DEVELOPMENT OF STEER-BY-WIRE ELECTRONIC AUTOMOTIVE STEERING SYSTEM

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Abstract

Conventional steering systems in the automobiles have mechanical connection between the steering wheel and the road wheels which leads to the limitations for realistic vehicle control and automation. In the modern EVs that are being developed, existence of mechanical links in the steering system is a hindrance for automation towards the implementation of driver assistance features such as lane keeping assist and collision avoidance and other smart driving features. Steer-by-Wire refers to an electronic automotive steering system in which the mechanical connection between the steering wheel and the road wheels is replaced by an electronic link. Compared to traditional steering methods, Steer-by-Wire presents many advantages in the areas of vehicle functionality, architecture and human interface. It also improves the vehicle stability, vehicle driving performance, comfort and maneuverability. This is because the Steer by wire mechanism is based on position sensor and Electronic controller unit (ECU) using servo drives.

Currently, in the EVs the steer by wire is implemented just by removing the steering column and disconnecting the steering wheel and the steering mechanism at the front axle. However, all the mechanical links in the Ackermann steering mechanism exists. Further, more research is happening towards the development of Steer-by-Wire electronics steering system on passenger vehicles by completely eliminating the mechanical links i.e Ackermann steering mechanism by having independent control of the both the front wheels satisfying the condition for perfect steering.

In the present project, an attempt has been made to visualize and demonstrate the working of an electronic Steer-by-Wire system. A lab setup for the Steer by wire system is developed and fabricated to demonstrate working the steering system using geared DC motors with simple electronic controls eliminating the mechanical elements viz. Ackermann steering mechanism, steering column, Rack and pinon, Tie rods etc. The wheel positions about the King pin are controlled simultaneously using a variable power supply that has predefined voltages calibrated for the various angles of rotation of the wheels satisfying the condition for the perfect steering.

The knuckle arm positions about the king pin for both the wheels are controlled by two independent simple lead screw and nut setup. Both the lead screws are driven and controlled by two directly coupled DC geared motors. Further, as the knuckle arm being connected to the nut, the position of the nut relative to the lead screw will decide the steering angle. Both the geared motors are controlled by the predefined power supply pulses that results in different angles of rotation for both the lead screws which ends up with different steering angles for the inner and outer wheels during steering. This lab set-up developed enables easy understanding and demonstrating the operation of Steer-by-Wire system eliminating completely the physical connectivity between the driver and the front axle.

Keywords: DC(Direct current)Motors, Motor driver, Knuckle Arm, Kingpin, Lead screw

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1. Introduction

In conventional steering system steering column, universal joint and rack and pinion is used to change the vehicle direction. The rotary motion of the steering wheel is transferred to the rack and pinion through the steering column which includes the universal joint. As the more mechanical linkages are included in the conventional steering system it obstacle for automation towards the implementation of driver assistance features. The adoption of steer-by-wire which aims to eliminate the physical connection between the steering wheel and the wheels of a car and by using electrically controlled motors to change the direction of the wheels and to provide feedback to the driver. In SBW systems without this mechanical linkage, the steering feedback is achieved by controlling an electric motor (feedback motor) that is attached to the steering wheel. The torque that can be felt by the driver, based on the steering wheel angle and the motion of the vehicle is usually described as steering feedback or steering feel. In SBW by eliminating the steering column if vehicle met with any accident the impact will not be transferred to the steering wheel .But in the real situation, the SBW system is faced many disturbances such as uneven condition of the road and parameter uncertainties of the system. The aim of this study is to develop a demonstrative set-up of steer-by-wire automotive steering system to easy understand the working of steer-by-wire by using the two dc geared motors. To satisfy the perfect steering condition and to control the wheels , wheels has to turn at different angles , to achieve this a code is introduced to change the speed of the dc motors and it is responsible for the angle of the wheels, It also improves the vehicle stability, vehicle driving performance, comfort and maneuverability. Both the geared motors are controlled by motor drives, aurdino and keyboard matrix. A code has been introduced to control the dc motors. the keyboard matrix is responsible the speed of the motor. According to the speed of the motor the length of the lead screw will change and ultimately it is responsible for the turning of wheel.

1.1 Past Studies

The steer by wire system (SBW) is a cutting-edge technology that will be used in the steering system of the next generation of vehicles. Between the steering wheel system and the front wheel system, it eliminates mechanical couplings of the column shaft. This paper's major goal is to emphasis front tyre angle control approach and variable steering ratio application(**Sheikh Muhamad Hafiz,Hairi Zamzuri)**

This essay explores the creation of a PID control strategy for VSBW system wheel synchronization and directional control. Front wheel and steering wheel angles are both controlled by two PID controllers. In order to produce a regulated steering angle, PID controllers use the front wheel tracking error. For the purpose of evaluating the control scheme's performance, the implementation environment is created using the Matlab/ Simulink programme.(**Mohd Zaidi Mohd Tumari)**

In the next generation of automobiles, steer-by-wire (SBW) systems have a chance to take the place of traditional steering equipment. Use of SBW systems will provide a lot of benefits for cruising comfort, driving safety, and environmental protection. The design of the control strategy for SBW systems is addressed in this study(**Manuele**

Bertoluzzo)

A good vehicle's handling characteristics and driver feel are now provided by the suspension and steering. Handling and feel are now software features that may be tailored for each driver thanks to steer-by-wire technology. This article presents a method for designing steer-by-wire suspensions in which geometric design parameters are selected to make the tyre reaction torque about the steer axis very predictable.(**Laws,C. Gadda,S.**

Kohn,P)

The steering systems of passenger cars are classified into three main groups: mechanical steering systems,hydraulic and electro-hydraulic-power-assisted steering systems,and electric-power-assisted steering systems. In this paper, a steer-by-wire technology is used, which eliminates the need for a mechanical connection between the steering wheel and the steering gear.(**A.Emre Cetin, Mehmet Arif Adli)**

1.2 The Existing System

In conventional steering system the inclusion of many mechanical linkages leads to the limitations for the vehicle control and automation. The steering mechanisms which are incorporated with the Ackermann mechanism doesn’t satisfy the perfect steering condition. Due to so many mechanical links it is hindrance for the automation.

1.3 The Proposed System

Steer-by-wire is a automotive steering mechanism which eliminates the physical connection between the steering wheel and road wheel. The steering wheel and road wheels are connected by the electrical link. As more research is going on implementation steer-by-wire. An attempt has been taken to fabricate the demonstrative lab set-up of steer-by-wire to explain the working of steer-by-wire for easy understand.

2. Methodology Used

As of now the more research is going on implementation of steer-by-wire an attempt has been taken and to develop a pure steer-by-wire system by using the two independent dc geared motors to control the wheel position and vehicle

direction.although there are several limitations in system which proposed by us but the main aim is to fabricate a development of steer-by-wire automotive steering system. The methology used for the demonstration is that initially identify the how normal steering/power steering will works and then identify the limitations of the existing system i.e basically a conventional system, then identify the companies which are utilize the steer-by-system and how they are operating the system, and then proposed a system which is completely eliminating the mechanical linkages and satisfy the steering condition. After gathering a detail information about the existing system and the proposed system, a code has been introduced in such a way that it change the wheel positions independently and also satisfy the perfect steering condition. And code is written in embedded C and it is checked in the Arduino ide software and then uploaded into the Arduino uno. And this code has been written in such a way that it give the input variable input voltages to the motor drivers, motor drivers gives the different voltages to the motors. The following figure shows the simple circuit which gives the overall picture of how they connected.

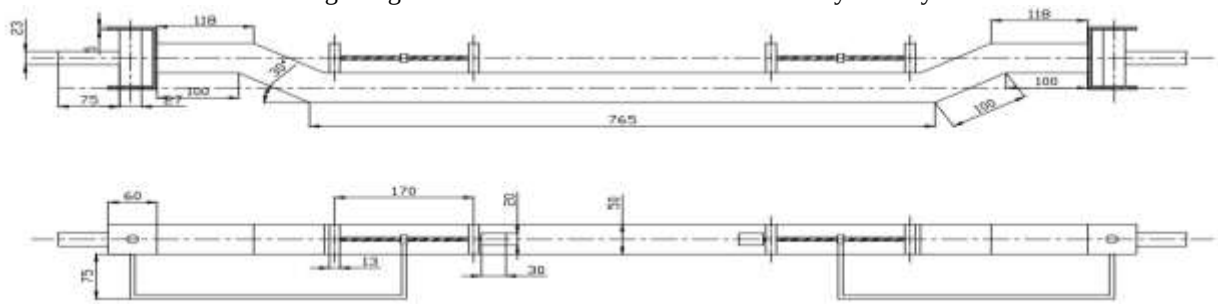
3. Algorithm for The Code

Step-1: START
Step-2: DECLARING THE VARIABLES(PINS)
Step-3: void setup()
Initialization of the variables, libraries used for the code
Step-4: void loop()
This function keeps on repeating the instructions and actively controls and monitors the Arduino
Step-5: if(key==1)
The motor speed changes to 255 and the left wheel takes a turn and comes back to initial position
Step-6: else if(key==2)
The motor speed changes to 200 and the left wheel takes a turn and comes back to initial position
Step-7: else if(key==3)
The motor speed changes to 150 and the left wheel takes a turn and comes back to initial position
Step-8: else if(key==4)
The motor speed changes to 255 and the right wheel takes a turn and comes back to initial position
Step-9: else if(key==5)
The motor speed changes to 200 and the right wheel takes a turn and comes back to initial position
Step-10: else if(key==6)
The motor speed changes to 150 and the right wheel takes a turn and comes back to initial position
Step-11: else if(key==7)
The motor speed changes to 255 and the left wheel turn to certain angle and stop
Step-12: else if(key==8)
The motor speed changes to 200 and the left wheel turn to certain angle and stop
Step-13: else if(key==9)
The motor speed changes to 150 and the left wheel turn to certain angle and stop
Step-14: else if(key==*)
The motor speed changes to 255 and the right wheel turn to certain angle and stop
Step-15: else if(key==0)
The motor speed changes to 200 and the right wheel turn to certain angle and stop
Step-16: else if(key==#)
The motor speed changes to 150 and the right wheel turn to certain angle and stop
Step-17: else
The entire system becomes stop
Step-18: STOP

4. Fabrication

As per the dimensions an axle and knuckle arms are fabricated and assembled by the knuckle pin. Lead screw arrangement is mounted on the axle according to the design which is proposed

The following designs are used for the fabrication of steer-by-wire system:



Steps involved in fabrication of steer-by-wire lab set-up:

- After fabrication of axle and knuckle arms is done, knuckle arms is placed inside the fabricated c-clamps at both sides of the axle by using the knuckle pin or king pin about which knuckle arm and wheel is rotates.
- An lead screw arrangement with flexible coupling is attached on both sides of the axle at the length of 250mm from the both ends of the axle.

- A couple of rigid links is connects the knuckle arm and the lead screw. i.e it connected to the nut of lead screw. The position of the lead screw will decide the position of the knuckle arm.
- Two independent motors are connected to the lead screw arrangement i.e motors are connected to the flexible coupling of lead screw arrangement.
- Both the geared motors are controlled by the different predefined voltages which results in different angle of rotation of lead screw according to the rotation of lead screw ,nut position will change so different angle of rotation of wheels can be achieved. Different voltages are given to the two motors at time by using the simple control unit which consists of the keypad matrix, Arduino, motor drivers and speed controllers etc.

3. Result and Discussions

In steer by wire the wheel angle plays a major role. normally in a car the steering wheel can rotate up to 35 to 40 degrees.The prefect steering mechanism condition is $\cot \Phi - \cot \theta = c/b$,by using this formula we calculate the θ and Φ. C=axle length,B=wheel base .for example if vehicle takes the left turn θ value should be larger than the Φ than only it satisfy the steering condition and it gives the stability and control over the vehicle. If the condition doesn't satisfy there is a chance of vehicle can be rolled. If the condition is θ=Φ then the vehicle is in rest.

The total length of axle is = 1700mm

We can consider the wheel base as twice the length of the axle that is

Wheel base(b) = 1700*2 ==>3400mm

Then

$\cot \Phi - \cot \theta = c/b$

Where c=1700mm,b=3400mm

$\cot \Phi - \cot \theta = 1700/3400$

$\cot \Phi - \cot \theta = 0.5$

Sample calculation:

Left Turn:

$\cot \Phi - \cot \theta = 0.5$

The Φ1(inner angle) is less than θ1(outer angle) it stastify the perfect steering mechanism,

$$\theta_1 > \Phi_1$$

5.3.1 Left turn table:

θ	Φ
8.56	8
14.5	13
18.5	16

Right Turn:

$\cot \Phi - \cot \theta = 0.5$

The Φ1(inner angle) is greater than θ1(outer angle) it stastify the perfect steering mechanism,

$$\theta_1 < \Phi_1$$

5.3.2 Right turn table:

θ	Φ
8	8.56
13	14.5
16	18.5

After executing the code the wheels will turn according to the speeds in the code. Keypad matrix is used to change the direction of the wheels. Total three speeds are included in the code they are 255,200 and 150. if one(high speed) is pressed the wheels will turn to left side and return to their initial position, in the same way two(medium speed), three(low speed) buttons also work with different speeds. If four is pressed the wheels will turn to right side and return to their initial position, in the same way five, six buttons will work with different speeds. If seven is pressed the wheels will turn to left side with a speed of 255 and stop with a certain angle ,star(*) is pressed to return to initial position. The same operation will consider to right side. By using the buttons in the keypad matrix speed and direction of wheels will change. A protractor is fixed on the top of the c-lamp and pointer is attached to that to know the how much the wheel is turning in degrees.

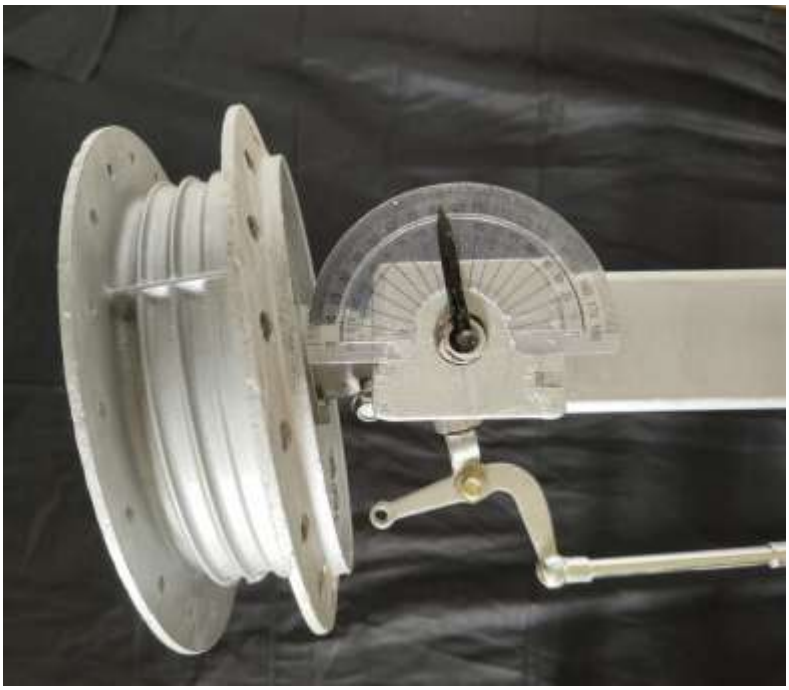
The following diagrams are the different wheel angle positions (in degrees) and speeds :

Left Wheel :

5.2: Right turn left side 1

5.3:Right turn left side 2

5.4:Right turn left side 3



5.5:Right turn right side 1

5.6:Right turn right side 2

5.7:Right turn right side 3

Right wheel :

5.8:Right turn right side 1

5.9:Right turn right side 2

5.10:Right turn right side 3

5.11:Left turn right side 1

5.12:Left turn right side 2

5.13:Left turn right side 3

4. Conclusion and Future Work

As this work is mainly focused on eliminating the mechanical linkages and satisfy the perfect steering mechanism and this work is not focusing on the vehicle stability aspects like steering ratio, steering damping, steering geometry, suspension design and ties etc, there is future scope for working on this aspects to improve the vehicle stability if steer-by-wire is implemented on vehicle. As steer-by-wire system is mainly dependent on electronics if any malfunction in the system could have serious consequences and another challenge is that steer-by-wire system needs redundant system, because the system entirely on electronics there is a need for backup systems, so there is future scope to implement the redundancy system and reliability to the this steer-by-wire.

In conclusion what are the steer-by-wire system that are exists in the automobile industry they are not purely steer-by-wire system they remove the steering column and place the actuators or motors on the steering wheel and control the Ackermann mechanism by using the the motors and electronic control units and the mechanical links still exists. In this work an attempt has been taken to develop a steer-by-wire which is controlled by the dc motors and entirely eliminating the Ackermann mechanism

and other mechanical linkages and also satisfy the perfect steering condition. This work is done by using the dc motors and simple electrical control unit and lead screw arrangement.

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