2006-922: A VEHICLE DRIVABLE BY A LAPTOP PC

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A Vehicle Drivable by a Laptop PC

Abstract

This paper describes the details of converting a regular vehicle into a vehicle that is drivable by a laptop PC. The work was done as a design project in the first controls course in our curriculum. The students applied the knowledge that they gained through the controls course and the microcontroller course to design and built the controllers and the actuators that facilitated the driving of the vehicle by a laptop PC. The vehicle was a 1993 Geo Metro. Initially this vehicle was a five speed manual transmission car. It was converted into an automatic transmission vehicle. This allowed easier control of gear shifting by the PC. Futher modification to the car was done. The original steering wheel, the covering of the transmission lever, and front car seats were removed. This allowed the installation of the drive mechanism. For each of the four operations of steering, accelerating, braking, and transmission gear shifting, a set of drive mechanism was designed and built. Each drive mechanism consisted of an acutuator driven by a dc motor, motor driver chips, and sensors. The sensors sensed the positions and the signals were fedback to a microcontroller that controlled the actuators. The microcontroller used was the Freescale MC68HC12B. Special attention was paid to safety in this project. Careful consideration was given to the scenario of loosing control of the vehicle during testing. Safety procedure was developed and followed strictly. No accident occured during the testing. The modified vehicle was tested in an empty parking lot after notification of authorities. In the test the laptop took the keyboard inputs for accelerating, braking, steering, and gear shifting and issued control signals to the drive electronics. The vechicle responded accordingly as designed. When the speed of the vehicle was kept less than 10 miles per hour, it was maneuverable around the testing area easily. Trying to drive the vehicle from a keyboard was somewhat difficult at high speed and it took time to learn. The work performed in this project can be used for a follow-up project, which goal is to remotely control the vehicle.

I. Introduction

One of the goals of this design project is to explore the possibility of performing all drive controls of an automobile by a laptop computer. A block diagram of our design is shown in Figure 1.



Figure 1: Vehicle Drive Control Block Diagram

The laptop receives keyboard inputs from the user. The inputs are right turn, left turn, acceleration, braking, forward, reverse, and other commands. These keyboard inputs are read by a 68HC12 microcontroller^[1-7]. The microcontroller will then control the steering wheel, the brake, the gas pedal, and the transmission lever through mechanical designs actuated by dc motors. The positions of the brake pedal, gas pedal, and transmission lever are sensed by potentiometers. The signals were fedback to the microcontroller for acheiving accurate position feedback control^[9-17].

The automobile used in the experimentation was a 1993 Geo Metro. Major modifications were done on it so that it could be controlled by the laptop computer. First, the original five speed manual transmission was converted to automatic transmission so that gear shifting could be implemented more easily.

Second, the casing for the transmission lever were removed. and mechanical parts and another motor were connected to the lever so that it could shift between Parking, Reverse, Neutral, and Forward.

Third, the original steering wheel was welded to a flywheel and other mechanical parts. The gears of the flywheel were coupled to a gearhead motor controlled by the microcontroller. This allowed the control of steering by the microcontroller.

Lastly, mechanical parts and a seperate motor were connected to the brake and gas pedals so that pressure could be applied on the brake through the dc motors.

The main purpose of this project is to provide experimental data for the analysis of the control techniques and to investigate the possibility of remote control of the vehicle in the future. The participation in the Department of Defense's DARPA Grand Challenge is out of our range at this point.

The rest of this paper is organized as follows: the design approach is described in the next four sections and it covers the dc motor selection, motor driver selection, braking control, acceleration control, transmission control, and steering control. Resources used in the microcontroller and programming is described in Section VI. Testing results are described in Section VII and concluding remarks are provided in Section VIII.

II. DC Motor Selection

Based on the available budget, cordless drill dc motors were selected in drive control systems. A photo of the actual cordless drill used in this project is shown in Figure 2. These dc motors are gearhead dc motors. The motor shafts of this type of motors are coupled to the output load shafts

through specific gearing systems. The purpose of the gearing system is to increase the torque performance. These motors operate on 18 V power pack batteries. At no load, it drains 1.5 to 2.0 A. When the shaft was locked a current measurement indicated 5.6 to 6.0 A of maximum current drawn from the batteries. The scenario of locked shaft seldom occurred in our project but in our design we tried to accommodate this case. The power requirements of our design were based on these measurements.



Figure 2: Cordless Gearhead DC Drill

Each dc motor was removed from the drill casing and was mounted into the vehicle drive systems. Proper mounting brackets were fabricated to hold the motors in place so that they could withstand vibrations caused by a moving vehicle.

III. DC Motor Driver IC Selection and Operation

The next step was to select dc motor driver chips for controlling the dc motors. The criteria were that the chips could deliver 3 A of current continuously and 6 A of current momentarily to the motor up to an operating voltage of 20 V and that it could be easily controlled by the Freescale's MC68HC12 microcontrollers. The LMD18200T^[8] manufacutred by National Semiconductor Corporation was chosen. The LMD18200T is an H-bridge dc motor driver. It is capable of providing 3 A of current continuously and 6 A of current momentarily to any inductive load up to an operating voltage of 55 V.

The particular package selected was the 11-lead TOS-220 package as shown in Figure 3. The TOS-220 package allows easy mounting of heat sink to it and therefore has better heat dissipation capability over the other available packages. These motor driver chips were used to control all the dc motors installed into the vehicle for steering, braking, accelerating, and transmission shifting.



Figure3: LMD18200T TOS-220

The operation of this chip in our project is briefly described as follows: we used the simple, locked anti-phase PWM mode. In this mode, the direction and amplitude of the control signal are embedded into the PWM signal. A pinout diagram of the configuration used is shown in Figure 4. A 50% duty-cycle PWM signal represents zero drive.

A duty cycle more than 50 percent will drive the motor in one direction. The higher the duty cycle the more is the current delivered to the motor.

A duty cycle less than 50% will drive the motor in the opposite direction. The smaller the duty cycle the more is the current delivered to the motor in the opposite direction.



Figure 4: DC Motor Control Circuit

IV. Braking, acceleration, and transmission Control

The design of the braking, acceleration, and transmission control were similar. It was based on the classical position feedback control method. A linear potentiometer was attached to the moving part of each mechanical unit to provide a voltage feedback to the MC68HC12 for sensing the positions. For braking, a potentiometer sensed the position of the brake pedal. For acceleration, another potentiometer sensed the position of the gas pedal. For transmission, a third potentiometer sensed the position of the transmission at Park, Reverse, Neutral, and Drive. The braking, acceleration, and transmission control are shown in Figures 5, 6, and 7, respectively.

In each of the three controls, each dc motor was mounted to a pivoting mounting bracket. The motor load shaft was attached to a threaded rod which length was different for different system. A female threaded pivoting joint was attached to each mechanical unit (brake and acceleration pedals and transmission stick). The threaded rod linked through the female joint, just like a bolt

through a nut. When the motor was rotating, the threaded rod rotated in the same direction. The rod applied force on the female joint that pushed a pedal or the stick up or down depending on the direction of rotation. The potentiometers sensed the positions. The potentiometer signals were read by the microcontroller. When the desired positions were reached, the microcontroller would stop the motors. Since the pedals and the transmission lever did not move in a linear manner but more in an angular motion, the voltage readings from the linear potentiometer were nonlinear.



Figure 5: Braking Control

Test was conducted on these three systems (braking, acceleration, and transmission). The data collected showed that each motor could be powered from the vehicle's 12 V battery. The average

current drain by these systems was around 2.5 A, which was within the 3 A limit of the LMD18200T.



Figure 6: Acceleration Control



potentiometer feedback female joint threaded rod gearhead/slippage dc motor Figure 7: Transmission Control

V. Steering Control

This system was one of the most difficult to implement. Finding a way to attach the dc motor to the steering column and to have enough torque to turn it left or right was no easy task. A simple solution was devised where a flywheel (as shown in Figure 8) together with its starter gearhead linkage (as shown in Figure 9) were used. The flywheel was welded to the steering wheel itself and the starter gearhead was welded to the dc motor's drive shaft (Figure 9). The dc motor drove the flywheel so as to turn the car left or right. With a large number of teeth on the flywheel, it provided additional mechanical advantage while the starter gearhead already had very good gear ratio per turns. The torque was much increased and the dc motor was sufficient to drive the steering column. However this came at price, because increasing the torque form the motor shaft

to the steering meant that the load to the motor increased as well. This increased the current requirement for the motor to run properly.

Special mounting braked was fabricated for the steering to link up the motor with the flywheel in such a way that it could be disengaged if needed. This was necessary because we desired that a user could still steer without any interference from the flywheel. The mounting bracket was designed in such a way that it could be lowered or lifted about one inch away from the flywheel's teeth and locked in place with a fastening knob. A photo of such mechanical arrangement is shown in Figure 10.



The system was tested to see if it was capable of turning the steering column and the tires by the dc motor. The tires were inflated to its maximum limit to reduce the friction. Test indicated that the 12 V from the vehicles battery source was not sufficient to drive properly the steering. It was a little sluggish. A 18 V power pack battery was used and the response was much better. During this function testing current measurements were taken. When the steering was disengaged the system drained approximately 4.0 to 4.5 A; however, when engaged this current drain jumped up

to as much as 7.5 A. It was a clear indication that one single LMD18200T would not be able to provide this amount of current.

To solve the current problem of the steering system, it was decided to use two LMD18200Ts connected in parallel and to use a separate power source of 18 V battery, which was from the original drill. The connection of the two LMD18200Ts is shown in Figure 11. This configuration solved the current problem and the steering was much improved.

It was intended to use a hall-effect sensor (ATS612LSB by Allegro) to sense the position of the flywheel and to use the input capture method supported by MC68HC12 microcontroller to determine how much the steering column turned and used that as the feedback signal. However, due to insufficient time, this was not implemented.



Flywheel linkage

dc motor dc motor gearhead shaft linkage starter gearhead

Figure 9: DC Motor w/starter gearhead



Figure 10: Steering Control Unit



Figure 11: Two LMD18200 to drive the dc motor

VI. Resources used in the microcontroller and programming

This system consists of four subsystems, as mention earlier, controlled by the MC68HC microprocessor from a user's consol (laptop) to activate different functions of the vehicle.

Four PWMs of the microcontroller were used for driving the braking control system, the acceleration control system, the transmission control system, and the steering control system. Three analog-to-digital converters of the microcontroller were used for reading the potentiometers of the braking control system, the acceleration control system, and the transmission control system. The microcontroller, the motor drivers and other components were mounted on a protoboard, which was attached to the dashboard as shown in Figures 12 and 13.



cut-off switches68HC12BSubsystemsFigure 12: System Control Unit

starter



Figure 13: Control systems in the vehicle

Programming implementation was decided to be in assembly to increase performance and to minimize memory usage. The assembly program accepted keyboard inputs from the user at the consol (laptop). Each keyboard input was evaluated and a corresponding subroutine within the program was called to activate one of the four control systems. Eleven commands were devised to control the vehicle's functions:

- 1. "A" accelerate (depress gas pedal)
- 2. "S" decelerate (release gas pedal)
- 3. "B" brake (apply brake)
- 4. "U" release brake
- 5. "P" move transmission stick to Park
- 6. "R" move transmission stick to Reverse

- 7. "N" move transmission stick to Neutral
- 8. "D" move transmission stick to Drive
- 9. "F" steer left
- 10. "H" hold the current steering wheel position
- 11. "J" steer right

The program did not support multi-tasking, for instance, while the program was performing steering, it could not perform braking or acceleration functions.

VII. Testing results

The vehicle was taken to an empty parking lot for testing. Appropriate authorities were notified. Safety was the issue that we carefully considered. Strict safety protocols were developed and followed.

The control systems were very responsive to the input commands. The vehicle was tested for each of the following motion controls: forward, reverse, braking, accelerating, stop-and-go, and steering. The vehicle was taken back to the lab and minor adjustments were made on it.

The minor adjustments made were on the brake pedal control system, the gas pedal control system, and the transmission control system. On the braking system, the threaded drive rod were made aligned correctly with the brake pedal.

On the gas pedal control system, adjustment were made so that the vehicle's speed would not exceed 10 miles per hour for safety reason. The speed was made to increase in small intervals.

On the transmission control system, the lever was adjusted to be exactly in the Park, Reverse, Neutral, and Drive positions.

In the final testing, the user was able to maneuver the vehicle at a slow pace in the parking lot without any difficulty. A video demonstration will be provided in the presentation.

VIII. Concluding remarks

The project goals were met. The team was able to design a vehicle control system that can take keyboard input commands from a laptop and manipulate the vehicle accordingly in forward, reverse, braking, accelerating, stop-and-go, and steering left and right. During field testing it was learned that trying to drive a vehicle form a keyboard was somewhat difficult and took time to learn. However if the speed of the vehicle was kept less than 10 miles per hour, it could be easily maneuvered around the testing area. Remote control of the car is possible by replacing the laptop interface with wireless interface to the 68HC12.

Some improvements are need. First, the steering response time needed to be shortened if speed was allowed to increase. Second, incorporate real time multitasking so that accelerating (or braking), steering, and transmission control can be done at the same time.

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