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Design and Implementation of the Intelligent Stop and Go System in Smart Car, TAIWAN *i*TS-1

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Abstract—**In this paper, the intelligent Stop and Go system (S&G) is designed and implemented for low speed traveling vehicles in urbane area. The human-driving like fuzzy logic control is applied for achieving desired speed and safe inter-vehicle spacing. By proposed intelligent Stop and Go system, the following functions can be obtained including collision avoidance, traffic accidence reduction, driving pressure decrease, and increment of traffic capability. Furthermore, the real car equipped with sensors and a longitudinal controller is provided to demonstrate three scenarios that meet the situations of low speed vehicles in urban area. Three seniors include pedestrian crossing, stop in front of obstacle, and Stop and Go. The application of proposed intelligent Stop and Go system is possible for low speed driving assistance in urban area by our experimental results.**

I. Introduction

The main objective of the intelligent transportation system (ITS) is to integrate man, vehicle, and information of roadway for providing a safe environment of transportation and solving practical traffic problems. In the researches of intelligent vehicle, how to apply technologies of electronic, information, machine and sensor in ITS has became a popular subject for mobile industries and academic organizations. One of ITS technologies is how to increase the traffic capability by intelligent vehicle. In highway, the speed of vehicles locates in 40 km/h to 170 km/h and the preceding vehicles keep traveling. Therefore, the adaptive cruise control (ACC) is a popular method for increasing capability of traffic. On the contrary, in urban area, the speed of vehicles is less than 40 km/h and the preceding vehicles stop and go frequently. The intensive attention causes the sufferance of driver's sprit, and even more, leads to traffic accidents. It is driver's nightmares. Furthermore, in this situation, the traffic capability is reduced and much time is spent for drivers. Therefore, the Stop and Go (S&G) is developed to deal with these problems. Our work is to design an intelligent stop and go system (ISGS) for solving previous mentioned problems and is verified in a real car.

Recently, the researches of S&G basically can be classified into four fields including human driving comfortable consideration, robust control, intelligent control, and others. In human driving comfortable consideration [1-4], the researches consider how to generate the proper reference signal for controller to let driver feel comfort by LQ, statistical analysis, least square method, and least-squared with forgetting factor respective papers. By these approaches, the design of controller will be simpler than incorporating comfortable consideration into controller. About robust control, [5] uses the second order sliding mode control to implement the stop and go system in a real car. The model match control (MMC) based on sliding mode control is applied into S&G in [6]. The MMC based on sliding mode control is more robust and rapid response than MMC based on conventional PID controller. In intelligent field, the fuzzy logic controller is applied into electronic vehicle control rather than conventional vehicle in [7]. The other researches including, study in S&G longitudinal vehicle model and vision-based S&G for longitudinal and lateral are addressed in [8] and [9], respectively.

Our work achieves the characteristics of safety, humanization and efficiency in ITS. In the following, the functions of our work are provided to satisfy three kinds of characteristics. The functions of our work contain collision avoidance, traffic accidence reduction, scanning dead space elimination of radar, driving pressure decrease, controller with intelligent human-like driving behavior consideration, and increment of traffic capability. Finally, three scenarios including pedestrian crossing, stop in front of an obstacle, and S&G are demonstrated.

The paper is organized as follows. In Section II, the overall structure of ISGS is specified. The experimental results including three scenarios are exhibited in Section III. Finally, the conclusions are given in Section IV.

II. Intelligent Stop and Go System

In this section, the overall design structure of ISGS and, longitudinal model of S&G are introduced.

A. The Overall Structure of an Intelligent Stop and Go System

The overall design structure is shown in Fig. 1. The vehicle sensors, including laser range finder for distance measurement, velocity sensor, and sensors of braking pedal and throttle angle position are adopted. The measured states are transferred into fuzzy logic controller, which commands the vehicle to follow a given speed and safety spacing by throttle and braking systems. In the case of an existing front obstacle, the vehicle will stop completely with safety distance. When the obstacle vanishes, the vehicle will go forward as preset velocity.

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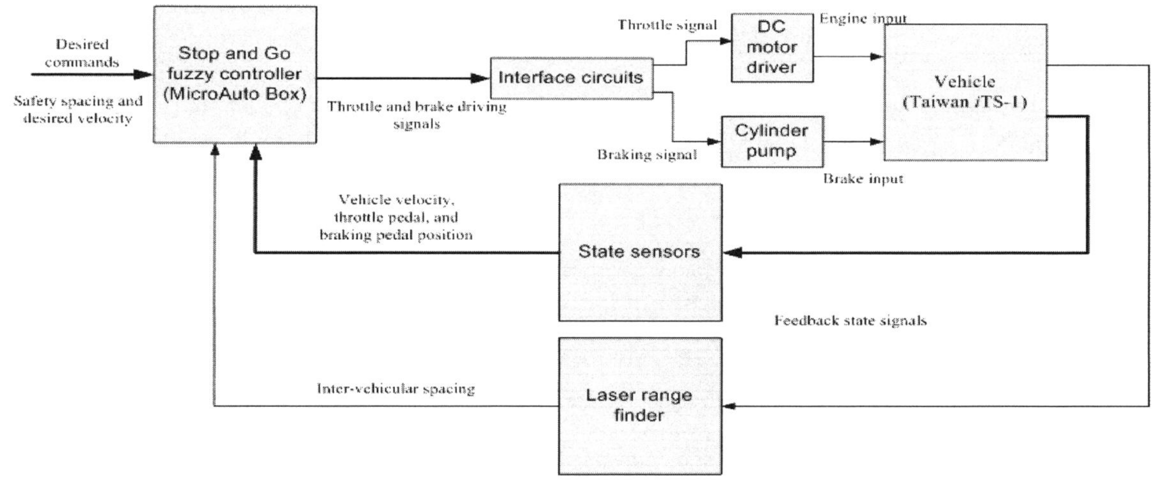


Fig. 1 The overall structure of ISGS

B. *Longitudinal Model of Stop and Go [7],[8]*

Basically, longitudinal vehicle dynamic is complex and nonlinear. It contains engine and transmission systems, brake system, and drive train system as shown in Fig. 2. The real car, TAIWAN, *i*TS-1 provided by China Motor Corporation, is shown in Fig.3. The relative parameters of real car are listed in Table 1. Assumptions of no torsion of driving axle and slip at the wheel are considered for simplify of longitudinal S&G vehicle model [8]. The distinct components of longitudinal vehicle model of S&G can be listed as following [7].

1) I/O of Engine and transmission systems
   - Input: Throttle angle (i.e. Engine input)
   - Output: Driving engine torque
   - Output (engine torque) dependent on
     - Engine input
     - Gear ratio of transmission system
     - Vehicle speed and wheel speed
   - Gear ratio is a nonlinear function of the engine input
2) I/O of Brake system
   - Input: Brake input
   - Output: Braking torque
   - Braking torque is a nonlinear function of braking pressure
3) I/O of Drivetrain
   - Input: Driving engine torque and braking torque
   - Output: vehicle speed/acceleration
   - Drivetrain is effected by wheel inertia and external disturbance (aerodynamic drag, rolling resistance, and climbing torque)

The more detail mathematical descriptions of longitudinal S&G vehicle model can be referred in [8].

Due to the nonlinearity of vehicle model, uncertainty of vehicle parameters and external disturbances from aerodynamics and road condition, the fuzzy logic is a better choice for controller design.

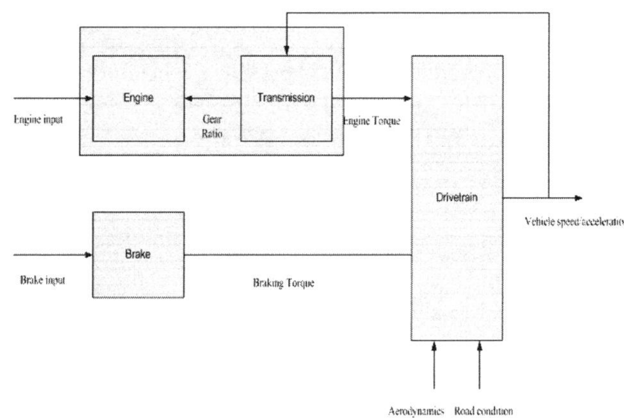


Fig. 2 Longitudinal vehicle model of S&G [7]

Fig. 3 TAIWAN *i*TS-1

TABLE I
THE RELATIVE PARAMETERS OF TAIWAN *i*TS-1

MISUBISHI SAVRIN 2.4	
Engine type	L4 DOHC 16V VVT+DDM
Exhaust	2400 c.c.
Horsepower (hp/rpm)	150/6250
Torsion (kgm/rpm)	19.2/3000
Transmission	INVECS-II SPORT-MODE 4 A/T
Weight	1640 kg

III. Intelligent Fuzzy Logic Controller

In our design as shown in Fig. 4, the fuzzy logic controller is adopted, because accurate mathematical model and imprecise inputs are not needed. Moreover, it can handle nonlinearity and uncertainty rather than conventional nonlinear controller. Finally, the linguistic control laws are like the driving behavior of human being. In our design, two fuzzy logic controllers for throttle and brake systems are applied to achieve desired commands including safety distance (D_d) and desired velocity (v_d). The PID (K_{PB} , K_{IB} , and K_{DB}) and PD (K_{PT} and K_{DT}) gains are tuned properly for imitating human driving behavior. The membership functions and rule tables of fuzzy logic controllers for throttle and brake systems are shown in Figs. 5 and 6, respectively. The switching mechanism bases on whether $D \geq D_d$ is or not. D is the inter distance measured by laser range finder. If $D \geq D_d$, the braking driving signal is enable. On the other hand, if $D < D_d$, the throttle driving signal is enable.

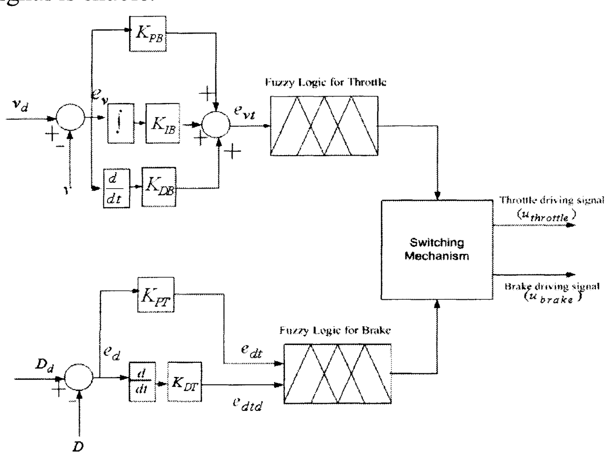
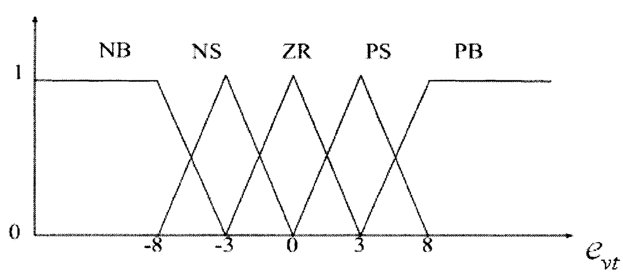
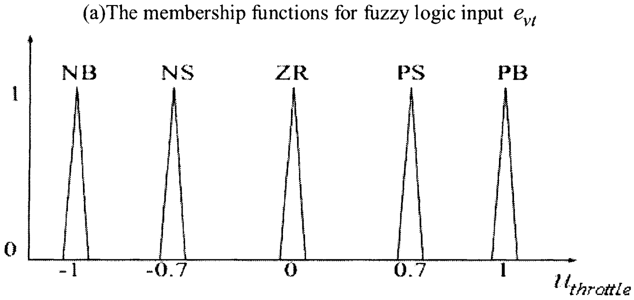


Fig. 4 The Structure of intelligent fuzzy logic controller



(a)The membership functions for fuzzy logic input e_{vt}

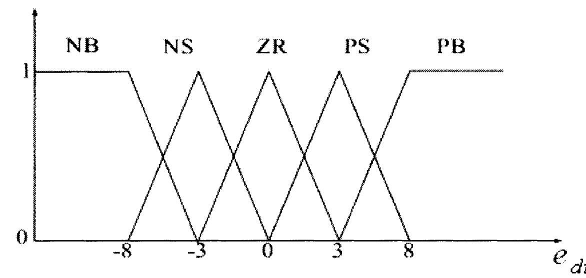


(b)The membership functions for fuzzy logic output $u_{throttle}$

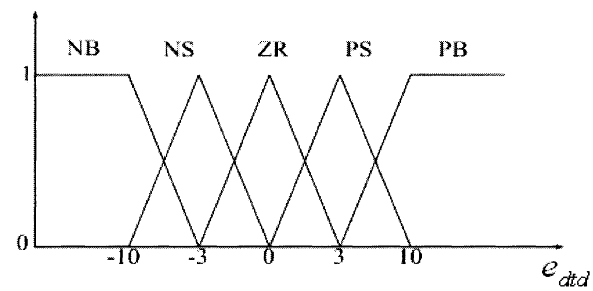
e_{vt}	NB	NS	ZR	PS	PB
u_{brake}	NB	NS	ZR	PS	PB

(c) The rule table for fuzzy logic of throttle control

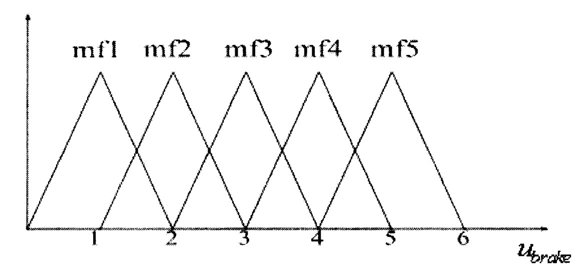
Fig. 5 Membership functions and rule table for throttle system



(a) The membership functions for fuzzy logic input e_{dt}



(b) The membership functions for fuzzy logic input e_{dtd}



(c) The membership functions for fuzzy logic output u_{brake}

e_{dtd} \ e_{dt}	NB	NS	ZR	PS	PB
NB	mf1	mf1	mf1	mf1	mf1
NS	mf1	mf1	mf1	mf3	mf5
ZR	mf4	mf4	mf4	mf4	mf5
PS	mf5	mf5	mf5	mf5	mf5
PB	mf5	mf5	mf5	mf5	mf5

(d) The rule table for fuzzy logic of brake control

Fig. 6 The membership functions and rule table for brake system

IV. Experiment Results

In this section, the equipments in TAIWAN *i*TS-1 will be described first. Three kinds of scenarios are arranged to meet the traffic situations in urban area. The results show that proposed ISGS can be applied into real application.

A. Vehicle Equipments

The equipments in TAIWAN *i*TS-1 as shown in Fig. 7 can be described as following:

1) In-Vehicle Controller: The intelligent fuzzy logic is implemented in real-time hardware MicroAutoBox to generate throttle and brake driving commands for achieving desired signals.
2) Sensors: The laser range finder is provided to measure inter-vehicle distance and designed to eliminate the dead space of scan for safety as shown in Fig. 8. The total scan angle of radar is 100° ($40^\circ \sim 140^\circ$). The scan angle $83^\circ \sim 97^\circ$ of laser range finder is chosen to detect the distance with respect to preceding vehicle. The additional 3° in both sides are used to detect obstacles for reducing the dead space of scan. The velocity is measured from appearance of vehicle speed. The positions of throttle angle and braking pedal are measured by throttle and brake position sensors respectively.
3) Braking System: The cylinder pump mechanism is used to force the braking pedal to achieve proper action.
4) Throttle System: The DC motor controlled by PWM is applied to control the angle of throttle.
5) Power System: The power system including inverters and two batteries is provided for MicroAutoBox, computer, and interface circuits.
6) PC: The PC is provided for recoding all data from in-vehicle sensors.

B. Experimental Scenarios

The experiment with TAIWAN *i*TS-1 is held at a public parking lot. In the following, three scenarios are demonstrated for verifying the feasibility of our ISGS.

1) Scenario 1: Pedestrian crossing (velocity15 km/h, safety distance 4m and automatic start-up)

In this scenario, the real car approaches at 15 km/h, then the pedestrian in front of vehicle 15m is detected. This information is sent to the controller, and the cylinder pump mechanism is acted to brake real car before the pedestrian 4m. After pedestrian crosses the road, the real car will go forward continuously as set velocity 15 km/h. The relative experimental data is shown in Fig. 9.

2) Scenario 2: Stop in front of an obstacle (velocity 15 km/h and safe distance 7m)

In the following, an obstacle appears in front of vehicle, and the vehicle will enable brake before 14m of this obstacle. The vehicle will stop before the safety distance 7m. Fig. 10 shows the relative experimental data.

3) Scenario 3: Stop & Go (star-up distance 5m and safe distance 3m)

Due to the traffic jam getting worse day by day, in this scenario, the situation of traffic jam is considered. In this situation, all vehicles stop and go by front vehicles in 0~5 km/h one by one slowly. The ISGS is designed for reducing driver spiritual loads.

In this scenario, by the distance and velocity of front vehicle measured with laser range finder, the fuzzy logic controller will control throttle and brake to follow front vehicles.

From Fig. 11, when the inter distance is larger than 5m, the experimental vehicle will follow up and stop before front vehicle 2~3m. Therefore, the intelligent stop and go systems will reduce the spiritual load and increase the traffic capability.

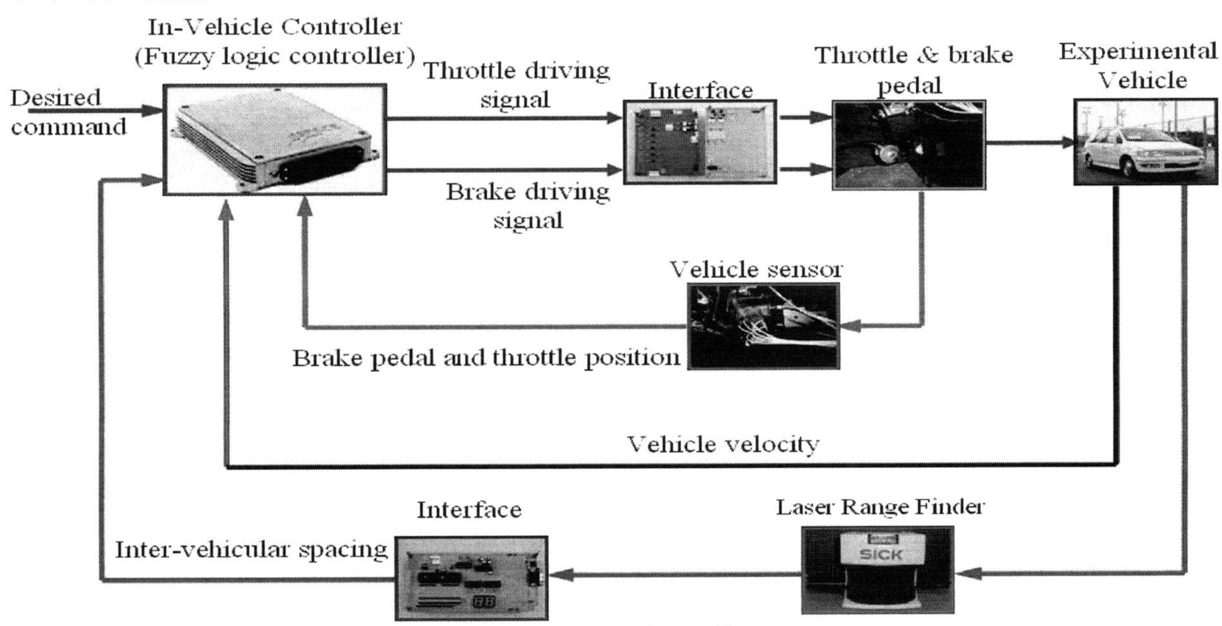


Fig. 7 The control structure of ISGS with equipments

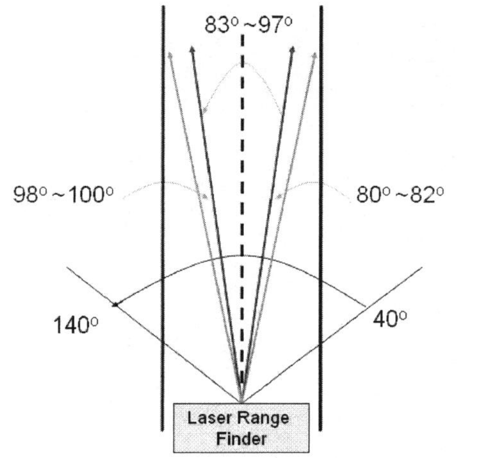


Fig. 8 Dead space elimination approach of laser range finder scan

V. CONCLUSION

By our developed technology and tested on real roads, the application of intelligent stop and go can be utilized to improve the traffic situation. Three scenarios including pedestrian crossing, stop in front of an obstacle, and stop & go have been demonstrated on the real road for verifying the feasibility of the proposed ISGS.

ACKNOWLEDGMENT

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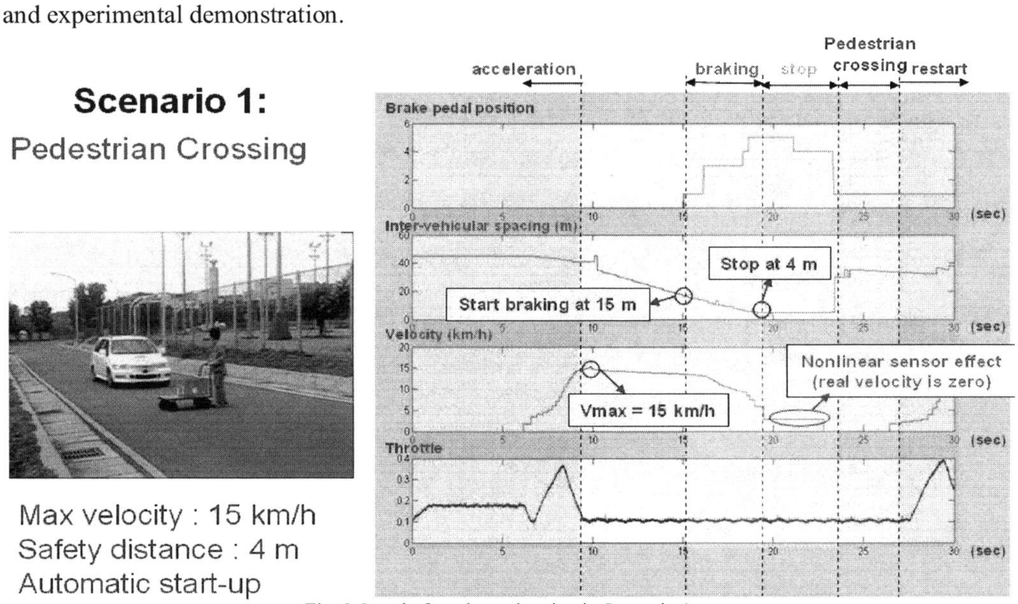

Fig. 9 Stop before the pedestrian in Scenario 1

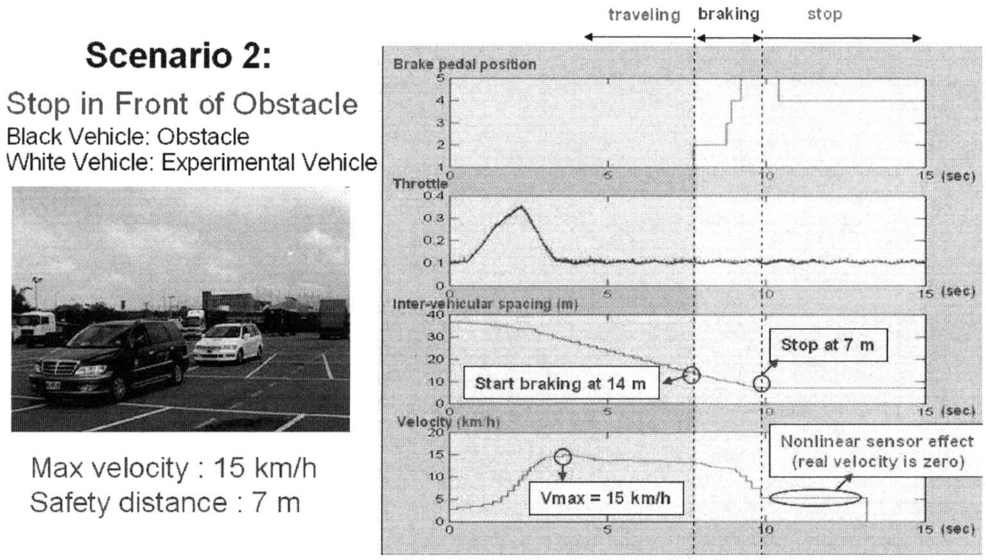

Fig. 10 Stop in front of obstacle in Scenario 2

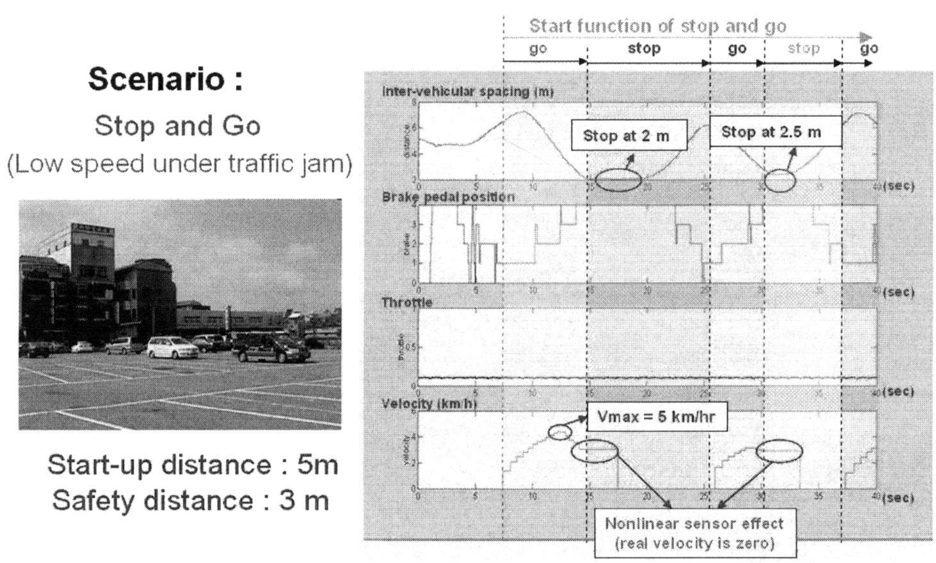

Fig. 11 S&G in Scenario 3