E90 Proposal: STEER-BY-WIRE

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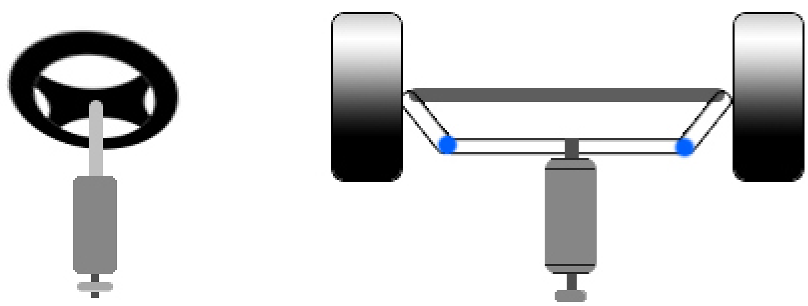


ABSTRACT

I propose to build and test a steer-by-wire system that will demonstrate that the physical connection between the steering wheel and the wheels of a car can be eliminated in favor of a more robust system that allows for easy modifications. The system will mimic regular power steering and the driver will feel no difficulty adjusting to the new system and yet will benefit from the many advantages of the system.

1. INTRODUCTION

Today's automobiles benefit more and more from the many uses of electronic systems. The integration of a steer-by-wire system can enhance these systems in many ways. In particular, the handling and the safety of the cars can be improved significantly. Since a steer-by-wire system is easily modifiable, different drivers will be able to adjust the system to accommodate their styles and this will enhance handling. I addition, disabled people and the elderly will benefit immensely from steer-by-wire because they will be able to situate the steering wheel to meet special needs. Traction control systems are very closely tied with driving safety and they can be enhanced with steer-by-wire vastly. For instance, if the car starts sliding and the driver loses control of the car, steering into the wrong side, the system could interfere and take over controls. Very sudden changes in steering could also be avoided with such a system.

Since there are virtually no physical connections between the steering wheel and the wheels, a steer-by-wire system can be implemented on different cars easily. The steering wheel could be placed on either side of a car (or anywhere else). Both of these improvements would reduce costs of production and allow a wider range of designs.

2. Technical Discussion

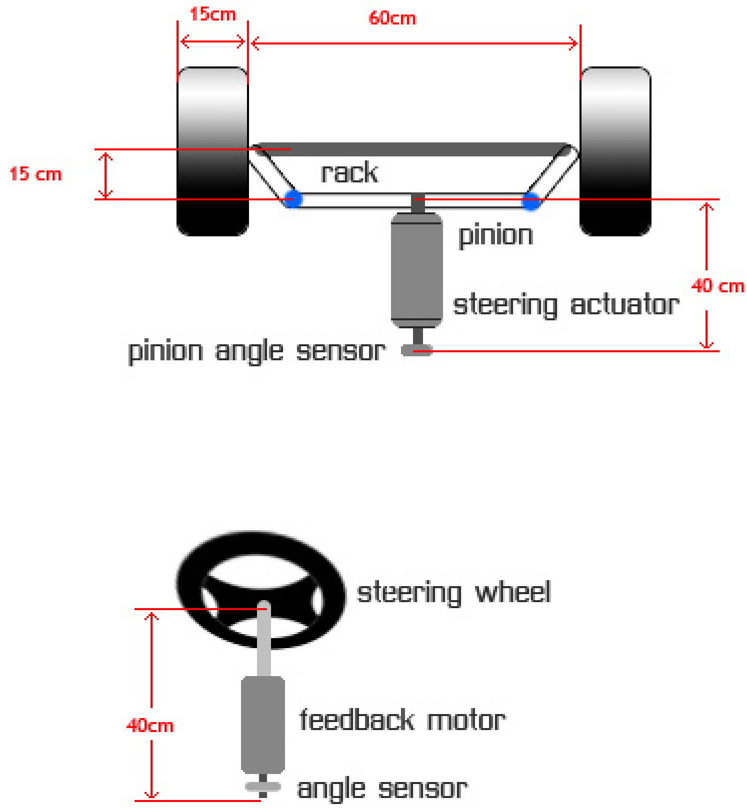


Figure 1. Physical components of the steer-by-wire system

This project will include the building of the physical steer-by-wire system and its control. In the first phase, the system shown in fig 1 will be built. The second phase will consist of coding the control algorithms using MATLAB® and designing and implementing the digital to analog and analog to digital components of the system. Finally the system will be tested and improved for accuracy and precision.

2.1 Rack, pinion and the Ackerman steering

For stability purposes, automobiles turn around a center of rotation which means the front wheels of the car have different angles when they are turned. If the front wheels stay parallel to each other at all times, one of the wheels tends to slip and this creates a lot of danger. On a rainy day or an icy road this could potentially cause the car to spin. This problem is avoided using the Ackerman steering principle seen in fig 2. Ackerman's principle is a method of aligning wheels such that the front wheels of a car are at different angles. If we think about a car going around a circle, we would expect the wheels away from the center of the circle to cover a longer distance. Since both front wheels of the car have to be at the same speed (same driveshaft is used for both wheels) one of the wheels has to slip. Ackerman's principle is an attempt to minimize slippage.

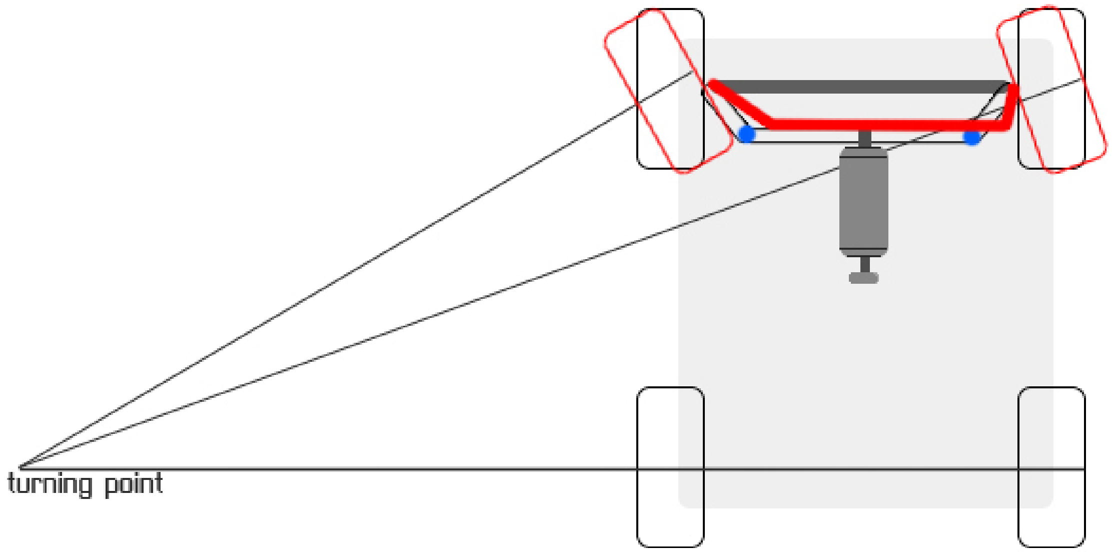


Figure 2. Ackerman steering principle

An unparallel configuration of the tires stabilizes the car and minimizes slippage. In order to implement such a system, the rack will be built with flexible joints and ball bearings as seen in fig 3.

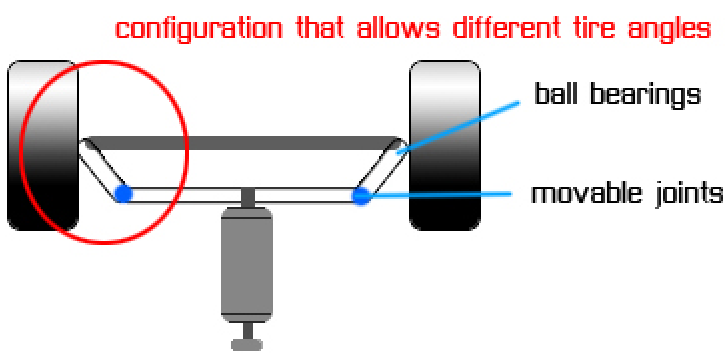


Figure 3. Configuration that allows the Ackerman steering principle

The servo motor (steering actuator) will provide the force to move the rack and turn the wheels. There will be a rotary sensor that detects the pinion angel. This sensor will be very precise to sense even the smallest changes in rotation. (There are commercially available sensors that measure the absolute angle with resolution $\sim\pm 0.1^\circ$ and accuracy $\sim\pm 0.4^\circ$) At high speeds accuracy can be very important since a slight deviation will have a huge impact in the direction of the car. Although the driver can compensate for some of the discrepancies, ideally the car should go straight when the steering wheel is at rest.

2.2 Steering Wheel and Feedback

The steering wheel will have an angle sensor and a servo motor that will provide resistance to steering. The configuration can be seen in fig1. Controller for the feedback motor will acquire input from the sensor attached to the pinion and will mimic power steering. When the driver steers right or left he will feel a resistance and it will depend on the angle of the pinion and the speed of the car. The only stable configuration (configuration for which the driver will feel no force from the steering wheel) will be when the steering wheel is at rest and the wheels are straight. So, if the driver has completed a turn and lets the steering wheel go, the wheels will turn to their straight configuration while the steering wheel will accordingly turn to its resting position, just like a regular steering wheel does.

Feedback to the steering wheel is an essential component of this system. Without feedback, the car would feel like a remote controlled vehicle and the driver wouldn't feel anything even if the wheels all of a sudden turned in one direction or hit a stone that caused one of the wheels to veer away.

2.3 Rolling Platform.

The wheels will stand on top of a rotating cylindrical platform. This rotation speed of the platform will be adjustable in order to test different speeds and its effect on the control system. It will also provide support to the wheels, and different weights of the car will be simulated by strengthening or loosening the contact with the wheels.

2.4 Control Software and Circuitry

I am planning on using MATLAB® to control the system. It is possible to control the system using an analog circuitry, however, this would not allow for easy modifications and considering the technology today's automobiles have, it makes more sense to use a digital control system.

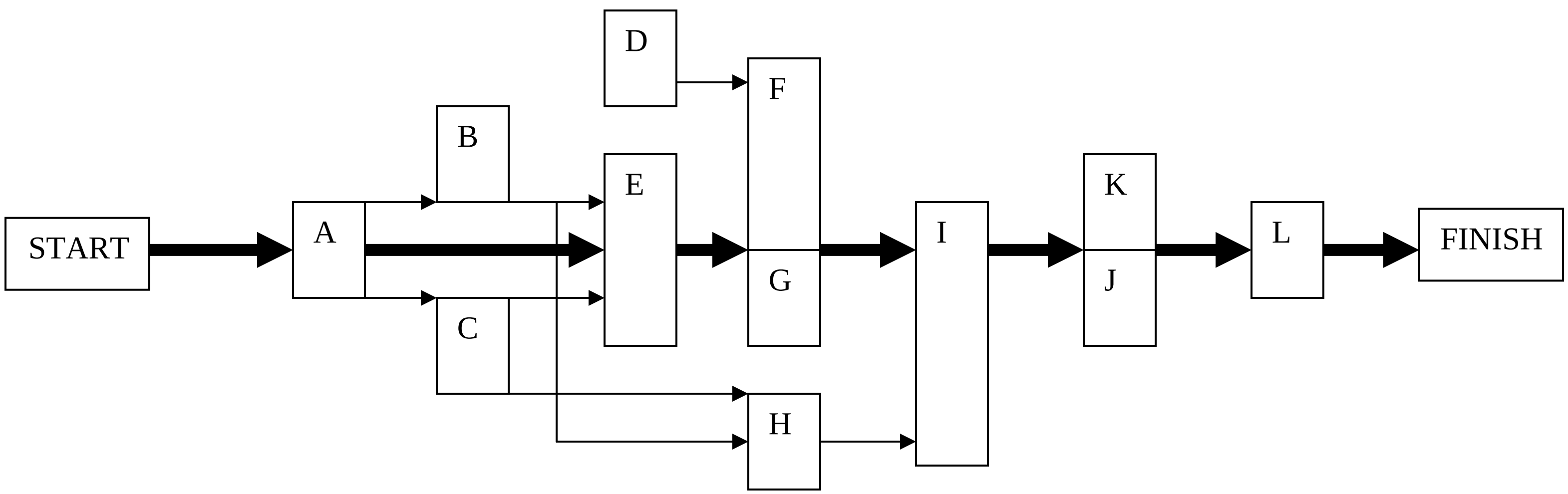
The data acquisition system will be helpful in providing A/D and D/A conversions and extra circuitry that requires higher currents and voltages required to drive the servo motors will be designed. I have worked with MATLAB and the data acquisition board and will use my background in control theory to implement this system.

3. PROJECT PLAN

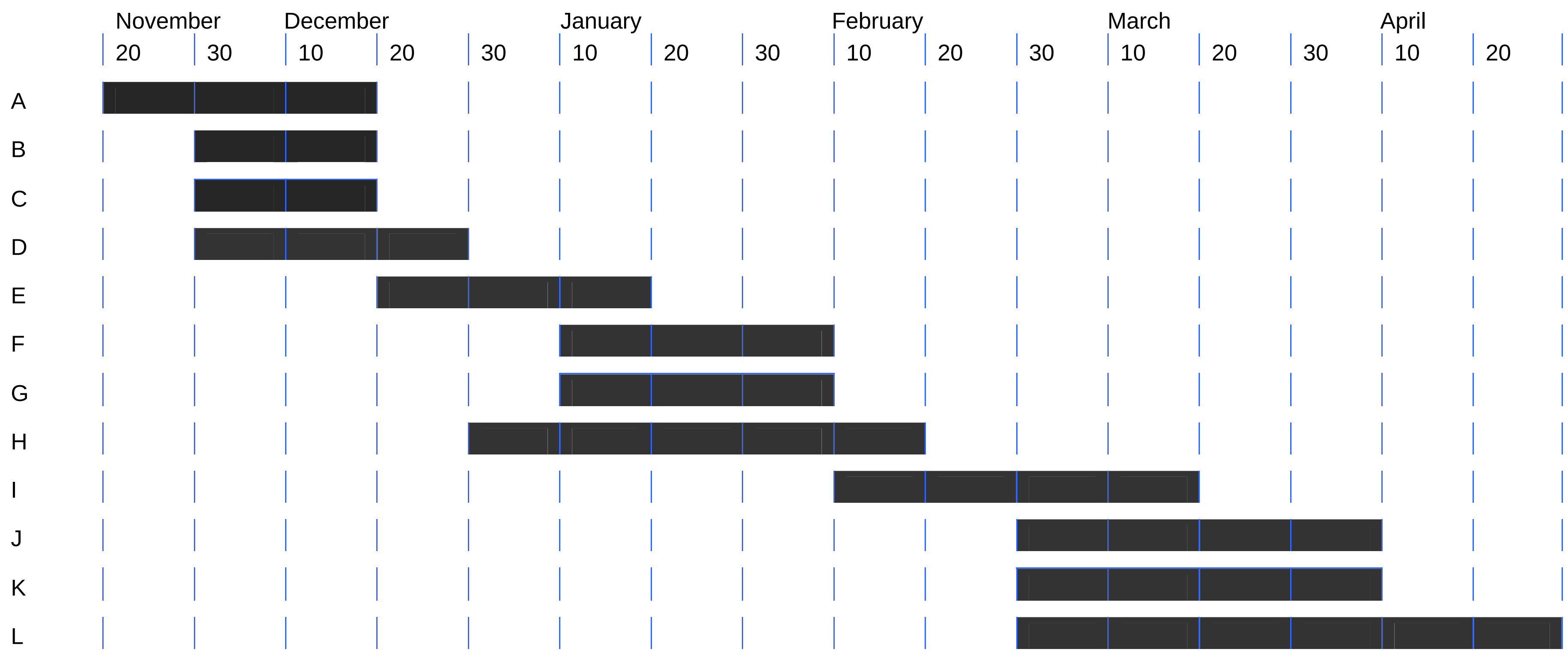
The following table includes the major parts of my project.

	TASK	SUCCESS IS WHEN
A	Building rack, pinion and the wheels	The physical components are built and are robust.
B	Choosing and buying sensors for pinion and steering wheel	The sensors are attached to the pinion and are working as expected.
C	Choosing and buying (possibly different) servo motors for the pinion and the steering wheel.	The servos are tested for power, torque and force requirements.
D	Building rotating cylindrical platform	The platform can rotate at variable speeds.
E	Combining the servo motors with their relative parts	The servos and the sensors are put in the system and they can move the system into desired configurations; they are able to turn the system right or left to certain angles and the sensors are consistent with motors.
F	Finding transfer characteristics of steering wheel	Step and impulse responses are measured and their validity is confirmed.
G	Finding transfer characteristics of the pinion and rack	
H	Designing and building circuitry that will assist data acquisition	The analog to digital circuitry provides accurate inputs to the computer and the digital to analog circuitry provides the correct signals sent by the computer. A wide range of inputs and outputs will be tested.
I	Coding control algorithms	Depending on the transfer characteristics of the steering wheel, the stability of the system is confirmed using techniques from Control Theory. Given sample inputs, the algorithms should provide the desired output.
J	Testing steering wheel feedback control	If the algorithm can put the system in certain conditions. For instance, if the wheels are turned, the steering wheel provides a force in the opposite direction.
K	Testing rack and pinion control	
L	Combination of both parts and extensive testing	Another user can confirm that the system feels like an ordinary car.

Critical Path for Project



GANTT Chart for the Project



4. BUDGET

A lot of the materials used in this project will be obtained from the labs in Hicks and main components will be built in the machine shop. The software will also be made available by the department. Main expenses will be the servo motors and sensors. Here are the approximate prices of the equipment:

2 x servo motors ~$100 each	= $200
2 x angle sensors ~$20 each	= $40

With miscellaneous expenses, I am expecting the project to cost about $250.