Path Tracking Control for Autonomous Road Vehicles

Path Seeker Project Proposal

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Path Seeker
At the edge of path tracking control

Team Members

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Project Supervisor
Prof. Ashoka K. S. Bhat
Abstract

The proposed project is a small scale autonomous road vehicle capable of following a line printed on the road. Dubins’ cars are kinematic models of wheeled vehicles that move only forward in a plane and possess a lower bounded turning radius. A vehicle will be built that resembles a Dubins’ car and it will be controlled using a PID controller. If time permits, a sonar will be added to the vehicle to allow it to interact with its surroundings. Even though this is not a project proposed by an outside sponsor, it has a lot of potential.
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Path Tracking Control for Autonomous Road Vehicles

Path Seeker Project Proposal

1 Introduction

The purpose of this proposal is to give a description of the proposed project, to emphasize its objectives and motivations, and to describe what type of equipment will be needed from the engineering labs in order to complete it. A previous version of this project proposal was already presented in September of 2003. This is the final version.

2 Team Members and Supervisor

The project was started early due to the large amounts of work that it will require. The team members are:

<table>
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<tr>
<th>Name</th>
<th>Student #</th>
<th>E-mail</th>
<th>Discipline</th>
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</table>

This is the definitive list of members. The project supervisor will be Dr. Ashoka K. S. Bhat. The team has already spoken to him and he has agreed to be the project supervisor.

3 Project Objectives

The purpose of the project will be to construct a small autonomous vehicle that has the ability to follow a trajectory set by a continuous path printed on a flat surface. If time permits, a sensor will be added to allow the vehicle to detect objects in front of it and avoid collisions. The aim of the project is to develop a simple low cost platform that could ultimately be used as a test vehicle for path tracking control algorithms.

We intend to build a two axis vehicle (that resembles a commercial sedan) that is 1/10 of the size of a regular car and that can follow a line on the floor. The vehicle will be an autonomous vehicle controlled by an on board programmable microcontroller. The line on the floor is to be a thin line of a bright material on a black surface and will be a relatively simple and smooth path with curvature constraints. A position sensor will be placed underneath the front axle of the vehicle to provide the microcontroller with the position of the vehicle with respect to the desired path. As mentioned before, if time allows, a sonar will be placed on the front of vehicle to allow a more robust interaction with the external environment. The proposed autonomous vehicle will be called Path Seeker (PS).

4 Path Tracking Control

In the past two or three decades, a lot of interest has emerged in the development of path tracking control schemes for wheeled vehicles that only move forward on a planar surface and possess a bounded turning radius. Such a vehicle is called a Dubins’ car in honour of the mathematician L. E. Dubins, who first addressed this control problem [5].

Definition 1 Dubin’s cars are kinematic models of wheeled vehicles that move only forward in a plane and possess a lower bounded turning radius.
The motivation for developing control schemes for Dubins’ cars is that they are an essential part of the kinematic models of road vehicles, aircraft cruising at constant altitudes and sea vessels [3].

Dubins demonstrated that a vehicle that can only move forward with curvature bounds is controllable [5]. A wide variety of control schemes have been developed for Dubins’ cars (e.g. [2] and [4]). An optimal control scheme for Dubins’ cars was developed by A. Balluchi and P. Soueres [2]. This optimal control algorithm requires two pieces of information as inputs: the position of the vehicle with respect to the desired path and the heading angle error of the vehicle.

4.1 Scope of the Project

To construct a vehicle with position sensing that computes both the position of the vehicle with respect to the desired path and the heading angle error, would be extremely difficult in only four months. In this project we will attempt to build a position sensor that computes only the position of the vehicle with respect to the desired path. This sensor will be tested using a simple PID controller.

A path tracking vehicle that uses a PID controller, and does not use the heading angle error information, is not guaranteed to converge to a solution of the controlability problem. Nevertheless, the PID controller will work for very simple paths consisting of relatively large circles and straight lines.

The motivation behind this approach is that, in a future project, a replica of the position sensor that will be installed on the front axel could be added on the rear axel of the vehicle to provide a second reference point. The extra reference point would provide an approximation to the heading angle error. With the extra heading angle information the optimal control scheme could be implemented.

5 Project Motivation

Even though the ELEC 499 / CENG 499 guidelines recommend to take advantage of outside sponsors to undertake project, we have decided to propose our own project for various reasons. First, the problem of motion control is a standard engineering problem of a manageable size that directly combines all the basic concepts of analog/digital control, motor control, signal processing and digital design that we have learned in some third and fourth year level courses. The problem is not focused on a very specialized research subject or complex industrial application, it is rather focused on system integration, a very valuable skill. Second, the subject of control of autonomous vehicles is one of interest for the members of the team and we wish to pursue a project in this area. Finally, we understand that there are many advantages in taking a project from an outside sponsor; nevertheless, due to constraints in time and resources and group preferences, we decided to propose our own project.

6 Technical Specifications of the Vehicle

The 1/10 scale vehicle will consist of the following components:

1. Vehicle chasis and body.
2. Microcontroller based on the MC68HC11 that can be programmed in C like language by using a PC and a serial communications port (might change if a better one is found).
3. Position encoding sensor mounted at the bottom of the car body.
4. One DC motor for propulsion and a speed controller (PWM control).
5. One DC servo to control the steering of the vehicle.
6. Two sets of batteries: one for the motor and another for the microcontroller.
7. One sonar sensor to detect objects in front of the vehicle.
6.1 Vehicle’s chasis and body

The body and the chasis of the car will not be built from scratch. A standard 1/10 scale car chassis we will be used to build on top of it. A picture of the chassis that will be used is included in Figure 1. The body will be a simple plastic structure attached to the chasis.

6.2 Microcontroller

The proposed microcontroller was developed for robotics applications and has some features that make it easy to interface sensors and motors. A programming platform has been developed for the microcontroller (with libraries to control some sensors); it is called the MIT HandyBoard System. A picture of the microcontroller is shown in Figure 2. The microcontroller might be changed if we do not find it convenient for the task at hand. All the technical details of the microcontroller can be found in reference [6].

6.3 Position sensor

The position encoding sensor is the only component of the entire project that has not been developed or purchased. Up to now there are two preliminary ideas on how to build such device. The first solution will be to try to develop such a sensor using an array of photoreflectors. The datasheet of the proposed photoreflctor is included in a *.pdf file attached to this document. There are still debates on how such a circuit will be constructed since an encoder will probably be needed to encode all the possible states of
6.4 Sonar

If time allows, a sonar will be used and interfaced with the microcontroller to detect the distance of objects in front of the vehicle. The sonar to be used is a Polaroid 6500 sonar module. A picture of the sonar is shown in Figure 3. This specific sonar was designed to operate with the chosen microcontroller so it is assumed that it will be relatively easy to interface it. The sonar has already been acquired.

7 Project Schedule

As stated before, the project is divided in four major phases. The project schedule was developed based on this task organization and it is shown in Table 1. Evaluations of this project schedule will be carried out on January 18 and March 9 of 2004 when the progress reports are due. The technical feasibility of the project will not be fully determined until phase two has been completed successfully. An early deadline has been set for the development of the position sensor (the first week of February) so that if there is no success in building one, there is still time to introduce modifications to the project.
### Project Phase

<table>
<thead>
<tr>
<th>Phase</th>
<th>Goals</th>
<th>Completion Date</th>
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<tbody>
<tr>
<td>Phase one</td>
<td>Physical Construction of the vehicle must be completed. All of the required lab infrastructure must be arranged.</td>
<td>January 12, 2004</td>
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<tr>
<td>Phase two</td>
<td>Finish a working prototype of position encoder sensor.</td>
<td>February 3, 2004</td>
</tr>
<tr>
<td>Phase three</td>
<td>Mount the onboard microcontroller. Program the vehicle to follow a line on the floor at constant speed. Modify the position encoder sensor and make a new prototype if needed.</td>
<td>March 26, 2004</td>
</tr>
<tr>
<td>Phase four</td>
<td>Add a sonar sensor to the vehicle and modify the control program.</td>
<td>March 26, 2004 (if time allows)</td>
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</table>

Table 1: Project schedule.

### 8 Equipment Requirements

Besides all the vehicle parts (most of which already have been purchased), access to the ELW equipment and facilities will be required. The following things will be required:

1. A PC with Windows 95 or a more recent version with Internet access.
2. 100MHz two channel oscilloscope or better.
3. Pulse generator.
4. Multimeter.
5. DC power supply.
6. Locked storage space.

The team is willing to bring a PC into the lab and leave it there as long as the lab access is restricted and internet access is available.

### 9 Conclusion

The team believes that this project will satisfy the difficulty requirements expected from an ELEC 499 / CENG 499 project, but we are open to any suggestions. As it already stands, it will not be an easy project to complete.
References


