MODELING AND SIMULATING THE DYNAMICS OF AN ADAPTIVE THROTTLE SYSTEM ON AN AUTOMOBILE

MÔ HÌNH HÓA VÀ MÔ PHỎNG ĐỘNG LỰC HỌC HỆ THỐNG GA THÍCH ỨNG TRÊN Ô TÔ

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ABSTRACT

Currently, with the rapid development of science and technology, research and application of information technology, electronics, and automation in various automotive features, such as warning systems and automatic distance-keeping with vehicles in front, automatic throttle control, have become essential for enhancing safety and convenience for drivers. This article discusses an adaptive cruise control system aimed at monitoring the distance with the vehicle ahead. This system allows for the automatic control of the throttle by electronic control signals instead of manual pedal operation. In the research, a predictive control model (MPC) is utilized within the Matlab/Simulink software to simulate the control process of the research model.

Keywords: *automotive dynamics, distance control, adaptive throttle control, predictive control, Matlab/Simulink software, vehicle speed control, automatic throttle system modeling.*

TÓM TẮT

Hiện nay với sự phát triển mạnh mẽ về khoa học kỹ thuật, việc nghiên cứu, ứng dụng công nghệ thông tin, điện tử, tự động hóa lên một số tính năng như cảnh báo, hỗ trợ giữ khoảng cách với xe phía trước, điều khiển ga tự động trang bị trên các xe ô tô để tăng tính an toàn, tiện nghi cho lái xe là yêu cầu cấp bách. Bài báo đề cập đến hệ thống ga thích ứng nhằm kiểm soát khoảng cách với xe ô tô chạy phía trước, hệ thống cho phép điều khiển tự động bướm ga của xe bằng tín hiệu điều khiển điện tử thay vì người lái tác động vào bàn đạp ga. Trong nghiên cứu sử dụng mô hình điều khiển dự đoán – MPC (Model Predictive Control) trong phần mềm Matlab/Simulink để mô phỏng quá trình điều khiển của mô hình nghiên cứu.

Từ khóa: *Động lực học ô tô, kiểm soát khoảng cách, điều khiển ga thích ứng, điều khiển dự đoán, phần mềm Matlab/Simulink, kiểm soát vận tốc ô tô, mô hình hóa hệ thống ga tự động.*

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1. INTRODUCTION

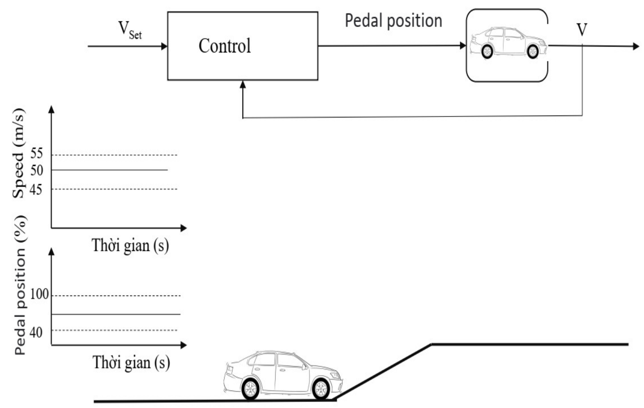

Figure 1. Diagram of the Adaptive Throttle System Operation

Currently, with the strong development of science and technology, the research and application of information technology, electronics and automation on car safety systems such as: Electronic Throttle Control (ETC) allows automatic control of the vehicle's throttle by electronic control signals instead of the driver acting on the pedal railway station; The Traction Control System (TCS) uses sensors to monitor traction status and adjusts the throttle and brake system to prevent wheels from sliding; Electronic Stability Control (ESC) reduces the risk of derailment and loss of control by automatically intervening on the brakes and throttle to maintain vehicle stability in dangerous situations (such as slipping or tipping); Adaptive Cruise Control allows the driver to set a sustained speed on a highway or highway; Collision Warning System Using sensors and radar, this system can detect potential incidents and warn drivers through audio or visual to help drivers react in time; Lane Keeping Assist monitors the vehicle's position in the lane and provides warning or intervention to keep the vehicle in the middle of the lane, preventing misdirection; The Distance Warning system monitors the distance between your vehicle and the vehicle in front and warns you if you are too close or at risk of a collision. For the purposes of the study, the paper refers to the distance control system between an adaptive throttle car and a front car, which allows automatic control of the vehicle's throttle by means of an electronic control signal instead of the driver acting on the accelerator pedal (Fig. 1): The sensor/radar on the research vehicle will recognize the distance to the vehicle ahead to decide whether to accelerate or decelerate, thereby controlling the corresponding position of the accelerator pedal (electronic throttle system).

2. BUILDING DYNAMICS MODELS

The math model describes the interaction between an adaptive throttle car and a vehicle ahead to maintain a safe distance. In this study, a vehicle equipped with adaptive throttle (adaptive vehicle), a system that uses sensors/radar, measures the distance to the vehicle ahead of it running in the same lane ($D_{đo}$), sensors/radar and measures the relative velocity of the vehicle ahead ($V_{đo}$), at which point the control system decides which mode to use based on sensor/radar measurements according to The specific real-time is as follows (Fig. 2):

- Mode 1 (speed control): The vehicle with adaptive throttle has a speed lower than the vehicle in front, at which point the system will control the adaptive throttle vehicle to accelerate to the set speed by controlling the increase in throttle opening.

- Mode 2 (distance control): The vehicle with adaptive throttle has a speed greater than the vehicle in front, at which point the system will control a safe distance from the vehicle ahead

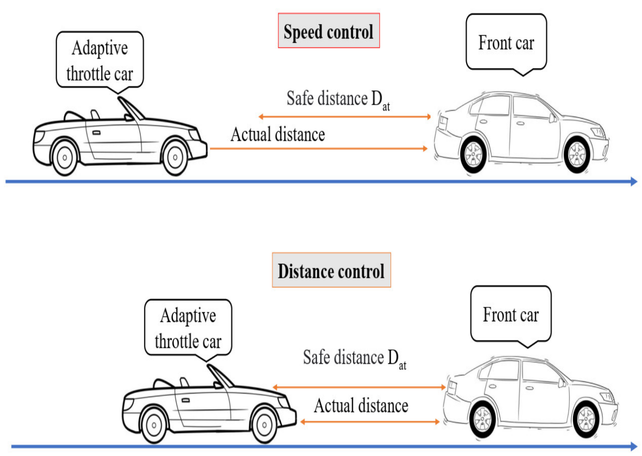

Figure 2. Diagram showing the control mode of vehicles fitted with adaptive throttle system

Thus, the adaptive throttle system is responsible for making the car with adaptive throttle able to move at the speed set by the driver, while maintaining a safe distance from the vehicle ahead. The differential equation of motion of the system is formulated as follows [1]:

Motion differential equation for the vehicle ahead:

$$\frac{dA_t}{d_t} + \frac{1}{0{,}5s+1} + v_{0t} = v_t \quad (1)$$

$$\frac{dv_t}{d_t} + x_{0t} = x_t \quad (2)$$

Motion differential equations for adaptive throttle vehicles:

$$\frac{dA_{tu}}{d_t} + \frac{1}{0{,}5s+1} + v_{0tu} = v_{tu} \quad (3)$$

$$\frac{dv_{tu}}{d_t} + x_{0tu} = x_{tu} \quad (4)$$

The relationship equation between the adaptive throttle vehicle and the vehicle in front by the distance of the two vehicles [2]:

$$d = \int_{t1}^{t2} (v_{tu} - v_t)dt \quad (5)$$

Where:

X_{0T}: initial position of the car in front;

V_{0t}: initial set velocity of the vehicle ahead;

v_t: variable velocity of the vehicle ahead;

x_T: initial location of the vehicle with adaptive throttle;

A_t: variable acceleration of the vehicle ahead;

V_{0tu}: initial set velocity of the adaptive throttle vehicle;

v_{tu}: variable velocity of the vehicle on the adaptive throttle mounting side;

A_{tu}: variable acceleration of the vehicle on the adaptive throttle mounting side.

3. CONTROLLER FOR MODEL

The paper uses MPC, which uses a model to predict the response of an adaptive throttle vehicle at times to the vehicle ahead within a certain forecast range. Based on this forecast response, an optimization algorithm is used to calculate the sequence of future control signals within the control range so that the deviation between the forecast by the model and the given standard signal is minimal. The MPC control method is a method of designing controllers in the time domain so that it can be applied to linear as well as non-linear systems [3, 4].

Objectives to control the operating mode of the adaptive throttle system:

- If the measured distance (by sensor/radar): $D_{đo} \geq D_{at}$: safe distance, the velocity control mode works. The control objective is to follow the speed set by the driver.

- If $D_{đo} < D_{at}$ then the distance control mode works. The control objective is to maintain a safe distance.

The control block diagram is represented as Fig. 3.

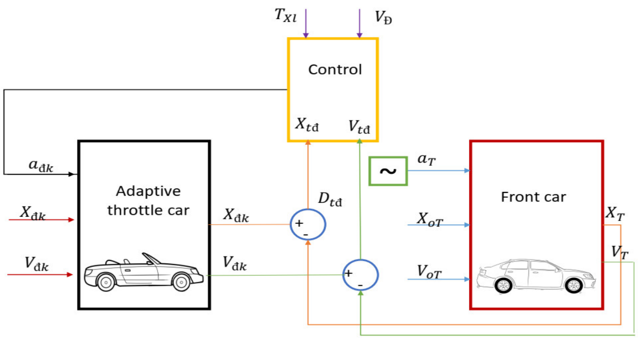

Figure 3. Adaptive throttle control block diagram

Steps to solve the problem of binding forecast control [5]:

At the time ki already has the value $x_m(ki), U(ki)$

Step 1: Calculate $x_m(ki+1)$:

$x_m(ki+1) = A_m x_m(k) + B_m U(k)$

$=> x_m(ki+1) = x_m(ki+1) - x_m(ki)$

And: $y(ki+1) = C_m x_m(k+1)$

$$x_m(ki+1) = \begin{bmatrix} \Delta x_m(ki+1) \\ Y(ki+1) \end{bmatrix}$$

Step 2: Define values

$$\gamma = \begin{bmatrix} Umax - U(ki) \\ Umin + U(ki) \end{bmatrix},\ M = \begin{bmatrix} 1\ 0 \ldots 0 \\ -1\ 0 \ldots 0 \end{bmatrix}$$

Calculate the minimum value of the target function.

$$\gamma = (R_s - Y)^T (R_s - Y) + \Delta U^T \bar{R} \Delta U$$

With binding conditions:

$M\Delta U \leq \gamma$

Determine the control value variation $\Delta U(ki+1)$ is the first component of the ΔU.

Hence the control signal at the step $ki + 1$

$u(ki+1) = u(ki) + \Delta u(ki+1)$

So here we have the control state values at the time of sampling $ki + 1$:

$x_m(ki+1), u_m(ki+1)$

Repeat step 1 until $\Delta U = 0$.

4. SIMULATE THE OPERATION OF THE MODEL

Use Matlab/Simulink software with MPC controller to simulate system operation. Choosing to simulate a car running on the highway, the acceleration of the vehicle in front changes in a sinusoidal shape during simulation, the output of the adaptive throttle control unit is the acceleration signal of the car with adaptive throttle.

Based on the minimum safe speed and distance regulations [6], the selection of simulation conditions parameters is as follows: Initial position of the vehicle ahead: $x_{0\_pt} = 100$ (m); Initial speed of the vehicle ahead: $v_{0\_pt} = 28$ (m/s); The initial position of the vehicle with adaptive throttle: $x_{0\_tu} = 0$ (m); Initial speed of the vehicle with adaptive throttle: $v_{0\_tu} = 16.8$ (m/s).

Input parameters for the simulation model: Set speed (V_{dat}), The set is changed to simulate for two cases: Control the speed of the vehicle with the throttle adaptively to the set speed when the vehicle velocity in front is greater than the set speed, and Control the speed of the vehicle with the throttle adaptively to ensure a safe distance when the vehicle speed in front is small than set velocity. The output parameter of the model is the acceleration of the adaptive throttle vehicle.

Simulation results:

- Where $V_{dat} = 22.4$ (m/s) controls the set velocity, shown in Fig. 4: The acceleration of the throttle vehicle is then gradually reduced and by the 5th second the acceleration is zero; correspondingly, the speed of the throttle vehicle prefers to increase to the set velocity (5th second), it remains the same; Because the set speed of the adaptive throttle vehicle is smaller than the vehicle speed ahead, the distance between the two vehicles increases compared to the safe distance.

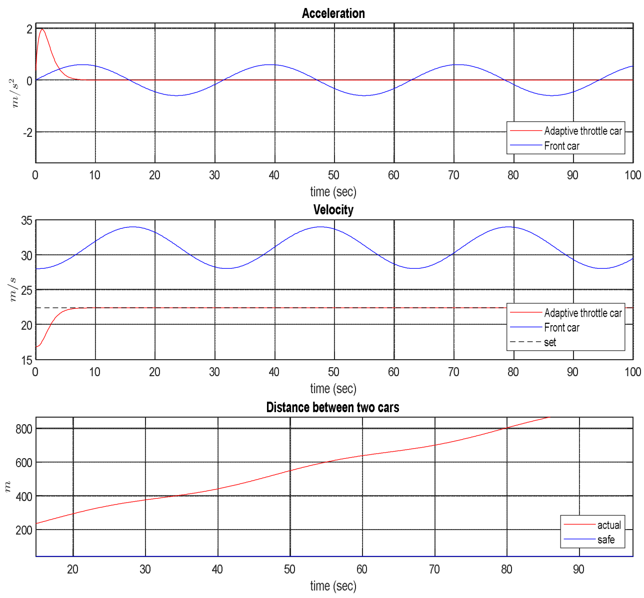

Figure 4. Acceleration representation of adaptive throttle vehicle and vehicle ahead when $V_{dat} = 22.4$ (m/s)

- Where V_{dat} = 33.6 (m/s) controls to maintain a safe distance, shown in Fig. 5: The acceleration of the vehicle with positive throttle then decreases and by the 10th second the acceleration is zero then from the 45th second the acceleration follows the vehicle ahead; correspondingly, the speed of the throttle vehicle prefers to increase to the set velocity (10th second) and from the 45th second the control follows the vehicle velocity ahead; Since the set speed of the adaptive throttle vehicle is greater than the vehicle speed in front, the distance between the two vehicles gradually decreases and by the 45th second begins to control the distance to maintain a safe distance.

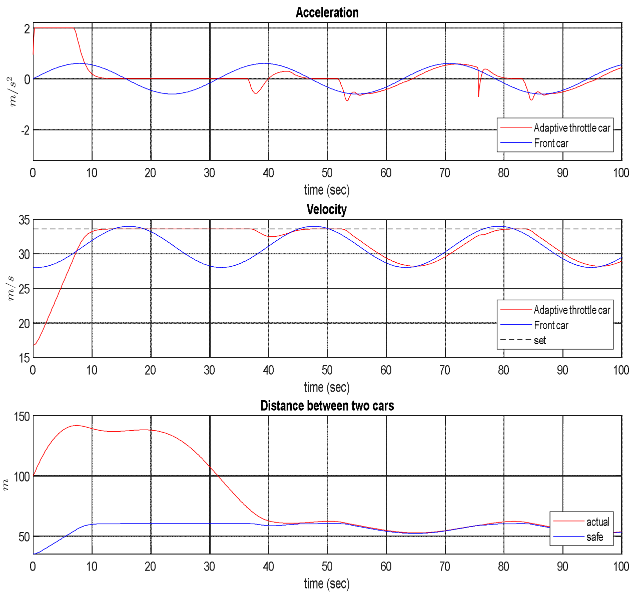

Figure 5. Acceleration representation of adaptive throttle vehicle and front vehicle when V_{dat} = 33.6 (m/s)

5. CONCLUSIONS

The article models and simulates the adaptive throttle system installed in a car, simulated by Matlab/Simulink software in 2 modes: Speed control when the speed of the vehicle fitted with the adaptive throttle system is less than the speed of the vehicle in front and the set speed; Distance control when the speed of the adaptive throttle vehicle is greater than the speed of the vehicle in front and the distance to the vehicle in front is less than the safe distance. The simulation results show the effectiveness and reliability of the research model. The controller ensures that the actual distance between the two vehicles is greater than the set safe distance. When the actual distance is large enough, then the controller ensures that the vehicle with the accelerator adapts to the speed set by the driver.

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THÔNG TIN TÁC GIẢ

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