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Cruise Control in Vehicle's using PID Controller

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***Abstract*—Cruise control is an automotive system that controls the speed of a vehicle without driver involvement. This article describes a simple method of implementing a PID (Proportional-Integral-Derivative) controller for vehicle cruise control. The controller reduces errors between the desired and actual speed by continuously adjusting the throttle in response to external disturbances. Simulation results demonstrate the efficacy of this traditional control method in providing stability, zero overshoot, and fast settling time, which results in driving comfort and fuel efficiency.**

***Keywords*—Cruise control, PID controller, vehicle automation, control systems, simulation.**

I.INTRODUCTION

The development of automation in the automotive sector has resulted in vehicle systems that are becoming intelligent, efficient, and driver-assistive. Among the technological developments, the cruise control system is a key innovation that is designed to be comfortable for long-distance travel, maximize fuel efficiency, and control speed. The system allows the vehicle to move at a preset speed without constant driver input, reducing driver fatigue and improving highway management. With the current cars evolving to semi-autonomous and autonomous technologies, cruise control is a fundamental feature in the intelligent mobility era. Cruise control operates as a closed-loop feedback system that makes continuous throttle input adjustments to maintain the vehicle at the set speed. The system responds efficiently to varying external factors like changes in slope of the terrain, aerodynamic drag, wind pressure, and load changes. These dynamic parameters require a control technique that is flexible and responsive, yet stable. Of the numerous methodologies that exist, the Proportional-Integral-Derivative (PID) controller is popular because of its simplicity, ease of implementation, and reliability in real-time operations. The current paper suggests the conceptualization and simulation of a PID-based cruise control system using MATLAB and Simulink and evaluates its performance in real-world driving scenarios and system responsiveness in terms of overshoot, settling time, and disturbance rejection. It also suggests demonstrating the applicability of PID in the larger context of modern intelligent vehicular control systems.

Recent research has shown the efficiency of conventional control systems in auto applications. Turan (2023) proposed a new PID tuning method based on changes in proportional gain. The technique significantly improved the system's transient response, leading to a decrease in overshoot and an enhancement in settling time in simulations relative to conventional Ziegler-Nichols tuning [1]. Chandratre et al. (2021) performed an extensive survey of cruise control system structure, identifying key elements such as actuators, sensors, throttle devices, and the feedback loop. The results emphasized the importance of robust feedback systems in dealing with real-world disturbances [2]. Studies have also gone beyond conventional PID controls to investigate hybrid and intelligent control methods. Pananurak et al. proposed an Adaptive Cruise Control (ACC) system with fuzzy logic and PID controls for speed and inter-vehicle distance control. With drive-by-wire throttle and braking control, their system showed high adaptability for urban driving conditions in simulation [3]. Pradhan et al. also employed the Ant Lion Optimizer (ALO), a bio-inspired metaheuristic optimization algorithm, to tune PID parameters. Optimization minimized integral errors and enhanced robustness, highlighting the use of evolutionary methods in automotive control [4].

Moreover, Oguntosin and Olasina (2021) applied classical root locus and frequency-domain design methods to derive high-performance cruise control with close specifications—less than 5% overshoot and settling time less than 1.5 seconds—showing the continued relevance of classical control models if well-designed [5]. Prasad and Inayathullah also applied root locus methods to determine optimal PID gains for electric vehicle cruise systems, reasserting the ways visual tuning methods can be applied to stability and response optimization [6]. In off-road and mixed terrain, standard PID solutions tend to fail. Sailan and Kuhnert solved this problem by suggesting a feedforward-enhanced PID system for all-terrain vehicles. Their model included wind drag, slopes, and non-linear engine dynamics and was able to maintain constant speed in challenging conditions [7].

Efforts have also been made to enhance the intelligence of cruise control systems. Ioannou and Chien described an Autonomous Intelligent Cruise Control (AICC) system using a constant headway rule to minimize traffic shockwaves and provide smoother vehicle operation without the necessity of vehicle-to-vehicle communication [8]. Rajamani and Zhu introduced a semi-autonomous system with the driver and automated system sharing control. Their model provided smooth manual-automatic mode transfers, which benefit in mixed-autonomy traffic scenarios [9]. In data-based optimization, Chen et al. (2021) suggested an adaptive cruise control tuning strategy through real-time vehicle and traffic data. The system adaptively tunes controller parameters through machine learning to offer optimum performance in varied conditions, exhibiting the enhanced use of artificial intelligence in contemporary automobile control [10]. Collectively, the papers highlight the shift from traditional PID control systems to more intelligent, adaptive, and data-conscious cruise control systems. The combination of optimization, fuzzy logic, and AI-based tuning is a stepping stone to the direction of the future of intelligent vehicular automation. This paper keeps the tradition going by formulating and simulating a PID-controlled cruise system under simulated driving conditions and adding to the ongoing research to improve and optimize automated vehicle control techniques.

II. CRUISE CONTROL SYSTEM OVERVIEW

A cruise control system is a closed-loop feedback control system in which the controller continuously makes adjustments to the throttle based on speed error, or rather, the difference between the setpoint and actual vehicle speeds. The setpoint speed is set by the driver, while the actual speed is continually measured with the help of several sensors, such as wheel-speed sensors or the speedometer interface of the vehicle. Based on the real-time feedback, the controller computes the error signal, which will determine its actions for managing the throttle and the degree of that management. The final aim is the minimization of this error so that the vehicle speed follows the setpoint set by the driver as accurately as possible. However, maintaining a steady speed is difficult due to the effects of different dynamic and external factors. Which are:

Cruise control systems must counteract several dynamic effects to maintain a vehicle at a constant speed. Ground undulation affects engine power demand—ascending slopes require extra torque to counteract gravity, descending can induce unwanted acceleration, requiring a decrease in throttle or application of brakes. Change in vehicle mass and load affects inertia and thus the system's response to speed changes. Environmental resistances such as tire rolling resistance and aerodynamic drag increase with speed and may also be a function of road conditions, weather, and tire condition. Engine dynamics create a natural lag in throttle and speed response, which must be compensated in real time. In addition, external disturbances such as gusts of wind, changes in road friction, or interactions with other vehicles may disturb vehicle motion. To counteract these problems, cruise control systems typically use Proportional-Integral-Derivative (PID) controllers, which compensate for current, past, and future errors to generate stability and accuracy. More advanced systems, such as Adaptive Cruise Control (ACC), further optimize responsiveness using radar and vision inputs to control vehicle speed in terms of gap to following vehicles.

Thus, cruise control is an innovative application of control system engineering in the field of car design, enabling increased driver comfort, improved fuel efficiency, and progress toward semi-automatic driving technology. To make cruise control systems more efficient, modern vehicles typically employ advanced control algorithms that can handle these dynamic disturbances effectively. An excellent example of such an algorithm is Model Predictive Control (MPC), which predicts future system states and controls the throttle input accordingly to reduce speed variation over time. Besides this, modern adaptive cruise control systems employ machine learning techniques to improve performance by learning real-time driving scenarios. Employing real-time data from an ensemble of sensors ranging from radar to cameras and LIDAR, adaptive cruise control systems not only control speed but also improve safety by controlling the speed of the vehicle based on distance from other vehicles. Such developments are an indication of the development towards more autonomous driving technologies, where the vehicle can adapt to traffic conditions and environmental factors. The challenge remains in mitigating computational complexity while providing a smooth and comfortable driving experience. Additionally, real-time calibration of control parameters such as PID gains becomes unavoidable in handling variations in road conditions, vehicle loading, and meteorological conditions. With the development of technology, the cruise control system will be instrumental in bridging the gap between conventional vehicles and fully autonomous driving.

Fig.1 Cruise Control

III.REAL-WORLD HARDWARE IMPLEMENTATION

The operation of cruise control systems in vehicles is based on the use of several automobile-grade hardware components that provide precision, reliability, and safety. The hardware components are designed to work together, and the PID control algorithm is executed in the Engine Control Unit

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(ECU). The following is a thorough discussion of the key hardware components used in real cruise control systems that employ PID controllers:

A. Engine Control Unit (ECU)
The central processing unit of the vehicle is the Engine Control Unit (ECU), and it incorporates the Proportional-Integral-Derivative (PID) control algorithm. The ECU is provided with input from various sensors, processes the data, and sends control signals that adjust the vehicle's throttle in real time so that the set speed of the vehicle is maintained consistently. Example Models include Bosch ME7.x, Delphi MT05, Continental SIMOS. The ECU executes PID control loops, facilitates communication with the CAN bus to share information, and synchronizes with other vehicle systems like safety systems and transmission control. It typically features analog-to-digital converters (ADCs), non-volatile flash memory, high-speed microcontrollers, and PWM output signals.

B. Vehicle Speed Sensor (VSS)
The Vehicle Speed Sensor (VSS) calculates the vehicle's actual speed and supplies it to the Electronic Control Unit (ECU) on an ongoing basis. The sensor typically uses a magnetic reluctance sensor or a Hall-effect sensor to derive the vehicle's speed, which it supplies to the ECU to be calculated further. Magnetic reluctance sensors and Hall-effect sensors are the most widely used sensors. Some of the most popular VSS parts include the ACDelco 213-1605 and Bosch 0 265 005 303. The VSS's primary function is to translate vehicle speed into frequency pulses or signals, which the ECU computes to calculate speed differences to provide instantaneous control changes.

C. Electronic Throttle Control (ETC) Unit
The Electronic Throttle Control (ETC) system controls the throttle valve position based on control signals from the ECU, allowing for precise engine speed control with better response time and fuel efficiency. Some examples of models include the Bosch Electronic Throttle Control Module and the Denso Electronic Throttle Body. The ETC system functions by adjusting the throttle valve position through PWM or digital commands from the ECU, thereby maintaining the vehicle at the intended speed. To ensure control, the system employs feedback from the Throttle Position Sensor (TPS), which constantly provides feedback to the ECU.

D. Brake Pedal Position (BPPS) Sensor and Clutch Activation Switch.
For safe operation and normal functioning of the cruise control system, it should deactivate when the clutch or brake pedals are activated. The Brake Pedal Position Sensor (BPPS) detects brake pedal application, and the clutch switch performs the same function for vehicles with manual transmissions. The Bosch Brake Light Switch and Hall-effect-type BPPS are typical brake sensors, while the clutch sensor is typically a spring-loaded mechanical switch. These sensors operate by producing an input to the ECU to deactivate the cruise control system so that the driver can gain full control.

E. Accelerator Pedal Position Sensor (APPS)
The Accelerator Pedal Position Sensor (APPS) is an important component of the drive-by-wire system. The APPS measures the position of the accelerator pedal and transmits it to an electronic control unit (ECU) for manual speed control and cruise control applications, for example. You will find Denso and Bosch Dual-Track Throttle Pedal Sensors, among others, available in the marketplace. The APPS is mainly used to measure the position of the accelerator pedal and send the position signal to the ECU for feedback, and to enable the use of manual override as necessary.

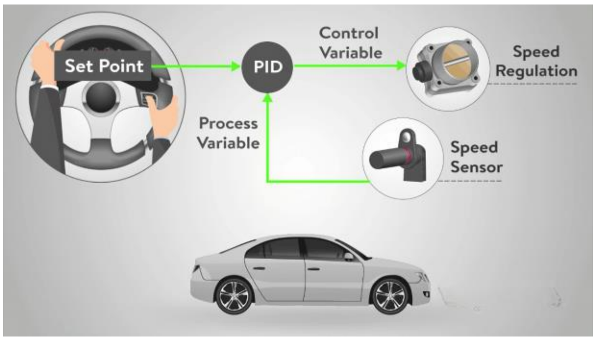

Fig.2 Hardware Implementation

IV.MATHEMATICAL MODELLING

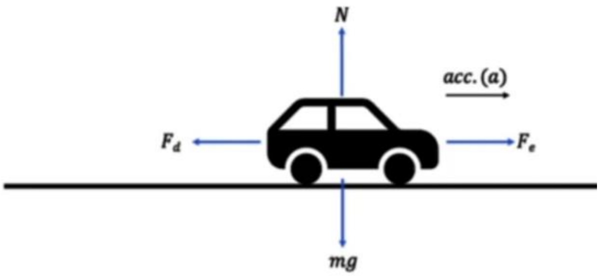

Fig.3 Free Body Diagram

Assumptions

- The car is moving on a flat road with zero slope
- Drag force is calculated using Stoke's law where

$$F_d \propto v$$

1. Deriving a mathematical equation for cruise control in a car.

2. Vehicle Dynamics: Newton's second law is applied in the horizontal direction to analyze the forces acting on the car.

3. Vertical Forces: The normal force N balances the weight mg, i.e., N = mg, and does not affect horizontal motion.

4. Horizontal Forces: The net force is F_e - F_d, where F_e is the force generated by the engine, and F_d is the drag force opposing motion.

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5. Newton's Law: Applying Newton's second law gives $F_e - F_d = ma$, where a is the linear acceleration of the car.

6. Throttle Control: The engine force F_e is controlled by the throttle position, which is directly related to the input given to the system.

7. Proportional Engine Force: The engine force is modeled as proportional to the input: $F_e = k_1 \times$ input, where k_1 is a constant.

8. Drag Force: Drag force is modeled as proportional to the velocity: $F_d = k_2 v$, where k_2 is the drag coefficient and v is velocity.

9. Force Equation Substitution: Substituting these into Newton's law gives: $k_1 \times$ input - $k_2 v = ma$.

10.Acceleration Definition: Since a = dv/dt, this becomes $k_1 \times$ input - $k_2 v = m \times \frac{dv}{dt}$.

11. Rewrite: Rearranging gives the equation $m \times \frac{dv}{dt} = -k_2 v + k_1 \times$ input.

12. Normalized Form: Divide both sides by m to simplify: $\frac{dv}{dt} = -\frac{-k_2}{m} \times v + \frac{k_1}{m} \times$ input.

13. Equation type: This is a first-order linear differential equation in terms of velocity v.

14. System Response: The equation shows how the velocity changes over time depending on throttle input.

15. Control Relevance: This model is critical in designing cruise control systems, where the throttle is adjusted to maintain a desired speed.

16. Steady State: When $\frac{dv}{dt} = 0$, the system reaches steady speed, allowing us to solve for the required throttle to maintain that speed.

17. Feedback Control: Controllers like PID use this model to continuously adjust the input and keep the car at the desired speed despite disturbances.

V. AUTOMOBILE CRUISE CONTROL SYSTEM (SIMULATION)

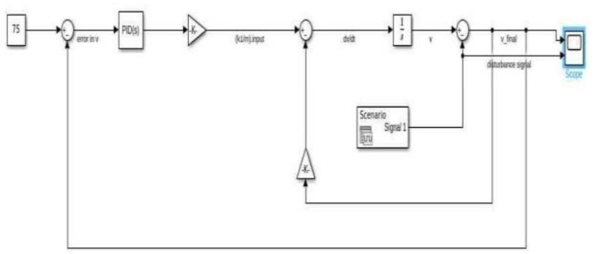

Fig4.Block Diagram

Here, the formula is given by dv/dt = $(\frac{k1}{m})$ input - $(\frac{k2}{m})$.v

Where,

m = 1000kg

k1 = 2

k2 = 100

1. Setpoint (75 $\frac{km}{h}$): This is the speed at which you wish the car to cruise, like using cruise control to set the car at 75 $\frac{km}{h}$ on the highway.

2. Error Calculation: The system calculates at all moments the difference between the desired velocity and the effective velocity attained. It is otherwise called the error.

3. PID Controller: The PID controller uses the error measurement to determine the right amount of throttle required to reduce this error. It allows a speed change with a smooth operation, hence preventing overshooting and oscillation.

4. Gain Block $(\frac{k1}{m})$: The PID output is scaled by an engine characteristic factor to transform it into the actual engine force.

5. Drag Force ($-k_2 v$) handling: Always, there is some resistance (e.g., slope or air drag), proportional to the current speed. This resistance is being subtracted to attain the net force.

6. Net Force → Acceleration $(\frac{dv}{dt})$: Newton's second law is applied by the system to calculate the rate of acceleration at which the car must accelerate or decelerate based on the net force.

7. Integrator $(\frac{1}{s})$: $\frac{dv}{dt}$ is integrated over time to give the vehicle speed at the instant. Integration is required for speed monitoring in the system.

8. Disturbance Input (Effects in Real-World Situations): A representative signal simulates external forces like terrain changes or wind conditions, which are fed into the system and can impact velocity temporarily.

9. Final Speed Output – v_final: It is a prediction of the actual velocity of the vehicle, taking into consideration the input provided by the accelerator as well as the external environment around the vehicle. It is the system's final output, providing the actual speed at which the cruise control can sustain the motion of the vehicle.

10. Scope: Finally, v_final is graphed against time in the Scope block. This is a visual display of how the system responds to the target speed, and adjustments can be made to the controller if needed.

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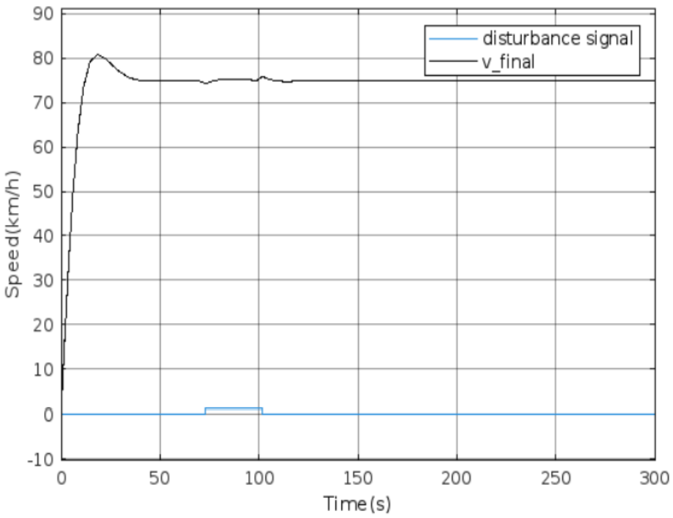

FIG.5 RESULT GRAPH FROM SCOPE

Figure 5 shows the response of a cruise control system over time. The black line is the velocity of the vehicle, which begins from rest. At first, the car accelerates smoothly to attain the desired speed and then hovers around 80 units, which means the system maintains the desired speed well. This behavior in steady state indicates that the cruise controller is properly tuned. At about the 75-second point, a disturbance is added, represented as a step in the blue line. This may be an external influence like an uphill slope, added load, or a gust of wind. After the disturbance, the speed of the vehicle slightly drops, but the controller immediately recovers and brings the speed back to its target value. The perturbation does not cause long-term instability to the system, reflecting strong stability and fast recovery of the system. Overall, the cruise control manages disturbances efficiently with limited overshoot or oscillation.

VI.FUEL EFFICIENCY ANALYSIS

Fuel economy is a critical parameter in today's automotive control systems that affects both economic and environmental outcomes. Cruise control systems are designed to have a constant speed, which in turn reduces the acceleration and deceleration variability. This minimization of engine workload fluctuation is the secret to enhancing long-term fuel economy. Figure 6 indicates a comparative study of fuel consumption rates within a 100-second interval between manual driving and cruise control. For manual driving, irregular throttle changes and frequent speed changes create a high fuel consumption variability rate, thereby lowering overall efficiency. Cruise control, however, indicates a smooth acceleration trend, with fuel consumption exhibiting a near-linear and lower trend. The simulation outcomes indicated that the cruise control permitted fuel savings of about 30–40% within the same time interval. This enhancement can be understood primarily due to the minimization of engine workload variability along with improved throttle regulation.

Secondly, smoother driving reduces the instances of gear shifting and braking, thus improving fuel economy, particularly on highways and long distances. Thus, cruise control not only increases driving comfort but also has the added function of promoting environmentally friendly and economical use of vehicles through the optimization of fuel consumption.

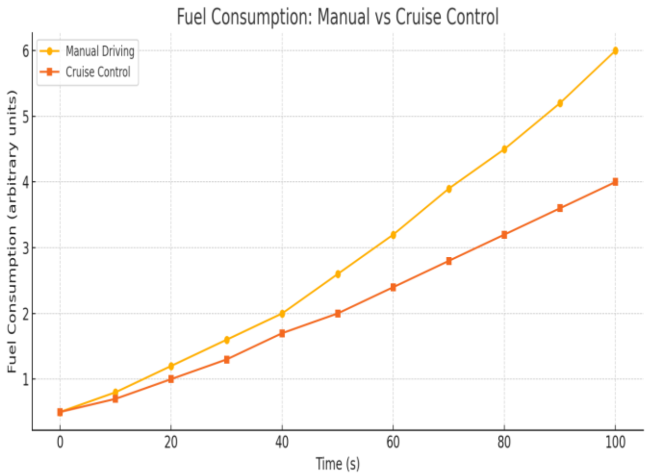

Fig.6 Fuel Efficiency Analysis with Cruise Control

The simulation also confirms the efficiency of the PID controller in vehicle speed control. Under dynamic modulation of the throttle input to external disturbances, the system controls speed around the setpoint. This is evidenced in the capability of the vehicle to accelerate to the desired speed and settle to a steady state. The reactive property of the PID controller leads to minimal deviation of error from the target speed even under disturbances like the change of road gradient or an abrupt change of load. In contrast to simple cruise control systems involving sudden throttle switching, the PID controller enables smooth throttle modulation. This equates to fewer jerky accelerations, less mechanical stress on the engine and transmission, and higher overall efficiency. The proportional component reacts to current errors, the integral component eliminates the built-up offset, and the derivative component anticipates error trends, combined to offer fast settling and zero steady-state error.

Amongst the external conditions, road slope impacts the behavior of cruise control most. Slopes uphill create resistance, demanding increased throttle input, whereas slopes downhill create overspeed, demanding a decrease in throttle. The PID controller handles such situations well by dynamically adapting the control signal as the error develops.

Fuel economy is a major benefit of PID-based cruise control. Smooth use of the throttle and avoidance of hard acceleration or hard braking lead to the best engine load profile, causing fuel savings of approximately 30–40% relative to manual

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driving. Relative to the conventional cruise control strategy based on proportional action alone or fixed speed limits, the PID controller is more accurate, stable, and flexible. It responds well to the continuous change of the environment and mechanics without causing excessive overshoot or oscillation, leading to a smoother ride. There are some limitations. The PID controller is sensitive to tuning parameters and relies on linear vehicle dynamics within the simulation model. Under conditions in practice, system performance can be degraded by drivetrain non-linearities, actuator saturation, and sensor noise. Hence, while the PID controller is highly effective in simulation, further improvements, e.g., adaptive gain tuning or inclusion in model-based or AI-augmented controllers, may enhance robustness in practice. In conclusion, the research verifies that PID-based cruise control is a valid, efficient, and scalable solution to the attainment of target vehicle speeds while improving comfort, fuel economy, and system responsiveness.

VIII.CONCLUSION

The current research was interested in simulating and designing a cruise control system for an autonomous vehicle, with emphasis being given to fuel efficiency and stability. The primary goal was to operate a vehicle at a specified speed by controlling the throttle input automatically as a function of varying road and load conditions. The proposed control logic was developed based on conventional control systems techniques and then optimized using a detailed simulation model. A complete simulation model was designed to simulate real vehicle behavior. Mass, engine thrust, road slope, and outside disturbances were added as parameters. MATLAB/Simulink was used to simulate the system, providing a realistic and flexible environment to test the control strategy under different conditions. The cruise control system exhibited robust efficacy in achieving and sustaining target velocity with negligible overshoot and steady-state error across diverse test scenarios. Additionally, the system showcased an efficient adaptability to perturbations, including variations in terrain such as inclines and declines, alongside abrupt fluctuations in load conditions. Graphical results of the simulation confirmed the performance of the controller. Speed-time and acceleration-time graphs indicated that the car was able to recover stably and rapidly after disturbances. In addition, system response characteristics were within acceptable control engineering standards, and there were zero steady-state errors and a small rise time in steady states. The simulation output also enabled control parameter tuning, enhancing real-time performance without compromising energy efficiency. This experiment again validated the viability of model-based control design for automotive use. Overall, the utilized cruise control model has demonstrated an impressive level of responsiveness and reliability. The simulation results provide a good foundation for potential real-world implementation and optimization in the future. The future may involve exploring adaptive or smart control methods, such as fuzzy logic or neural networks, and aiming for better system performance in highly dynamic situations. In summary, this study confirms that the use of simulation-driven development is a viable method of control system design in contemporary vehicles and significantly advances the area of automotive automation.

IX.REFERENCES

[1] PID controller design with a new method based on proportional gain for the cruise control system,-By Abdullah Turan
[2] STUDY OF CRUISE CONTROL SYSTEM USED VEHICLE Ajinkya Chandratre , Ajit Bhatjire , Pankaj Chaudhary
[3] Adaptive Cruise Control for an Intelligent Vehicle Worrawut Pananurak, Somphong Thanok, Manukid Parnichkun
[4] Performance Evaluation of PID Controller for an Automobile Cruise Control System using Ant Lion Optimizer Rosy Pradhan1,a , Santosh Kumar Majhi Jatin Ku Pradhan and Bibhuti Bhusan Pati
[5] CONTROL DESIGN AND ANALYSIS OF CRUISE CONTROL SYSTEM Victoria Oguntosin and Jamiu Olasina
[6] Root locus approach in design of PID controller for cruise control application Manju Prasad M , M A Inayathullah
[7] MODELING AND DESIGN OF CRUISE CONTROL SYSTEM WITH FEEDFORWARD FOR ALL TERRIAN VEHICLES Khaled Sailan and Klaus.Dieter Kuhnert
[8] Autonomous Intelligent Cruise Control Petros A. Ioannou, Member, ZEEE, and C. C. Chien
[9] Semi-Autonomous Adaptive Cruise Control Systems R. Rajamani and C. Zhu
[10] Data Based Parameter Setting Method For Adaptive Cruise Control JIE CHEN , GUIZHEN YU , (Member, IEEE), AND XUESHU YAN