture notes for velocity, steering and line tracking control. As this is the first time through the labs with this hardware and software interface, there may be a lot of exploration required to get things to work. All suggestions and comments are welcome, and the first teams to go through will be noted for their relative disadvantage.

Background:

This lab relies on three main elements from the course, motion modeling, PID control and nonlinear steering control. Please refer to the course notes on motion modeling and control for the relevant background. Additional resources that may be useful will be introductory controls texts on PID controller design, the low-level microcontroller board API ("Horizon Protocol v1.0"), and your trusty TA, PJ.

For this and all subsequent labs, you will be doing all of your coding in ROS (C/C++, Python) on the Linux OS installed on the Intel Atom netbook. As described in class, the code is multi-threaded and relies on curses to provide a terminal interface. Experience with ROS and pthreads will be of use here, but both libraries have solid documentation and extensive communities online. In order to control the vehicle, you will be issuing commands to a low-level microcontroller board and receiving sensor information from the low level board, USB and serial interfaces. This will allow you to directly operate on sensor data in your control design and set steering angle and motor voltage commands for the low-level board to execute. The API defines all the necessary command packets, and a sample program (C++ code and makefile) is available on the high-level platform to get you started.

Lab Instructions:

1. Develop a motion model for the vehicle, based on the bicycle model presented in class. The four wheel vehicle relies on Ackermann steering actuated by a servo and a voltage applied to the brushed DC motor. Implement the model in Matlab, as a simulator to validate the controllers to be designed in the following sections. This section does not need to be checked off by the TAs, but will be included in the report.

2. Using the robot as provided, identify the relevant model parameters such as mass, length, min/max steering angle, motor command to torque gain, motor time constant, steering bandwidth. This section does not need to be checked off by the TAs, but will be included in the

report.

3. Develop a PID controller for speed control, using GPS velocity or odometry as the measurement signal. Using the identified motion model, define a simple linear plant which connects motor voltage to speed, and design a PID controller for a good step response. Feel free to set P, I or D gains to zero, to add a DD term etc., whatever you think will be the most effective/simplest. Find a straight area with uneven terrain and demonstrate how the PID control is able to compensate for uphill and downhill sections. Experiment with different gains and controller configurations.

4. Develop a steering controller per the geometric steering control described in the nonlinear control notes (Stanley geometric controller). Find a wide open area, determine the locations of four waypoints and use the steering control at constant speed to navigate around the rectangle. Use the heading and position information from the GPS receiver to drive your controller. What happens at low speed? It may be best to initialize the controller with a known heading and start the test run in that direction. Is it possible to use the odometer measurements as well? How might you combine the two signals?

Lab Report Instructions:

The writeup should be between 5 and 10 pages long (title page and table of contents not included (ToC not needed)). The report should have the following information, organized into sections however you like. There is no need to describe your method in detail, but instead focus on the theory behind what was done and the results as described below.

1. Theory: The goals of these sections are to summarize how you did everything in the lab, so we can assess if you understood the underlying principles. Briefly describe the platform you used, including the relevant sensors and their characteristics. Define the vehicle model used in simulation, summarize the system identification technique used to define model parameters, and present the controllers implemented.

2. Results: The goals of these sections are to convince a skeptical reader that you have correctly identified the system parameters and have a model that captures the motion of the vehicle, and that you have selected appropriate controllers to enable autonomous robot operation. Present the results for the model identification and then compare simulation runs to real robotic runs for e.g. a step motor command or steering command at a constant speed (the two should line up to some extent, but explain any differences). For each of the controllers required above, present simulation and real data demonstrating successful control of the vehicle. Select motions that clearly present the capabilities of the controller, e.g. for the PID control, select a hilly terrain, record and present altitude data with the GPS and show how the controller is able to adjust for changes in road angle. Discuss how you developed the controller and any observations you made in terms of sensor characteristics and performance limitations. Present error plots and vehicle tracks, as well as the desired positions, headings and/or speed for each run.

I believe that this is perhaps a more vague description of the lab report and a different way of writing reports than you may be used to. The idea is to make you think like an academic, to present your ideas in a way that convinces everyone of their validity and does so quickly, without a lot of excessive detail. Since the work you are doing is coming so close to the cutting edge, it only seems natural to have you write this way. The 10 page limit may or may not be a hard one to meet, but it will be rigidly enforced. Of course, feedback and questions on this are welcome!

Lab Report Marking Scheme:

Please note that the difficulties with getting the robots functioning will be taken into account in terms of the marking of the lab reports, and we will be as fair as possible. I am extremely appreciative of all the work you have put into getting the vehicles going, and I look forward to smoother sailing in the later labs.

Content & Results: 60% total (~10% each, depending on robot functionality)

- Background & Theory - Motion Model, Measurement Model
- Background & Theory - Controllers to be implemented
- System Identification Results
- Speed Control Simulation Results
- Steering Control Simulation Results
- Vehicle Experimental Test Results

Discussion of simulation and experimental results, sensor issues, vehicle limitations: 20%

Presentation: 20%

- Nicely formatted, either single or double column, no need to double space
- Page limit observed
- Figures, tables labeled, no superfluous figures, no excessive displays of raw data
- Appropriate references provided
- No table of contents needed