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Development of Platooning Technology with Road Condition Monitoring

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Abstract: ***In this paper, we present a complete platooning system using a time-delay algorithm. The platooning is achieved by measuring the driver inputs from the lead vehicle and sending these inputs to the trail vehicle with a time-delay so that the trail vehicle can exactly mimic the motion of the lead vehicle. This system also does a road condition monitor as an add-on benefit which will help in assisting the driver of the trail vehicle/vehicle which takes the same path. The function of this monitoring system is to analyse the road surface using a lead vehicle and acquire sensor data, this acquired sensor data helps in assisting drivers who take the same track. The combination of both this platooning method and road condition monitoring system could potentially reduce the current risk of utilising this semi-automated driving system.***
Index terms: Platooning, Semi-automated driving, Road condition monitoring, Time-delay algorithm.

I. INTRODUCTION

Transportation is one of the most important aspects of everyday life and it has to meet the necessities of technological development so as to satisfy customer demands. Transportation and communication are considered the cornerstones of many human civilizations because of their important role in linking neighboring cities and villages. In today's growing world, people not only need a faster mode of transportation but also people prefer energy efficient and safer modes of transportation. Today's highways are not that energy efficient as well as in metropolitan cities we find traffic congestion throughout the day. The main reason for traffic congestion is heavy-duty trucks as well as inefficient usage of road space. Platooning can be used to overcome this problem efficiently. The roads in the Indian subcontinent are not given proper maintenance hence, we can see a lot of potholes and discontinuity in the roads after rain or natural disaster. When a new driver takes the path he may not be informed about the road condition, whether it is a good one or full of potholes. To overcome this problem we have included a road condition monitoring system along with platooning so that we are able to know the roads better by getting information from the user as well as giving a star rating to each road. This helps the new user to get an overall picture of the road which he/she may use.

II. LITERATURE REVIEW

A. Platooning

Traveling on highways is very common these days, especially when there are vehicles that share the same route or a part of the journey. Specifically, trucks that have the same starting point and destination taking the same route at the same time can be linked with each other so as to ease transportation and make the process more efficient. Linking the truck means communicating the necessary information to the follower truck so that it follows the truck which is cruising in front of it at a safe distance. In transportation platooning or flocking is a method for driving a group of vehicles together, having in mind to increase the road capacity, so as to reduce the traffic congestion [1].

1) *Advantages of Platooning:* The main advantage of platoons is that it reduces the distance between trucks or cars, using electronic communication technology. This allows many cars or trucks to accelerate or brake simultaneously as it will be much quicker than the human's reaction time. This helps to utilize the road space effectively since human intervention cannot have such close distance between vehicles with an accuracy of braking and accelerating. This system will provide a quick response to the real-time situation where a sudden emergency braking is needed. This also increases the efficiency of the follower trucks as the leader truck which is cruising will experience a drag force because of the air resistance, meanwhile, the follower vehicles will have minimal air drag effects. This is because the follower truck travels in the wake region created by the lead truck, therefore the air resistance is avoided. This will enhance the fuel economy of the truck as compared with conventional driving methods. Platooning can reduce CO2 emissions by up to 16% from the trailing vehicles and by up to 8% from the lead vehicle (according to the recent ITS4CV study by Ertico) [2], [3].

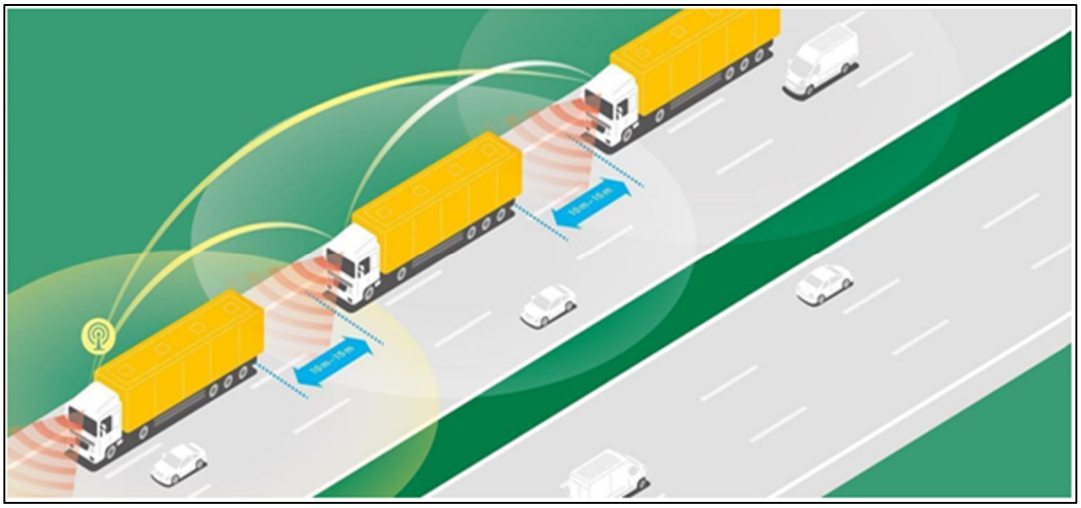

Fig 1: Platooning model
Image source : https://www.rapp.ch/de/stories/truck-platooning

B. Road Condition Monitoring

In real time scenarios, driving in a new unknown road is dangerous because we do not know about the road's present condition. This could possibly damage our car's chassis or under body if the ground clearance is very low. Also it could deteriorate the life of the suspension and the shock absorbers. Road condition monitoring system helps the driver by providing a driver assist, by showing the driver the condition of the road as good, moderate or rough, by getting the data from the previously visited driver.

This can be achieved by introducing a sensor which senses the vertical deviations of the car body, and alerting the driver if the deviations are too high.

III. PROPOSED SYSTEM

The Leader vehicle's driver inputs are recorded and sent simultaneously to the Trailing vehicle using Transceiver *NRF24L01*. The signals received are of discrete types which includes accelerate, reverse, steer right and steer left. The inputs to the trailing vehicle are executed after a specified time [4], [5], [6].

Ultrasonic sensors *HC-S04* are mounted at the front of the Trailing vehicle and it serves two purposes :

1) The Trailing vehicle maintains a safe distance with the Leader vehicle.

2) The distance measured between the vehicles using the ultrasonic sensor is used for Time-Delay Calculation.

A. Time-Delay Calculation

In general,

let the speed of rotation of the wheel be '***v***'

radius of the wheel be '***r***'

thus the angular speed of the wheel is '***w***'

$v = r w$

Now we know the linear velocity of the wheel/ car

To calculate the time lag, we need to know the distance for the Trailing vehicle to cover in order to initiate a steering turn.

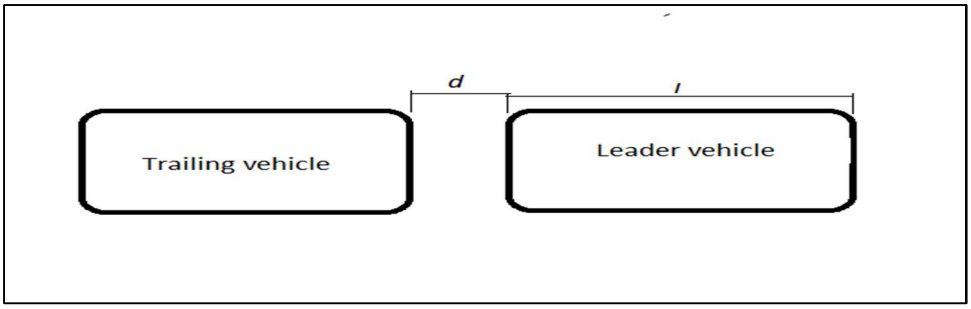

Fig 2: Time lag calculation

therefore the time required for the trailing vehicle to make a turn is

$$t = (d + l) / v$$

Therefore the control in the trailing vehicle is executed with a time lag of ***t*** seconds.
But in general, before executing the commands which are sent by the leader vehicle, the ultrasonic sensor measures the frontal clearance distance, if the distance is less than the safe distance (which is designed to be 15 centimeters in the case of our prototype) the commands will not be executed until the front vehicle moves a bit forward and increases the frontal clearance distance which is more than the safe distance [7], [8].

B. Road Condition Monitoring

An accelerometer sensor *MPU6050* is mounted in the Leader vehicle. The function of this sensor is to record the Z-axis acceleration with respect to distance travelled. The sensor is initially calibrated to a near zero value for a smooth road condition. When maximum deviation of Z-axis acceleration is recorded then the road is termed as Rough road [9], [10].

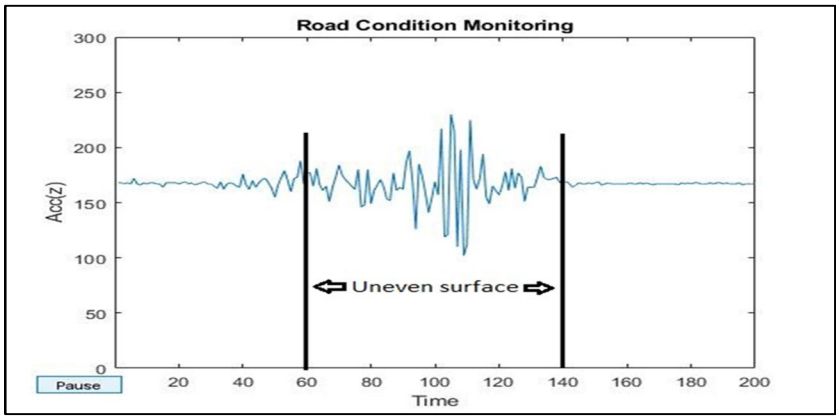

Fig 3: Road Condition Monitoring Graph

After the completion of the journey the path travelled is segregated as Rough, Medium and Smooth road based on the sensor values. This data could assist the Trailing vehicle driver or any other upcoming driver who takes the same path, thus altering the driver to slow down/ reduce speed for an upcoming Rough road. This could potentially improve the safety of the driver and passenger and reduce accidents [11].

IV. RESULTS AND DISCUSSION

The proposed Platooning system works by using the Time-Delay principle. The prototype model is developed in such a way that the Leader vehicle is controlled by a Bluetooth enabled mobile app *Arduino Bluetooth.* The Leader vehicle can accelerate, reverse, steer right/left and stop.

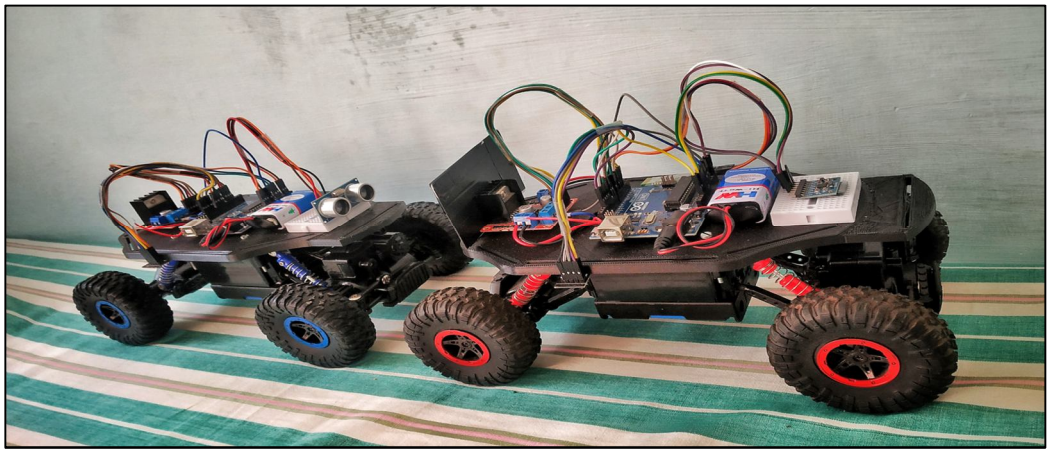

Fig 4: Prototype Model

When Platooning is enabled in the Trailing vehicle, the inputs from the Leader vehicle are sent to the Trailing vehicle using Transceiver *NRF24L01*. The Trailing vehicle mimics the motion but with a time delay.

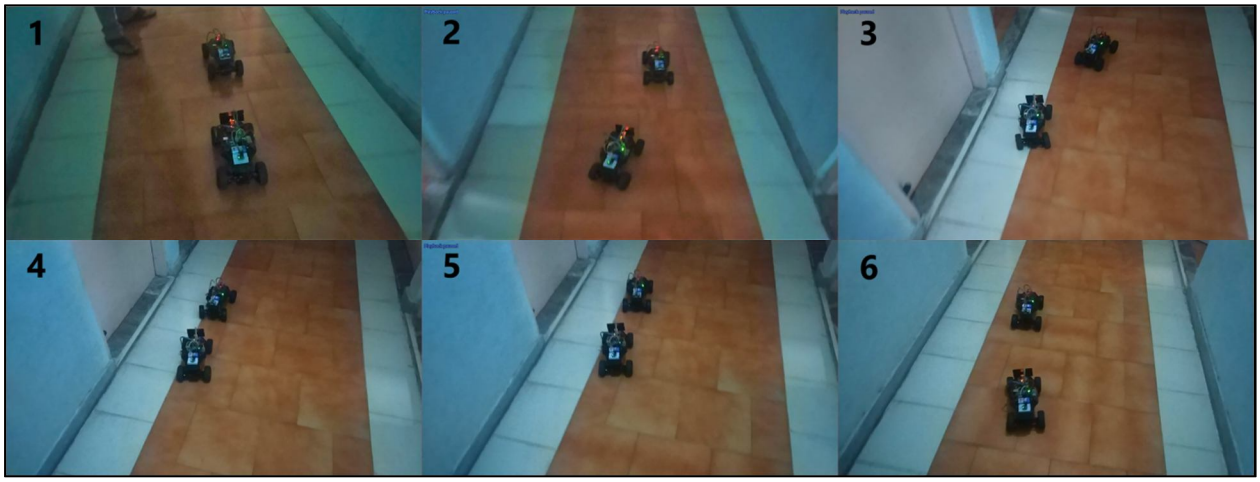

Fig 5: Working of prototype Model

In the above demonstration, safe distance is also maintained. When distance between the vehicles becomes less than the specified safe distance the Trailing vehicle automatically engages brakes, thus preventing collisions.
The Road Condition Monitoring system also works by assisting the Trailing vehicle. When the accelerometer sensor *MPU6050* detects Rough Track, it alerts the Trailing vehicle by sending a message through Transceiver *NRF24L01*. This is indicated by glowing up an LED in the Trailing prototype.

V. CONCLUSION

The proposed Platooning System uses minimal requirements for production and is also inexpensive compared to the other existing technologies. This system need not require any kind of connectivity like the internet for Platooning two vehicles. Also the response time for functioning a Trailing vehicle is lesser than the existing Platooning technologies, which implies more safety. When the proposed method is employed and developed with a feedback system, the Platooning could become more precise and accurate. Road condition monitoring system helps by assisting the Trailing vehicle driver by prompting the condition of the road ahead. The system can also be integrated with web mapping services like Google Maps, Maze for alerting about the condition of the road similar to the crowdsourcing traffic predictions by Google Maps.

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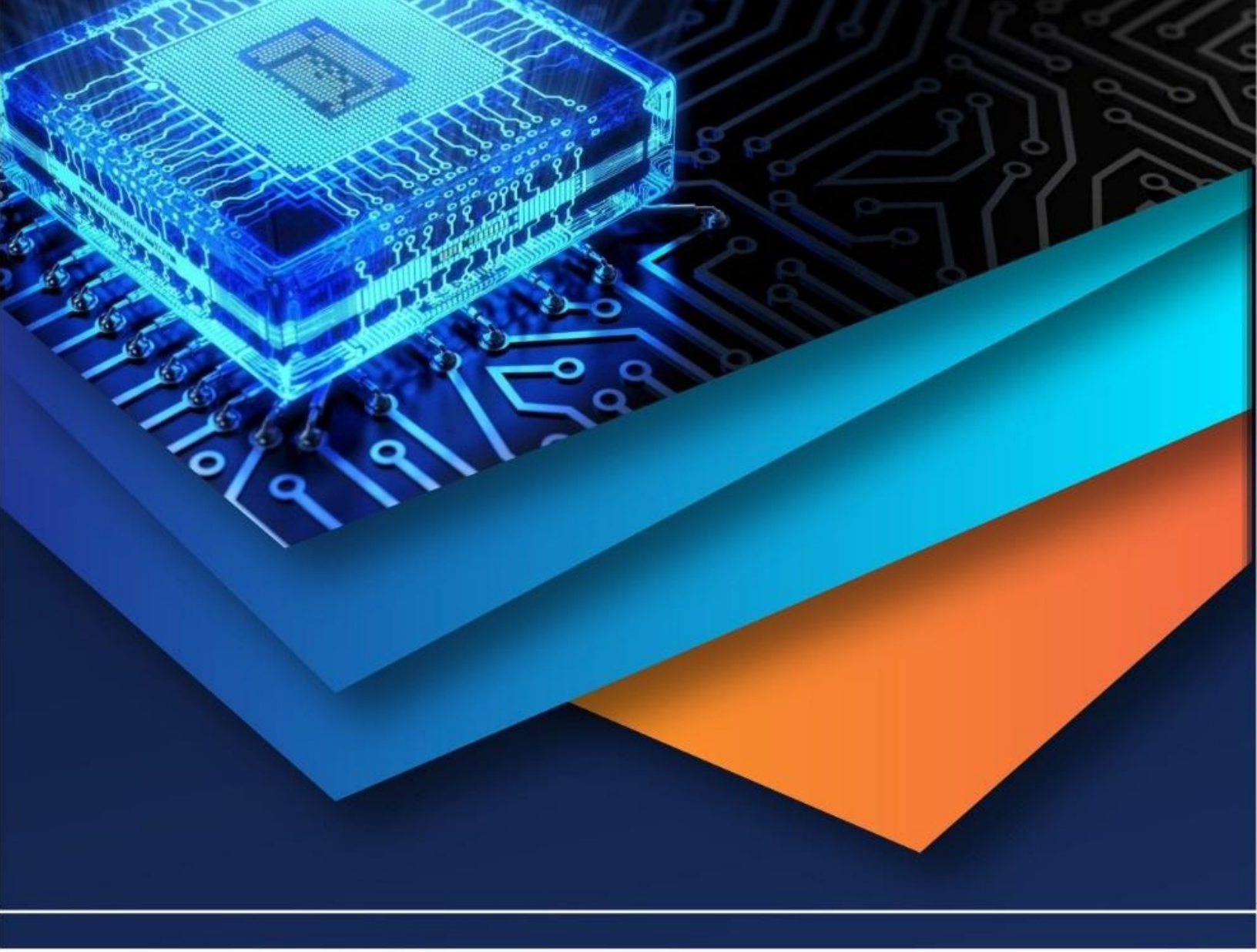

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