Active Steering and Torque Vectoring for Electric Vehicle

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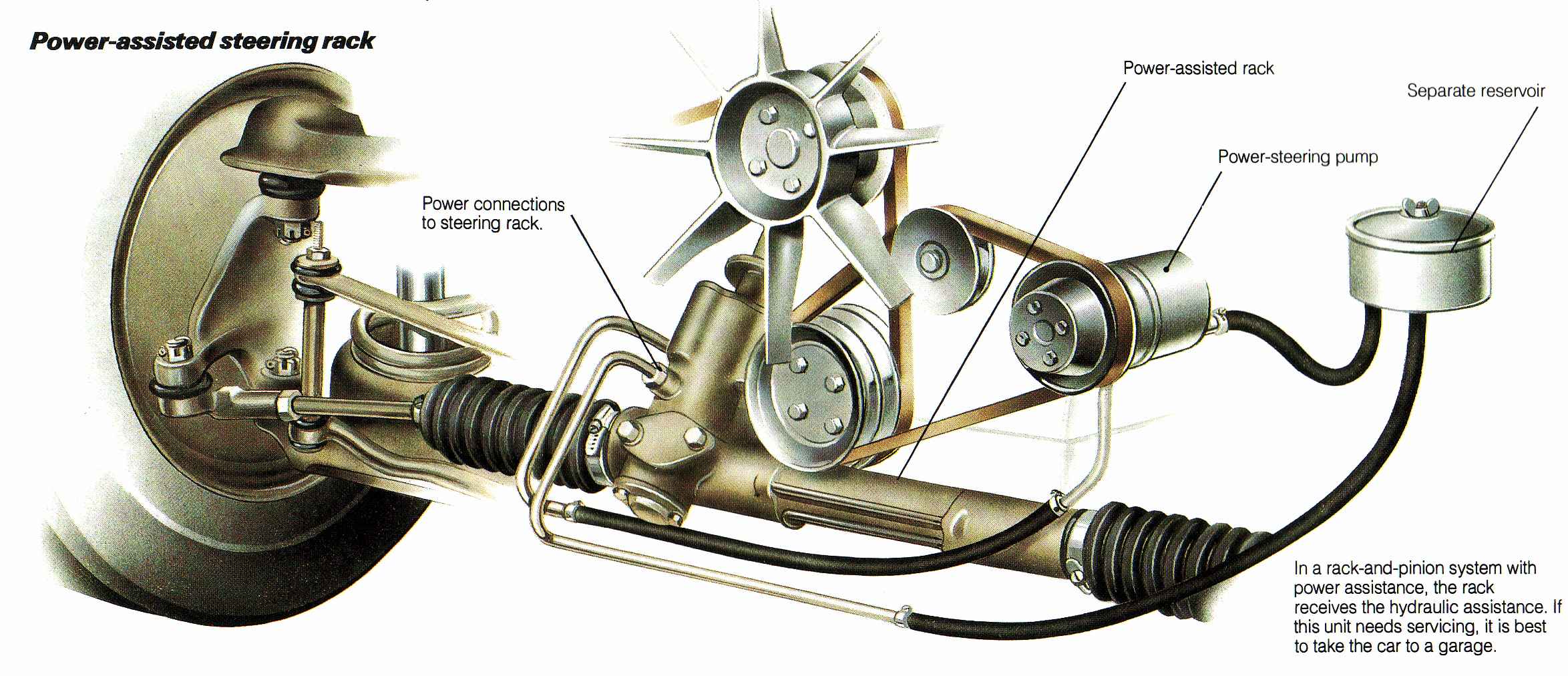
1. Problems

The Society of the development of alternative energy has been at the forefront of University of Missouri’s student design team. We have been developing Solar Cars throughout the 90’s. Early in 2000, we shift our focus to develop energy efficient urban vehicle. We were using Hydrogen Fuel Cell as an energy source. We have won the First and Second place in Shell Eco-Marathon Americas, competing with hundreds of student teams from Canada, Brazil, Mexico, etc. Last year, we have developed our first battery electric vehicle. The car made it to the track but it did not finish the race.

The reason we are doing the development is because the needs of human mobility. People need to go to one places and another at their own comfort and ease. However, the supply of fossil fuel is going to be depleted if we rely on that. Moreover, pollution from fossil fuel combustion is dangerous to human health, especially in the urban area. The pollution will also disturb the ecological balance of the nature. In a greater scale, pollution from fossil fuel will affect the climate of the earth because of the greenhouse effect. In addition to that, more and more people are moving to urban area. The needs for efficient mobility will be a necessity in today’s time.

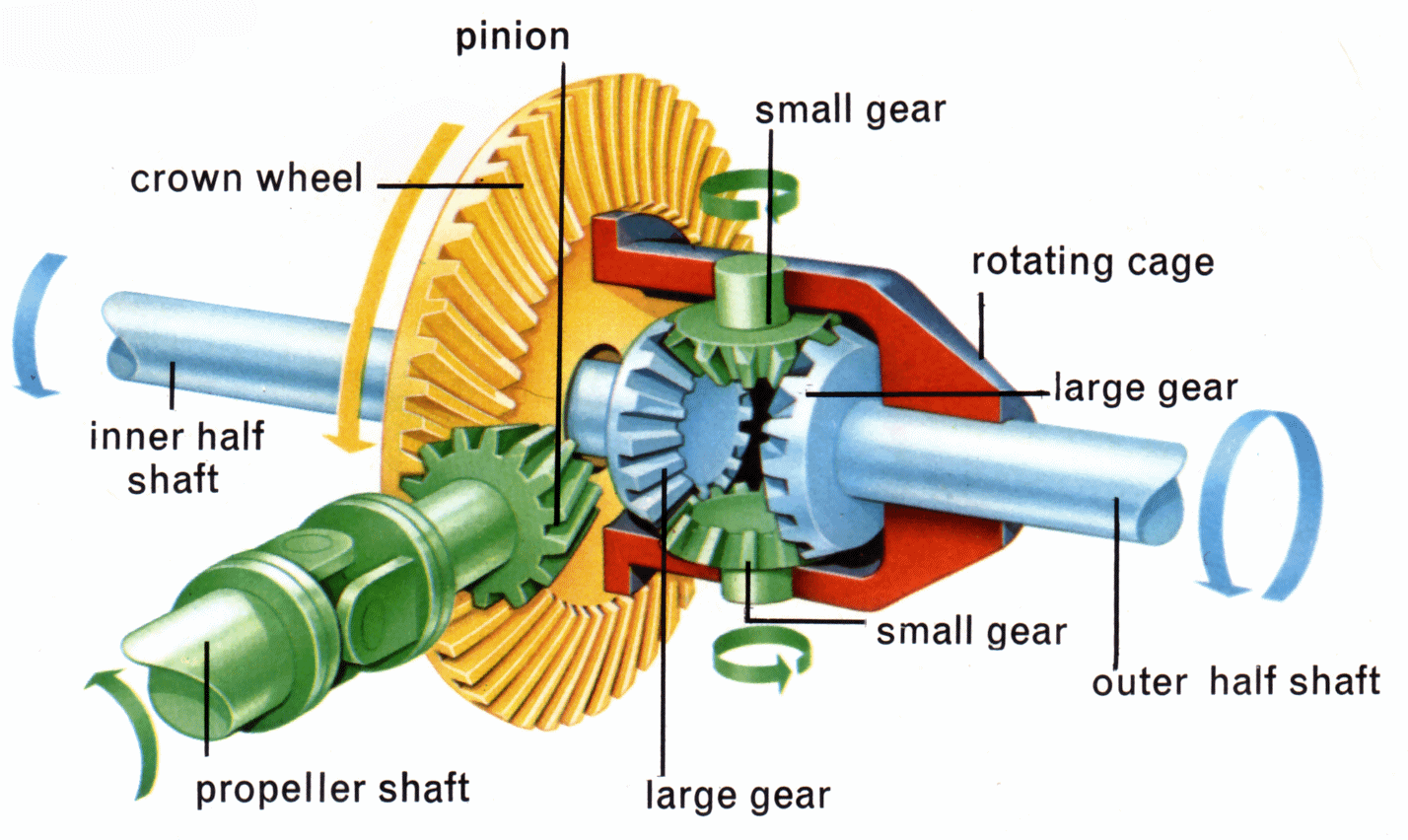
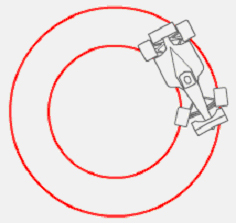
In order to mitigate those problems, we need to figure out an alternative fuel source to fossil fuel. One of the solution is electric mobility. The electrical energy is converted to mechanical energy to propel the vehicle forward. The fuel source can be many things such as hydrogen fuel cell, battery pack, and solar panel. Electric mobility does not produce harmful waste pollution as the fossil fuel engine does. It is also suitable for urban commuting which does not have a long range of travel. Even though the energy storage is limited, the system will be able to accommodate short distance commuting around urban area.

In this project, we want to develop a control system that will enable electronic power steering and also electronic torque vectoring. In a regular passenger car, the steering is controlled mechanically either using gears or hydraulic actuators. In gears steering, torque is sourced from human muscle entirely. In some quick maneuver, human muscle will not be able to response a quickly because it requires a lot of torques to turn the steering wheel. Similar to that, hydraulic steering use energy from the combustion engine to drive the pump. Hydraulic pump then pushes the steering arm on the car.



We wanted to use electronic steering because of the energy storage available in the car which is electrical energy. With not so many moving mechanical parts, we can fully control the steering rack using an electric motor.

In another case, a fossil fuel vehicle usually have a device called differential. It splits the torque delivered from the engine to both left and right wheels. This is necessary because when the car is turning, the wheel on the inside and the outside need to spin at different speed.



In electric vehicle however, we do not want to waste energy in mechanical friction between gears. In order to emulate the behavior of a differential, we use the method called torque vectoring. We use two electric motors in each rear wheel so that it can be spun at different speed. Not only achieving the work of a differential, this system also “steer” the car. If we vector the different torque produced in each wheel, we can see the torque will add up to the direction of the car is traveling. That is the reason why this project is called active steering and torque vectoring.

1. Objectives

The objectives of this project is to implement active steering and torque vectoring as a demonstration so that it can be implemented in future prototype electric vehicle. The objectives are as follows:

1. Quick steering response

Steering angle must change immediately after the steering wheel is turned. We need to make sure that the response is also linear to the steering wheel sensor.

1. Differential

According to the steering wheel position, we can determine how much torque is delivered to each wheel.

1. Open / Lock bias control

When the steering wheel is turned, we can determine how much slip each motor is having. A fully open differential will have all the torque delivered to the outer wheel and zero torque on the inner wheel. A fully locked differential will split the torque evenly to each wheel. Thus, each wheel will spin at the same speed. A fully locked differential may be needed if the car is traveling in a slippery surface such as snow and dirt. The surface might have uneven grip. If we leave the differential open, the car will turn to the direction where it is not supposed to go. Thus, we need to lock the differential so that the resulting torques are straight forward to the direction of the car traveling.

1. Brake control

The brake pedal sensor will actuate the pedal actuator. This has to have higher priority than any other actuator.

1. Technical approach
2. Software

Utilizing Raspberry Pi as a computing device, we use Raspberry Pi’s Raspbian OS to control all of the hardware communication and the decision making. This OS is Linux-based so that we can program it in C. Here we will have three modules:

Sensor Module

Processor Module

Actuator Module

1. Sensor module

This module will read from the potentiometer emulating different sensors. The sensors are brake pedal position sensor, accelerator position sensor, steering wheel position sensor, and also differential bias control knob. This is achieved using a four channel analog to digital converter. The ADC will communicate with the module through SPI interface. After reading the data from the ADC, the module will push the data to a named pipe to be processed by the processor module.

1. Processor Module

The processor module will grab data from the named pipe and process it. This determines how much torque is delivered to each wheel based on the steering wheel position. From the brake pedal position data, we will determine if we need to send power to the electric motor because if we press the wheel while pressing the accelerator pedal, we will waste energy. We will use semaphore to determine the access of the accelerator pedal. If the brake pedal is pressed, accelerator pedal output will be set to zero and flag will be set. The accelerator pedal is then ignored. This module is in one process with Actuator module so that all of the readings will be stored inside a global variable.

1. Actuator module

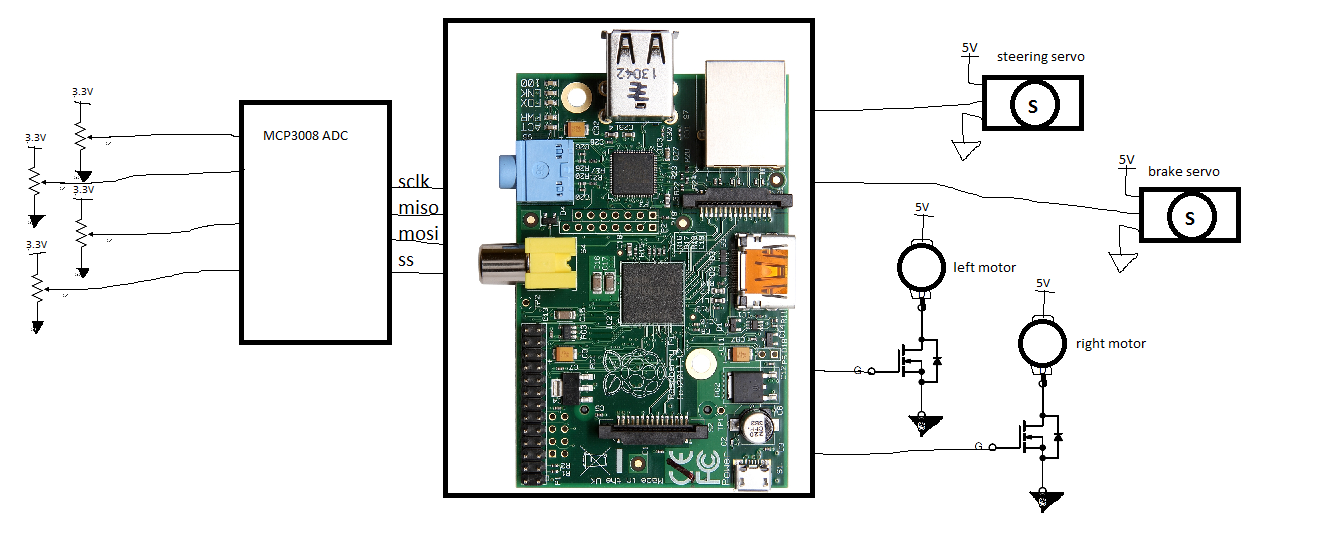
This module will grab the data processed by the processor module. The data is stored in a global variable. This will send PWM value to two electric motors emulating the one in the electric car. This also sends PWM values to two servos. One servo motor is controlling the steering rack and the other servo emulate the works of the brake actuator. Raspberry Pi does not have a built in Digital to analog converter so that we are using RPIO library to generate PWM using Direct Memory Access.

In addition to that, we can utilize Raspberry PI’s multi-core processor to split the tasks.

1. Hardware

Using an ADC, we emulate the work of a sensor using a potentiometer. We are using four potentiometer for steering sensor, brake sensor, accelerator sensor, and open / lock bias control knob. The data is then read by the software. At the output, we have A 360 degrees servo emulating the work of a steering rack. This will point the front wheel to the direction that the car is going. We also use a 180 degrees servo to emulate a brake actuator. Both servos will be controlled using PWM. To control the motor, we are sending a PWM signal to a MOSFET. The MOSFET will then vary how much current is flowing to the motor. The current will determine how much torque will be delivered.

Schematic:



1. Project Management

|  |  |  |
| --- | --- | --- |
| **Time** | **Activity** | **Status** |
| February | Project Conception. | Finished |
| March Week 4 | Gather all the parts necessary. | Finished |
| April Week 1 | Project proposal due, start constructing the hardware, work on sensor module. | On progress |
| April Week 2 | Work on processor module and actuator module. | Not yet started |
| April Week 3 | Test the implementation and troubleshoot it. | Not yet started |
| April Week 4 | Write the report. | Not yet started |

1. Deliverables

From this project, the deliverables will be a working prototype, source code, project report, project proposal, everything available to the public, and a video of how the system works.

1. Cost

Here is the breakdown of the cost of the project. This is just an estimate. Components such as breadboard, capacitors, and resistors and shipping costs may not be included.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Item | Supplier | Qty | Unit Price(US$) | Total Price(US$) |
| Raspberry Pi B | SparkFun | 1 | 39.99 | 39.99 |
| 10K potentiometer | Digikey | 4 | 0.85 | 3.4 |
| 180 degrees servo | Digikey | 1 | 12.99 | 12.99 |
| 360 degrees servo | Digikey | 1 | 13.99 | 13.99 |
| DC motor | Digikey | 2 | 3.19 | 6.38 |
| MCP3008 ADC | Digikey | 1 | 2.63 | 2.63 |
| IRL520 MOSFET | Digikey | 2 | 1.05 | 2.1 |

1. Limitations

This design is for demonstration purpose only. In the real world, the power source will be using a really high voltage battery. The low voltage logic needs to be regulated from that high voltage. The motor control is also much more complicated than this. Moreover, the system must be tested for vibration and environmental stress to be applied in a road legal cars. For demonstration and prototype purpose, this system is sufficient to emulate the working of a torque vectoring system.

1. Conclusion

After explaining the design of the systems, there are many advantages of using this systems. We are not only electrifying the mobility, but we add intelligence to it. Some of those are:

1. Reducing pollution from fossil fuel
2. More efficient mobility
3. Increasing vehicle performance in terms of handling, turning agility, and acceleration.

After finishing this project, we hope that this system can be implemented in a student vehicle competition such as Shell Eco-Marathon, Formula SAE Electric, Formula Hybrid, and so on. In a long term, this system is a stepping stone to a higher level design in automotive industry.