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# Stability improvement of quarter suspension system performance using Artificial Intelligence

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**Abstract:** Artificial Intelligence is a fast-advancing area that aims to develop intelligent systems qualified for performing challenges that traditionally require human intelligence. Suspension systems are critical in ensuring vehicle stability, comfort, and safety by isolating the vehicle body from road disturbances. Over the years, substantial advancements have been made in designing and controlling suspension systems to enhance ride quality, handling, and vehicle dynamics. In this research, improving suspension system response is done by using artificial intelligence. the results show that Artificial Intelligence has improved the system's stability with high efficiency.

**Keywords**: (AI, control system, suspension system, genetic algorithm, PID, mechanical engineering)

**Introduction**

Artificial intelligence is a computer system capable of performing piece of work associated with human intelligence like predicting future operations, object detection, explain speech, and creating new language. AI systems are systems that programed by programmers by conversion huge amounts of data and explore designs to model in their decision-making. humans some situation supervise an AI's learning tasks, producing good decisions and discouraging unsatisfactory decisions, however, some Artificial intelligence systems are intended to produce decisions in the absence of supervision. AI systems enhance their execution of particular tasks, permit them to deal with the new feed-in, and build resolve in the absence of explicitly programmed to do this. Artificial intelligence is learning machines to have one's opinion and acquire knowledge approximately like humans, in the same way of the objective of automating and solving problems more efficiently [12].

A suspension system in the context of automotive engineering is the group of mechanical parts and mechanisms that connect the body of the vehicle to its wheels. The cause of a suspension system is to ensure a sleek and convenient ride for the occupants by interesting shocks and vibrations caused by rough road superficies. The suspension system plays a crucial role in maintaining proper contact between the wheels and the road, which is required for vehicle stability, handling, and fracturing. It helps to distribute the weight of the vehicle evenly across all wheels, ensuring optimal traction and preventing excessive body roll during cornering or maneuvering. Key parts of a representative suspension system include:

1. Springs: are fundamental components that absorb shocks and hold up the vehicle's heaviness. There are a difference, such as air springs, leaf springs, or coil springs, and are responsible for maintaining ride height and providing flexibility.

2. Dampers/Shock Absorbers: Dampers, commonly known as shock absorbers, work in conjunction with springs to control the oscillations and vibrations caused by uneven road surfaces. They help dampen excessive motion and ensure that the wheels maintain contact with the road.
3. Control Arms/Wishbones: Control arms, also referred to as wishbones, are generally used in independent suspension systems. They connect the wheel hub to the chassis of the vehicle and allow vertical movement of the wheel while maintaining its alignment.
4. Anti-roll Bars/Stabilizer Bars: Anti-roll bars, or stabilizer bars, are intended to reduce body roll through cornering. They join both sides of the suspension system, transferring force between the wheels and reducing the vehicle's tendency to lean excessively.
5. Struts: Struts are a common component in MacPherson strut suspension systems, which combine the purpose of a trauma absorber and a structural support element. They are typically used in the front suspension of many vehicles[2].

Figure 1 real quarter car suspension system

Modern suspension systems may also incorporate advanced technologies such as electronic control systems, adaptive damping, and air suspension. These technologies allow for real-time adjustments to the suspension settings based on driving conditions, enhancing comfort, stability, and overall performance. there are several models of suspension systems such as semi-independent, dependent suspension, and independent suspension. The selection of suspension system be contingent on factors such as the cost considerations, vehicle's deliberate use, and desired ride characteristics. Overall, the suspension system is a stringent aspect of a vehicle's design, contributing to its safety, comfortable, and handling capabilities by sequester the occupants from road irregularities and support optimal tire contact with the road roof[2].

**System Modeling**

the system that have been used is quarter bus. It consists of two mass, two spring and two dumpers. All components are connected mechanically as in figure 2.

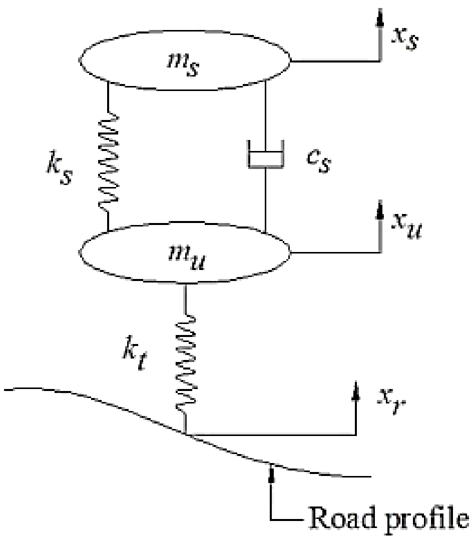


Figure 2 one wheel bus suspension system [4]

**Mathematical model of the system**

According to Newton's law of motion, the dynamic-equation can be obtained as the following[15]:

$$M_1\ddot{X}_1 = -B_1(\dot{X}_1 - \dot{X}_2) - K_1(X_1 - X_2) + U \qquad (1)$$

$$M_2\ddot{X}_2 = B_1(\dot{X}_1 - \dot{X}_2) + K_1(X_1 - X_2) + B_2(\dot{W} - \dot{X}_2) + K_2(W - X_2) - U \qquad (2)$$

Assume that all of the initial conditions are zero

$$(M_1S^2 + B_1S + K_1)X_1(S) - (B_1S + K_1)X_2(S) = U(S) \qquad (3)$$

$$-(B_1S + K_1)X_1(S) + \left(M_2S^2 + (B_1 + B_2)S + (K_1 + K_2)\right)X_2(S) = (B_2(S) + K_2)W(S) - U(S) \qquad (4)$$

consider the control input U(s) only, we set W(s) = 0. Thus, the transfer function G1(s) :

$$G_1(S) = \frac{X_1(S) - X_2(S)}{U(S)}$$

=(2820 s^2 + 15020 s + 500000 )/( 800000 s^4 + 3.854e007 s^3 + 1.481e009 s^2 + 1.377e009 s + 4e010) (5)

consider the disturbance input W(s) only, we set U(s) = 0. Thus, the transfer function G2(s) :

$$G_1(S) = \frac{X_1(S) - X_2(S)}{W(S)}$$

=(-3.755e007 s^3 - 1.25e009 s^2 )/( 800000 s^4 + 3.854e007 s^3 + 1.481e009 s^2 + 1.377e009 s + 4e010) (6)

**System Parameters**

**Table 1:** quarter bus parameters[15].

| | |
|---|---|
| (M1) 1/4 bus body mass | 2500kg |
| (M1) suspension mass | |
| (K1) spring constant of suspension system | 80,000 N/m |
| (K2) spring constant of wheel and tire | 500,000 N/m |
| (B1)damping constant of suspension system | 350 N.s/m |
| (B2)damping constant of wheel and tire | 15,020 N.s/m |

**Genetic AI Algorithm**

The genetic algorithm operates on a population of potential solutions, representing filter solutions to the problem. Each filter solution is encoded as a string of values, known as a chromosome or genotype. The genetic algorithm evolves this population over successive generations, applying genetic operators to simulate the processes of selection, crossover, and mutation, which are analogous to natural selection and genetic recombination[13].

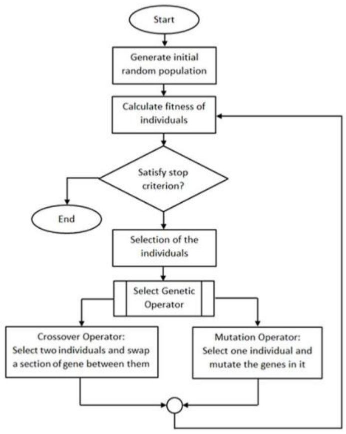


Figure 3 Genetic algorithm flowchart[13]

Recreating chooses individuals with high suitability values in the population. Through crossover and mutation of such individuals, the next generation of the creation population is determined by which individuals are the superior fit for their environment. The process of crossover includes two chromosomes reciprocating segments of data and is comparable to the process of recuperation. Mutation initiates small modifications into a small extent of the population, and it is delegated an evolutional levels[13].

**Lictruter review**

1. B. Srinivas, B. Lavanya and P. Surya Prasad in 2014 have been published a paper (Simulink Implementation for Improvement of Vehicle Directional Control using Relay Experiment Method) the overshoot and settling time met the requirements of the system. The overshoot is about 5%of

the input's amplitude and settling time is 5 seconds. [1]

2. Sharifah Hanisah in 2012 have discussing a master thesis (Design Of A Controller For Car Suspension System Via State Space Approach) the results was(ts=2.44 sec, os=59.60%,tr=1.55sec in state space controller) and (tr=1.23sec, ts=5.13sec and OS=75.30% in p controller)

And so much research in this practical of suspension systems. In this paper, results have been compared with the results of the previous studies.

**Experimental results:**

The system without a controller is compared with the controller of previous studies and the AI controller. First, the system the transfer function in equation (5) are implemented in MATLAB program and plotting the step response for investigating the system response in the case of no controller exists. The GA-AI controller has been added to the system to improve the response.

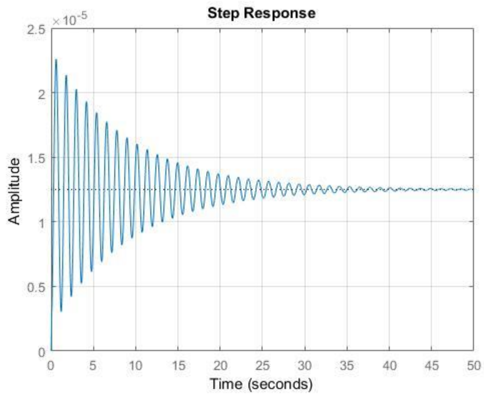


Figure 4 System without controller

It is clearly that the system is unstable so PID controllers have been added to the system to improve the stability. The tunning method is GA-AI.

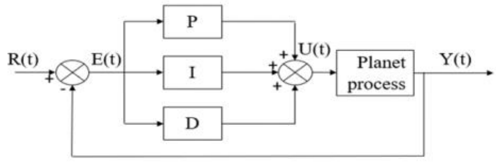


Figure 5 PID block diagram[13]

Controller = kp + ki/s + kd*s

Using the genetic algorithm, the PID parameters was:

KP=10

KI=10

KD=0.003

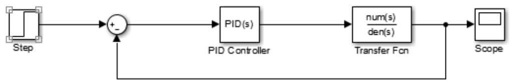


Figure 6 MATLAB Simulink implementation

By applying the parameters in the system and considering feedback to be 1, the time response becomes as follows:

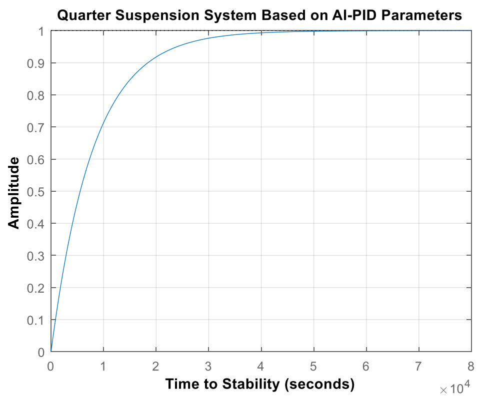


Figure 6 GA-AI controller

System parameters:

From figure 4, the settling time is 3.13 sec, rise time is 1.76 sec and the steady state is zero.

**Conclusion**

the genetic algorithm artificial intelligent PID controller has been designed and implemented to control a one-wheel bus suspension system after deriving the mathematical model of the overall system without considering the disturbance. The genetic algorithm artificial intelligent PID controller has improved the response of the suspension system, the GA-AI has the best performance. it has a fast-settling time of approximately 3 sec without overshooting. And settling time is 1.76 sec which is high-speed stability and the final value of 1 same as the setpoint.in other words, the system stability that refers to the Driver comfort and Vehicle stability on various off-road roads has been improved. The final result is that the AI can improve the stability of the systems under certain conditions.

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