AC 2011-2029: USE OF POWER WHEELS CAR TO ILLUSTRATE ENGINEERING PRINCIPLES

Dr. Howard Medoff, Pennsylvania State University, Ogontz Campus

Associate Professor of Engineering, Penn State Abington

Research Interests include Gait Analysis and Friction Characteristics of Human Locomotion

Robert L. Avanzato, Pennsylvania State University, Abington

Bob Avanzato is an associate professor of engineering at the Penn State Abington campus.

Use of Power Wheels® Car to Illustrate Engineering Principles

Abstract

In order to illustrate engineering concepts and increase student interest in engineering as a career, Power Wheels® cars were purchased and provided to student teams in a freshman engineering design course. The teams were asked to “reverse engineer” the vehicles e.g. determine how the power was supplied to the vehicle, examine the transmission, steering mechanism etc. Accelerometers and velocity sensors were also mounted on the vehicles for data collection. Another class of engineering sophomores, majoring in electrical and computer engineering, provided expertise to the freshman design course in the development of control devices, such as an automatic steering and vehicle speed control. The toy car platform was designed to support radio control of vehicle operations and also to allow semi-autonomous operation and vehicle response to sensors (such as an ultrasonic distance sensor) under computer control. This flexibility allows this electric car platform to support a wide range of future experimentation and design projects. Educational resources (lab exercises, team projects) developed to support this activity will be presented.

1. Introduction

Penn State University was awarded an NSF grant ‘Toys and Mathematical Options for Retention in Engineering (Toys ‘N More) in 2008. This is a five year grant extending to 2013. This project is being conducted at the University Park campus, as well as fourteen other Penn State campuses throughout Pennsylvania. The overall goal of the grant is to improve the numbers of students enrolled in retention in science, technology, engineering and mathematics courses, as well as increase retention in these courses/fields.

A Toy-FUN-damentals first-year seminar course has been taught at the University Park campus, and it has ‘proven to increase retention of women in the College of Engineering’. At the Abington campus, we have developed a modified version of this course, using Power Wheels® cars to illustrate engineering principles. Our overall project involves students in two existing courses -- Engineering Design (EDSGN 100-for freshmen students) and a sophomore-level Computer Engineering laboratory course in digital design (CMPEN 275).

This paper will outline the educational outcomes and contributions of each class in the analysis and modification of the Power Wheels® vehicle and also describes the collaboration between the two courses. The value of the Power Wheels® platform as an education tool will also be presented, and laboratory and projects will be described.

2. Engineering Design Course Integration

Our educational objectives in this project were to illustrate engineering principles through ‘reverse engineering’ of an existing product, require students to become familiar with instrumentation used to measure fundamental dynamic variables (position, velocity and acceleration), design a remote control operating system (forward/backward), and to control steering of the vehicle. The data collected by the on board instruments was analyzed and used to illustrate the relationship between position, velocity and acceleration of the straight line motion of these vehicles. Since this project was to be implemented by two separate classes, another goal was the increased interaction between these groups of students. One group was second year students who are predominately electrical or computer engineering majors, and the other group was first year students who have not yet chosen their engineering major. This interaction could assist the first year students in choosing their major.

The freshman engineering design EDSGN 100 course meets six hours per week for fifteen weeks and is typically the first ‘Engineering’ course taken by Penn State engineering students. The course objectives are to allow the students to become familiar with typical graphical communication procedures used in industry, including manual and computer aided design. Engineering test methods (data collection and analysis, presentation of results and report writing) are included. A series of designs in which teams of students will design, test and build a variety of engineering projects are required. In this specific course, the Power Wheels car was a major design project. In general, the design project varies among instructors and has included design of autonomous robots, design of a children’s playground, design and manufacture of a weighing system etc.

The fall 2009 EDSGN class was broken up into teams of four students each. Each team received one unassembled vehicle (cost $200). They were required to document the individual parts, and draw (using AutoCAD or Solidworks) selected components, as well as the completely assembled vehicle. Design of the drive train, including transmission gearing, and the steering system, was part of the documentation. The assembled vehicle is 44” long, 24” wide and 24” high, and weighs 40 lb. The vehicle normally operates with the driver depressing the ‘gas pedal’ which causes the battery powered motor to drive the rear wheels forward (or backwards by means of an internal switch). The steering is controlled manually by the driver, with a steering wheel connected to a mechanical linkage system at the front wheels. After assembling the vehicle, student teams were asked to modify the steering system to require the vehicle to only move in a straight line.

The teams were then given instrumentation to measure position, velocity and acceleration of the vehicles. These instruments (PASCO [1] position sensors, accelerometers and data loggers) were mounted to the vehicles by the teams. These activities generally required six to ten hours for completion (includes assembly of vehicle, ‘fixing’ steering, familiarization with and mounting instrumentation).

Initially the vehicles were run on an inside surface (vinyl tile). It was found that the traction between the surface of the tires (hard polymeric material) and the smooth vinyl tile resulted in the vehicles ‘spinning their wheels’. Teams then increased the traction of the tires on the vinyl surface by the use of rubber tire inner tubes or 'traction tape', which increased the traction of the tires sufficiently to allow the vehicles to achieve their maximum performance on the vinyl surface. The vehicles were then run on a level straight course, with an asphalt surface. Data gathered from these runs included position and acceleration of the vehicles. These data were then imported into an Excel file where appropriate plots were generated. Emphasis was placed on the relationship between the position, velocity and acceleration data and graphs. Comparisons between the slope of the position vs time graph and the velocity vs time graph, as well as the slope of the velocity vs time graph and the acceleration of the vehicles were noted.

Figure 1. Vehicle running on asphalt surface.

Figure 2. Top view of vehicle showing data logger in rear and speed sensor on hood

Figure 3. Front view of vehicle showing position sensor mounted on hood.

During the fall of 2010, the EDSGN students designed and implemented an assembly to allow radio control of the steering. A servomotor was used to drive the mechanical steering system. An example of a completed steering assembly is shown in the figure below in Figure 4.

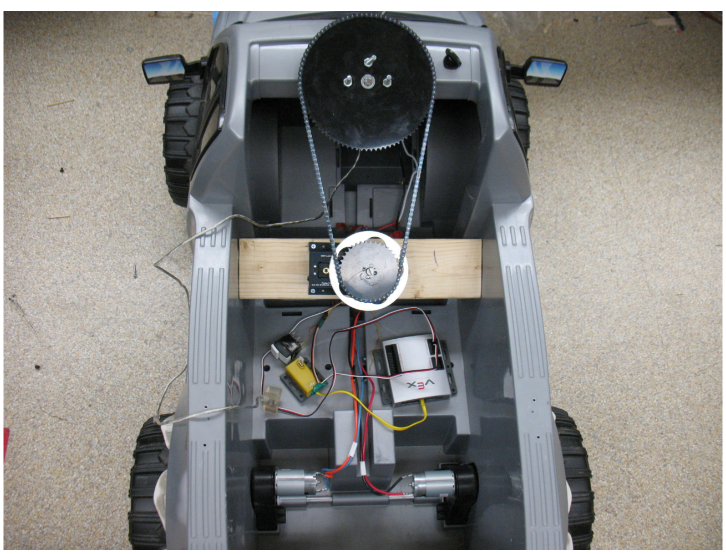

Figure 4: Servomotor-controlled Steering Mechanism

This project fit into the general EDSGN 100 course goals by allowing students to assemble a vehicle, modify the design, communicate with student peers, use engineering principles to measure vehicle performance parameters, and become familiar with data collection and analysis. At the end of this project, the teams were required to write a report including all pertinent information.

3. Computer Engineering Course Integration

Students enrolled in a sophomore-level introductory digital design laboratory course collaborated in the Power Wheels® project. This laboratory course traditionally covers basic digital circuit design using integrated circuits, hardware construction and debugging techniques, and instrumentation. For this particular course in fall of 2009, the objectives of this NSF project were to analyze and document the existing circuitry of the Power Wheels® car and to convert the system to operate under remote control. Secondly, the results of this conversion would need to be effectively communicated to the freshman students in the engineering design course. The radio control would be limited to forward and reverse motion of the vehicles (fixed steering). The forward and reverse speed control would allow students in the engineering design course to perform crash studies and also to record data.

A key result for the digital design course students was to fully document the step-by-step conversion procedure on a single Power Wheels® car so that students in the engineering design course would be able to make conversions of the other 4 vehicles independently. Approximately 15 students from the digital design course were involved in this fall 2009 collaboration effort. Students enrolled in this class are typically electrical engineering and computer engineering majors. The lab course meets one per week for 2 hours over a 15 week semester, and several lab sessions were devoted the Power Wheels® car conversion and communication of the circuit and system functionality. The digital design students successfully completed the circuit modifications and also created a set of procedures which allowed the engineering design students (generally freshmen) to successful convert the remaining four vehicles. The digital design students were also able to demonstrate the operation of the converted Power Wheels® prototype to the freshman design course (EDSGN 100) and field questions. In the fall of 2010, the CMPEN students provided support to the EDSGN students for the control circuitry for the servomotor-controlled steering mechanism. Additionally, CMPEN students wrote software to integrate a sonar sensor to the speed control of the vehicle to create a semi-autonomous obstacle avoidance system. That is, the car could be operated under radio control, but if the vehicle was too close to an obstacle, then the software would stop and reverse the motors momentarily to avoid a collision.

The materials necessary for the vehicle conversion process included a hobby-grade electronic speed controller to control the forward and reverse operation of the two DC motors which propelled the Power Wheels® car. A VEX microcontroller [2] transmitter, and receiver were employed to provide the radio control operation. The electronic speed controller (ESC) was interfaced to the controller. The VEX equipment (which is designed primarily for mobile robotics projects) was chosen because it provides the potential to add software control for future projects. This improves the overall value of the vehicles as educational tools. A variety of sensors and actuators can also be interfaced with the microcontroller. Using this solution strategy, the Power Wheels® electric cars can be operated in strictly radio-controlled mode (teleoperated) or can be programmed for semi-autonomous or fully autonomous operation. The cost for the speed controller (Goat Crawler) was approximately $120 each and the VEX controller along with R/C equipment and sensors was approximately $400 per vehicle. The software used in this project was EasyC (C programming language).

The circuits for the existing Power Wheels® electric cars (prior to conversion) and the block diagram for the radio-control version (after conversion) are shown below in Figures 5 and 6 below.

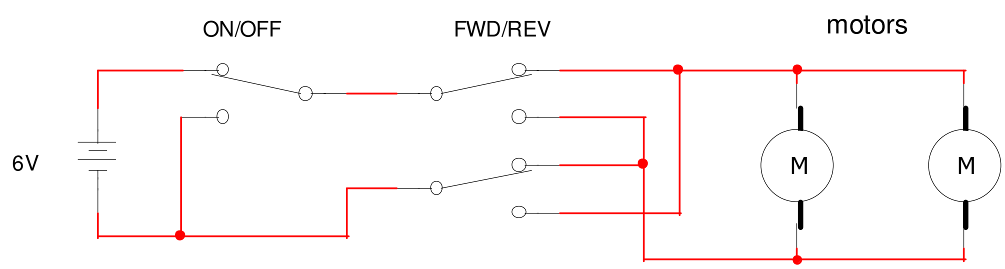

Figure 5. Original Power Wheels® Speed Control Circuit

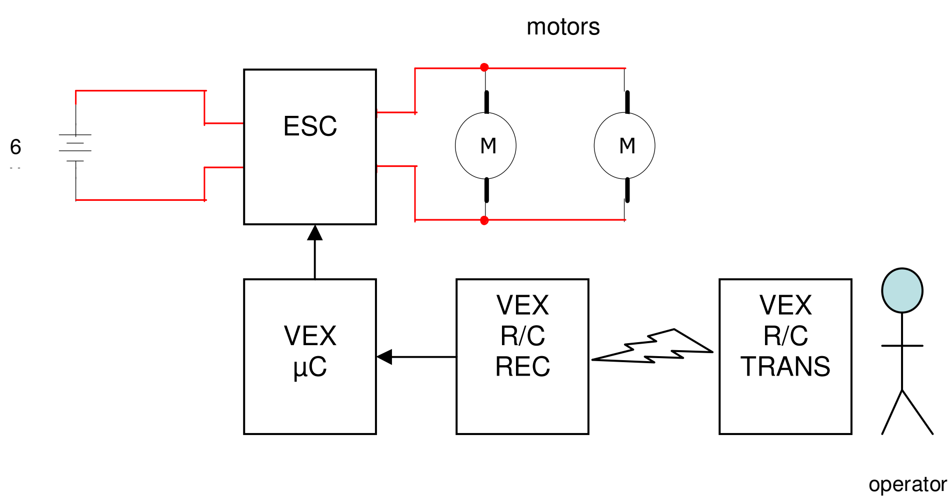

Figure 6. Modified Radio Control Circuit Block Diagram

Figure 7 shows a picture of students taking measurements with the Power Wheels® vehicle. Figure 8 is an example of an image that was included in the step-by-step instructions developed to aid the freshman engineering students in the circuit conversion for speed control.

Figure 7. Students modifying Power Wheels® vehicle

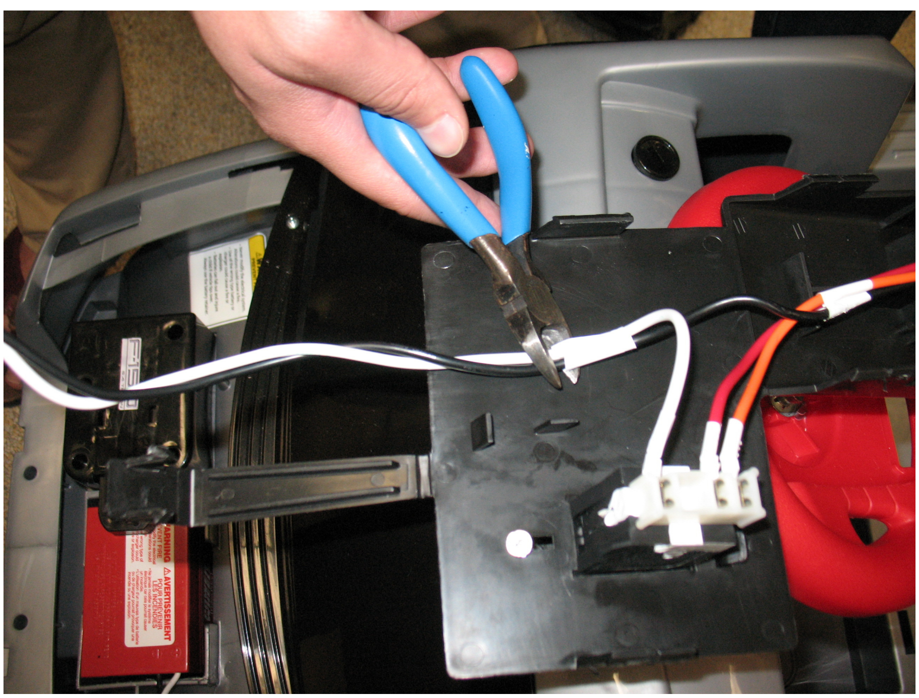

Figure 8. Image from Step-by-Step Instruction Manual

This project introduced the engineering students in the digital design course to basic analysis and design of electrical circuits, switches, instrumentation, motors, and microcontroller interfacing. Perhaps more importantly, students were required to effectively communicate with student peers and provide expertise and technology solutions. The interaction with peers was perhaps the most motivating aspect of the project and the students approached the collaboration with great enthusiasm.

4. Summary and Conclusions

The table below contains a summary of the lab projects that were developed and successfully completed in the 2009-2010 period to support the Power Wheels engineering design project. (The laboratories and project description will be made available to other educators.)

Lab	Title (description)	Course participation
1	Assembly of vehicle	EDSGN
2	Reverse Engineering of Vehicle (includes investigation of gearbox, steering torque, CAD drawings)	EDSGN
3	Conversion to Radio Control Speed Controller (wiring, speed controller, microcontroller; circuit diagrams; user manual)	CMPEN & EDSGN
4	Position and Velocity Sensor (sonar sensor; traction studies)	EDSGN
5	Force Plate Studies (vehicle collision; bumper design)	EDSGN
6	Steering Mechanism Assembly and Control (servomotor; mechanical gear assembly; microcontroller)	CMPEN & EDSGN
7	Semi-autonomous Obstacle Avoidance (software; sonar sensor interfacing)	CMPEN

Overall, the students in both courses were asked to engage in reverse engineering, analysis, design, creative problem solving, and effective communication. Most importantly, students from the respective courses collaborated to solve technical problems and achieve design goals. The Power Wheels® car was successfully modified and tested by teams of students and it has been demonstrated that this strategy provides a great deal of flexibility and usefulness as an educational tool. The students have responded in a very positive manner to this semester-long project and we plan to continue development and collaboration in future semesters. We hope that the collaborative educational approach, the description of the Power Wheels® platform, and the developed laboratory experiences will serve as a resource to other educators interested in enhancing undergraduate education and promoting interest and retention in engineering careers.

5. References

[1] PASCO website: http://www.pasco.com/
[2] VEX Robotics Design System website: http://www.vexrobotics.com/contact

6. Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. (0756992). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.