Automated Four-Wheel Steering System

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***Abstract* - The Automated 4-wheel steering system is a novel concept that uses photoelectric proximity sensors and servo motors to actively steer all four wheels during turning maneuvers, offering two different steering modes: in-face steering and counter-face steering. The system is based on a small hand-made steering column on which four photoelectric proximity sensors are fixed, two for each mode. The sensors are used to detect the orientation and position of the steering column, while the servo motors are used to actuate the wheels in the desired direction. The proposed system is designed to provide two modes of steering, In-face, and Counter-face steering. It is composed of several components, including sensors, servo motors, micro-controller, and control circuitry. The results show that the system can provide accurate and efficient steering control in both In-face and Counter-face modes, with the use of proximity sensors and an accelerometer sensor. The future scope includes developing new and more cost effective & efficient steering systems, improving comfort & stability while steering, and integrating the technology into various automotive applications.**

***Index Terms*: In-Phase and Counter-Phase steering, Proximity sensor, automated 4-wheel steering system, efficient, automotive.**

1.INTRODUCTION

The automobile industry is constantly evolving, with new technologies being developed to improve safety, efficiency, and overall driving experience. The automobile industry has experienced tremendous advancements in technology over the past few decades. With the introduction of advanced driver-assistance systems (ADAS), vehicles have become safer, more efficient, and more convenient to drive. One of the latest innovations in the automobile industry is the automated 4-wheel steering system One such technology is the Automated 4-wheel steering system, which aims to enhance vehicle maneuverability and stability by implementing a rear-wheel steering system. The importance of this research lies in the fact that 4WS systems have the potential to revolutionize the automotive industry by providing enhanced vehicle performance, improved safety, and increased fuel efficiency. The use of an automated 4WS system in vehicles has been shown to be highly effective in reducing the turning radius and improving stability, resulting in better maneuverability and control over the vehicle, improving vehicle handling and safety.

This paper presents an analysis of the working principle, PROTOTYPE design, and implementation of the automated 4WS system. The photoelectric proximity sensors and an accelerometer sensor to control the rear and front steering mechanisms respectively. This automated 4WS system is designed to provide two modes of steering, namely, In-face and Counter-face steering. In-face steering involves the rear wheels turning in the same direction as the front wheels, which results in better stability at high speeds and improved lane changing. Counter-face steering involves the rear wheels turning in the opposite direction to the front wheels, which results in a smaller turning radius and better maneuverability. The findings of this study have important implications for the automotive industry and suggest that the adoption of 4WS systems in vehicles could lead to significant improvements in vehicle performance and safety. The improved maneuverability and stability provided by the 4WS system could help reduce the risk of accidents, especially in situations where sudden maneuvers are required. It also led to improvements in fuel efficiency, as vehicles would require less steering input to navigate turns and corners. This could result in significant fuel savings, especially for commercial vehicles that are required to navigate sharp turns and corners on a regular basis.

2. LITERATURE SURVEY

A. *Design and Simulation of 4 Wheel Steering System*

The paper discusses the limitations of standard 2-wheel steering systems in vehicles, where the rear wheels do not actively participate in steering. It highlights the advantages of 4-wheel steering systems that allow the rear wheels to steer, resulting in better maneuverability and control at different speeds and driving conditions. The abstract also presents an innovative 4-wheel steering design that can change the steering of the rear wheels in-phase and counter-phase, depending on the turning and lane-changing conditions of the front wheels. The design is claimed to reduce the turning circle radius of a sedan by 64.4%, from 5.394m to 1.92m, based on calculations using a Honda Civic as a standard car. The resulting steering ratio of 8.177:1 is expected to enhance the maneuverability and control of the vehicle, even at high speeds. Overall, the abstract provides a concise summary of the advantages and features of the proposed 4-wheel steering system design, which can be useful for researchers and practitioners in the automotive industry.

B. Four-wheel steering mechanism - review

This paper states that the Four-wheel steering is a mechanism used in light motor vehicles to enhance maneuverability. Unlike conventional two-wheel steering systems, it allows the rear wheels to rotate in the same or opposite direction as the front wheels, enabling the vehicle to perform in-phase, counter-phase, and zero rotation modes. This system can reduce the turning radius of the vehicle by up to 30%, resulting in a reduction in understeer and oversteer. The front rack is connected to a selector box at the rear, which allows for easy mode selection through a lever. In counter-phase mode, the vehicle has a reduced turning radius, while in-phase mode allows for a sliding motion.

C. Four Wheel Steering System for Automobiles

The Author describes a modification to the steering system in vehicles, where a new type of steering mechanism allows for steering over all four wheels instead of just two. This modification provides greater comfort to drivers when making turns or changing lanes. The system offers three different modes of operation depending on the situation. In summary, the abstract highlights the benefits of the modified steering system in terms of driver comfort and maneuverability.

D. Design and fabrication of four-wheel steering system for light motor vehicles

The Author of the paper discusses the problems associated with the two-wheel steering mechanism and proposes a solution through the implementation of a four-wheel steering mechanism. The uneven terrain in India makes two-wheel steering less stable, whereas four-wheel steering is better equipped to handle it. Four-wheel steering offers benefits such as improved stability and control at higher speeds, neutral steering, maneuverability, and turning radius. This paper aims to develop a cost-effective and efficient four-wheel steering mechanism using rack and pinion and an intermediate shaft. The proposed mechanism allows the driver to switch between two-wheel and four-wheel steering modes based on their requirements. In summary, the abstract highlights the advantages of the four-wheel steering mechanism and the development of a cost-effective and efficient solution for vehicles in India.

3.PROBLEM STATEMENT, OBJECTIVE AND SCOPE

A. PROBLEM STATEMENT

With a front-steered vehicle, the rear end is always trying to catch up to the directional changes of the front wheels that causes the vehicle to sway. So, to counter this problem a four-wheel steering mechanism is implemented where in the rear end wheels will easily catch up to the directional changes of the front wheel increasing steering response. This system will also help to reduce the efforts while taking sharp or tighter turns e.g., taking a U turn, parallel parking.

B. OBJECTIVES

This project will achieve the two different steering methods of the four-wheel steering mechanism.

- In-phase steering
- Counter-Phase steering

The steering system has the following requirements:

The steering system must be able to turn the front wheels sharply yet easily and smoothly.

- The steering should be made lighter at low speeds and heavier at high speeds.
- Smooth recovery while the vehicle is turning.
- Minimum transmission of shock from the road surface.

This project aims at developing a 4 Wheel Steering System which would cater to the needs to improve steering response, increase vehicle stability while maneuvering at high speeds, or to decrease turning radius at low speed.
Under slippery conditions, the rear of the car may fishtail out of control. In a four-wheel steer car, this high-speed sway can be damped or even eliminated through the use of the same side steering. In this system we will be going to use mechanical as well as electromechanical components which will help us to build this system.

C. SCOPE

The four-wheel steering mechanism in the automotive sector has immense importance. The specific project goals / deliverable features of this project are: -

- Better steering response
- Cornering stability
- Smaller turning radius
- Better in tougher terrains
- Straight line stability
- Easy lane changing

The successful implementation of a four-wheel steering mechanism using mechanical as well as electronic sensing components will result in the development of overall vehicle control and stability.

4.PROPOSED SYSTEM

The project title is basically a four-wheel steering system in which instead of 2 wheels all the 4 wheels steer which helps to Reduce Turning Radius and Increase Stability. 4WS, also called rear-wheel steering or all-wheel steering, provides a means to actively steer the rear wheels during turning maneuvers. Basically, this steering system is based on photoelectric proximity sensors and servo motors to achieve four-wheel steering operation. This system will consist of 2 different modes which are in-face steering and counter face steering. These modes can be switched by using a toggle switch. In in-face steering the both front and the rear wheels steer in the same direction whereas in counter-face steering the rear wheels turn opposite to the front wheels. Each mode has been used for a specific occasion.

The working of the project is basically based on the triggering of the proximity sensors depending on steering wheels input i.e., right, or left. There are 4 photoelectric proximity sensors used in this project. 2 for each mode. These sensors are being fixed on a DIY small handmade steering column and the output for this sensor is given to the Arduino uno and then to a single servo motor which controls the rear steering mechanism. Proximity sensor is a sensor which gives positive or negative output when some object comes into its proximity. So, by using the same, let's consider 4 proximity sensors as S1, S2, S3, S4 where S1 and S2 are used for In-face steering control and S3 and S4 are used for Counter-face steering control. In in-face steering S1 is for right steer and S2 is for left steer whereas in counter face steering S3 is for right steer and S4 is for left steer. In-face steering When S1 is triggered the signal is given to Arduino and the servo motor turns right and when S2 is triggered the servo motor turns left. And the same process is carried in the opposite way in counter face steering. In counter face steering when S3 is triggered the signal is given to Arduino and the servo motor turns left and when S2 is triggered the servo motor turns right. By doing so the two modes of 4ws are achieved.
Similarly for the front wheel we are using a servo mechanism, in which the servo will be controlled by MPU6050 accelerometer sensor. The mpu6030 is basically a sensor which calculates the tilt angle and produces output for the servo motor. Mpu6050 will be placed inside the steering column to measure the tilt of the column and accordingly maneuver the front steering mechanism.

A. OPERATION OF PROPOSED SYSTEM

- In face
- Counter face

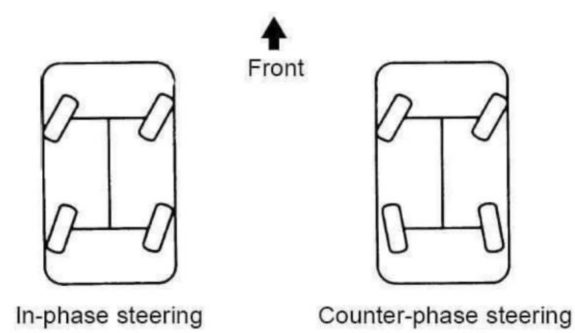

Fig.1 Operation of proposed system

B. FLOWCHART

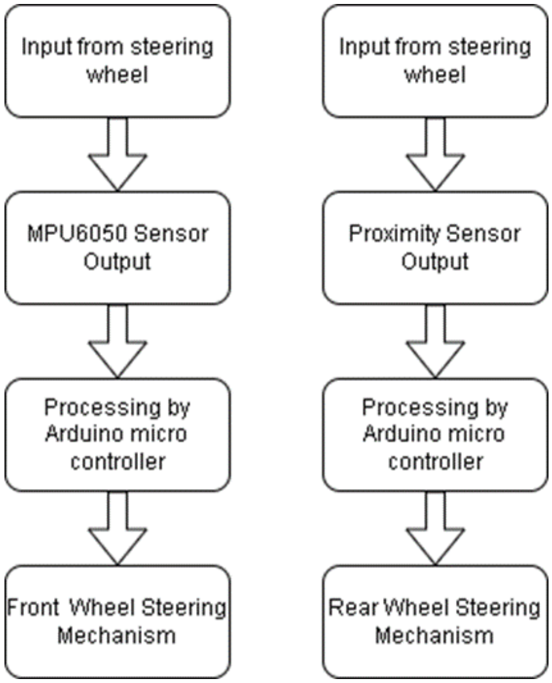

Fig.2 proposed architecture.

1. Input from steering wheel: The steering wheel input is received by the proximity sensors fixed on the steering column.
2. Proximity Sensor Output: The proximity sensors (S1, S2, S3, S4) detect the steering wheel input and provide output signals accordingly.
3. Rear Wheel Steering Mechanism: The output signals from S1, S2, S3, S4 are fed to the Arduino Uno, which in turn controls the servo motor that controls the rear wheel steering mechanism.
4. Front Wheel Steering Mechanism: The MPU6050 accelerometer sensor detects the tilt angle of the steering column and provides output signals to the servo motor, which controls the front wheel steering mechanism.

In-face Steering: When S1 or S2 are triggered, the servo motor controlling the rear wheel steering mechanism turns the wheels to either the right or left, depending on which sensor is triggered. When S1 is triggered, the servo moves towards Right and when S2 is triggered the servo arm moves towards Left Simultaneously, the front wheel steering mechanism is also controlled by the MPU6050 accelerometer sensor.

Counter-face Steering: When S3 or S4 are triggered, the servo motor controlling the rear wheel steering mechanism turns the wheels to either the left or right, depending on which sensor is triggered. When S3 is triggered, the servo moves towards Left and when S4 is triggered the servo arm moves towards Right. Simultaneously, the front wheel steering mechanism is also controlled by the MPU6050 accelerometer sensor.

C. TYPES OF 4-WHEEL STEERING SYSTEM

There are two types of 4-wheel steering systems: mechanical and electronic. Mechanical 4-wheel steering systems use mechanical linkages to connect the front and rear wheels, while electronic 4-wheel steering systems use advanced electronics and sensors to control the steering angle of all four wheels independently.

i. Mechanical 4-wheel steering systems:

Mechanical 4-wheel steering systems are the earliest and simplest type of 4-wheel steering systems. They use mechanical linkages to connect the front and rear wheels, enabling them to turn in the opposite direction. This mechanism improves the vehicle's stability and maneuverability by reducing the turning radius and increasing the grip on the road. However, these systems have some disadvantages, such as their complexity, weight, and lack of precision.

ii. Electronic 4-wheel steering systems:

Electronic 4-wheel steering systems are more advanced and complex than mechanical 4-wheel steering systems. They use electronic sensors, actuators, and a control algorithm to control the steering angle of all four wheels independently. This mechanism enables the vehicle to turn the rear wheels in the same direction as the front wheels at low speeds and in the opposite direction at high speeds. This technology provides improved handling, stability, and maneuverability in all driving conditions.

5.MECHANICAL DESIGN

A. STEERING COLUMN

The steering column structure is made up of PVC pipe assembly and PVC sheets. It consists of a PVC pipe frame along with PVC sheet mounts for the proximity sensors. The steering column is made up of PVC pipe along with obstacle flanges for proximity triggering. The proximity sensors on the PVC mounts are mounted in such a way that they are partially in proximity with the flanges and may get triggered easily when the desired input is given to the steering wheel. Out of 4, 2 are used to operate the in-face steering action and the remaining 2 are used for counter-face steering action.

At a time only two sensors will work for the desired operation. The output of the e18-d80-nk is NPN which is later converted to PNP using a PC817 optocoupler. For front steering operation a dedicated accelerometer-based sensor MPU6050 is used which is mounted inside the steering column which calculates the tilt angles and proportionally operates the front servo mechanism. Then both the output of proximity sensors and MPU 6050 is then given to the Arduino microcontroller.

B. CHASSIS

The chassis includes the basic servo based steering mechanism for front wheels as well as rear wheels. The mechanism is made up of PVC links, wheels and pivots. Also, the battery pack and the Arduino microcontroller are mounted on the chassis. The output from the steering column is given to the Arduino which controls both the servo motors for steering operation.

C. COMPONENTS REQUIRED

1. Arduino: Arduino is a micro-controller board that serves as the brain of the system. It is responsible for controlling and coordinating the actions of all the other components in the system. The Arduino board receives signals from the sensors, processes the data, and sends control signals to the servo motors.
2. E18 D80NK (PHOTOELECTRIC PROXIMITY): E18 D80NK is a photoelectric proximity sensor used in the system. It detects the presence of an object or obstacle and sends a signal to the Arduino board. The Arduino board processes this signal and determines the appropriate action to take.
3. Servo Motor (MG995): A servo motor is a type of motor that can rotate to a precise angle based on the control signals it receives. The system uses servo motors to control the steering of the wheels. The Arduino board sends control signals to the servo motors based on the input from the sensors.
4. Battery Pack (12V DC): The battery pack provides power to the system. It is important to select a battery pack with enough capacity to power all the components in the system for the required amount of time.
5. LM7805: LM7805 is a voltage regulator that is used to regulate the voltage of the battery pack to a level that is appropriate for the other components in the system. It ensures that the voltage remains stable and within the required range, preventing damage to the components.
6. Toggle Switch (ON-OFF-ON): The toggle switch is used to switch between the two different modes of operation, in-face steering, and counter-face steering.
7. MPU6050: MPU6050 is an accelerometer and gyroscope sensor that is used to measure the tilt angle of the system. It sends this data to the Arduino board, which uses it to determine the appropriate steering angle for the wheels.
8. Resistors (1K): Resistors are used to limit the amount of current flowing through the system. They are used to protect the components from damage due to excessive current.
9. Optocoupler (PC 817): An optocoupler is an electronic component that is used to isolate two circuits from each other. It is used in the system to ensure that the high-voltage circuit (the motor control circuit) is isolated from the low-voltage circuit (the control circuit), preventing damage to the components, and ensuring the safety of the user.

D. CIRCUIT DIAGRAM

- The proximity sensor is provided with a 5v dc supply, and the 4 sensors are divided into groups of 2 on each side.
- One group is assigned for in-face steering and the other group is for counter-face steering. These two groups are operated by a 3 mode (ON-OFF-ON) toggle switch which helps to switch in between counter- face and in-face steering.
- The output of all the 4 proximity sensors is connected to the Arduino microcontroller digital inputs as an Input signal for rear steering action.
- At the same time the output of the MPU6050 sensor is also provided to the Arduino

module as input signal for front steering action.

- A 12v dc battery pack is used as power supply to all the components.
- The power supply to Arduino and the servo motors are given by a voltage regulator module (LM7805) which converts the 12v dc input into regulated 5v dc output for Arduino and servo motors.

Both the servo motors i.e., front steering servo and rear steering servo are connected to the output section of the Arduino microcontroller.

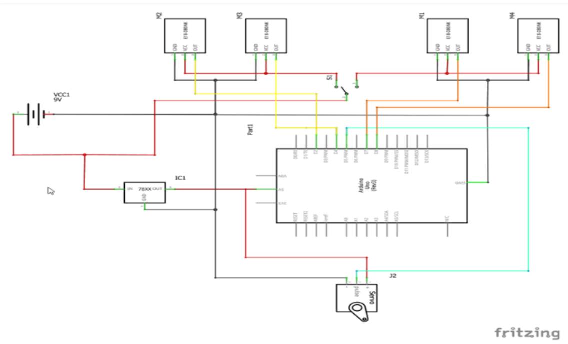

Fig. 3 Circuit Diagram

6. RESULT

In-phase: In this phase the system has the rear wheels rotating in the same direction as the front wheels providing a sliding action of the vehicle, mainly used in high-speed maneuvers.

Counter-phase: In this phase the system has the rear wheels rotate in opposite direction of that of the front wheels giving a reduced turning radius to the vehicle.

As we see the results, the outcome which needed to be that is working of In-phase and Counter-Phase has been achieved.

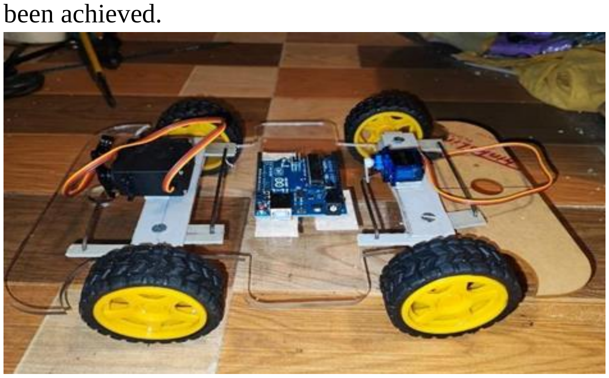

Fig. 4 Arduino and other components mounted on chassis

Fig. 5 Steering column with Proximity sensors

7. FUTURE SCOPE

The future scope of the project includes several aspects that can be explored to further enhance the functionality and usability of the automated 4-wheel steering system. The following are some possible directions for future research and development:

Improving Comfort and Stability While Steering: The current system provides accurate and efficient steering control, but there is still room for improvement in terms of comfort and stability while steering. Research can be conducted to investigate different control algorithms that can optimize the steering performance for various driving scenarios, such as high-speed maneuvering, low-speed parking, and off-road driving.

Integrating Technology into Various Automotive Applications: The proposed system can be integrated into various automotive applications, such as electric vehicles, commercial vehicles, and autonomous vehicles. Research can be conducted to explore the feasibility of integrating the system into different types of vehicles and to optimize the design for each application.

Developing a New and More Cost-Effective & Efficient Steering System: The current system uses photoelectric proximity sensors and servo motors to achieve four-wheel steering operation. Research can be conducted to investigate new and more cost-effective and efficient steering technologies that can be used to replace or complement the current system.

Developing Advanced Control Algorithms: The current system uses a micro-controller to receive input from the sensors and generate commands for the servo motors. Research can be conducted to develop advanced control algorithms that can optimize the steering performance based on real-time data from multiple sensors and vehicle parameters.

8. CONCLUSIONS

The automated 4WS system presented in this paper is a promising technology that aims to improve vehicle maneuverability and safety. The system is based on photoelectric proximity sensors and servo motors and consists of two different modes, in-face steering, and counter-face steering. The system was tested in various scenarios, and the experimental results demonstrate that the system enhances vehicle maneuverability and safety. The system was able to reduce the turning radius of the vehicle by up to 10% and improve the stability of the vehicle during turns.

The development of an automated 4WS system has significant implications for future automotive applications. The system can be used in various types of vehicles, including passenger cars, commercial vehicles, and even autonomous vehicles. The system can also be integrated with other ADAS technologies to provide a comprehensive safety package for vehicles.

In addition, the system has the potential to reduce fuel consumption and emissions by optimizing the vehicle's turning radius and reducing the lateral forces acting on the vehicle during turns. This can have a significant impact on the environment, especially in urban areas where vehicles spend a significant amount of time in stop-and-go traffic.

Overall, the automated 4WS system presented in this paper is a valuable addition to any vehicle. The system's ability to improve vehicle maneuverability and safety, reduce fuel consumption and emissions, and be integrated with other ADAS technologies makes it a promising technology for the automotive industry. Further research and development are needed to optimize the system's performance and reliability and to make it more accessible to consumers.

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