Driving Safety Support Systems based on Driver Behavior

Keqiang LI,

Lei ZHANG, Feng GAO, Jianqiang WANG, Dezao HOU

Tsinghua University

P.R. China

Outline

Background

Driver Safety Distance Model and Driver behavior

Controller Design of Driving Safety Support Systems

Experimental Platform of Driving Safety Support Systems

Experiment Results of Driving Safety Support Systems

Conclusion

Background

- Road Traffic Safety
- Intelligent Transportation Systems
- Driving Safety Support Systems

Road Traffic Safety

Statistical result of road traffic accidents in China

Accidents amount	Death Toll	Injury Toll
517889	107077	480864

Statistical result of Vehicle collision accidents

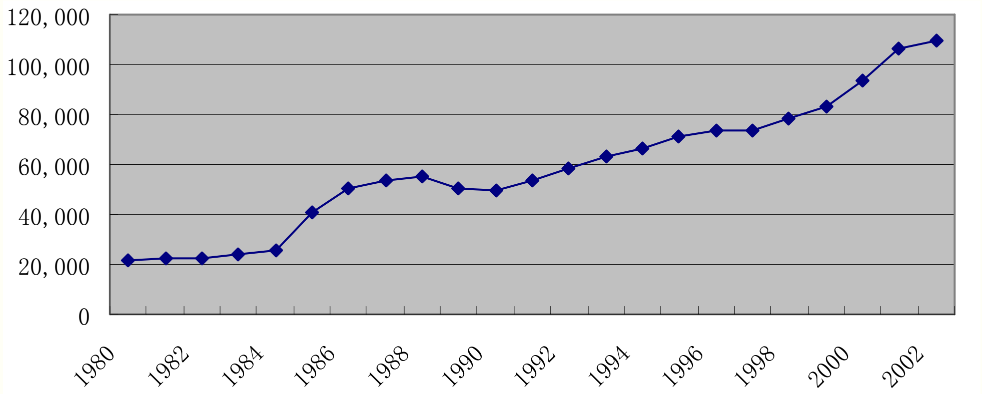
	Accidents amount (%)	Death (%)	Injury (%)
Head-on Collision	23.9%	29.6%	26.7%
Side Collision	38%	27.9%	38.8%
Rear-end Collision	15.5%	14.4%	12.6%
Total	**77.4%**	**71.9%**	**78.1%**

Deaths due to traffic accidents per 100 million vehicles

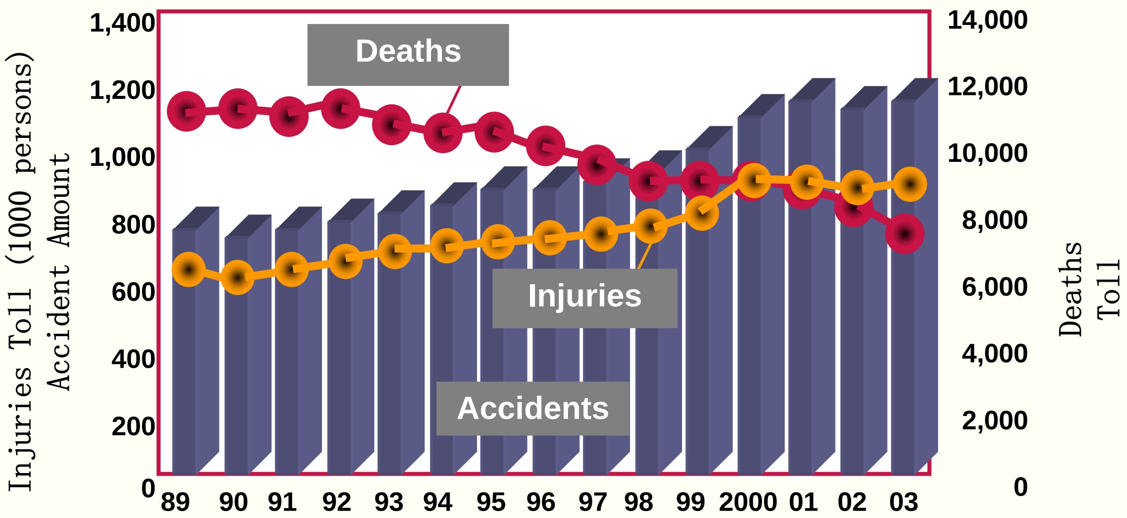
Japan	USA	China
110	220	4000

Road Traffic Safety

Deaths due to traffic accidents in China from 1990 to 2002



Traffic accidents in Japan from 1989 to 2003

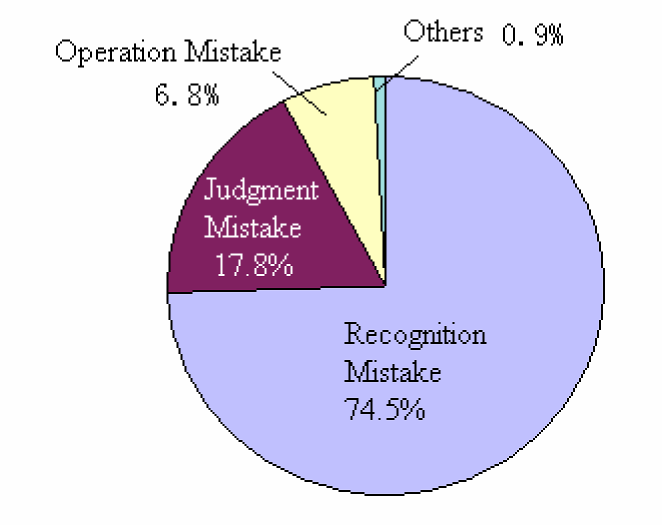


Road Traffic Safety

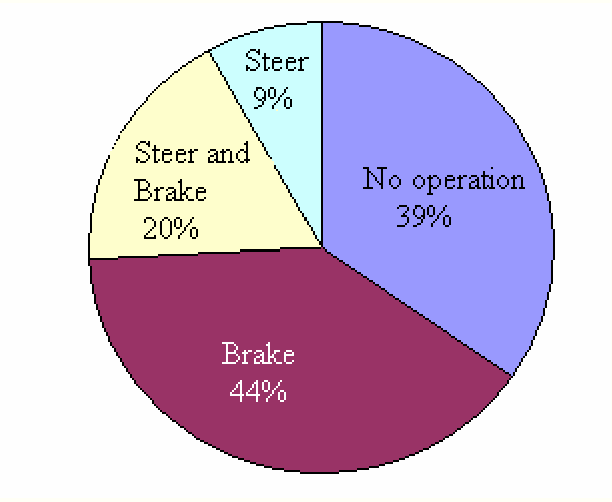
Statistical result of accidents caused by drivers' mistake

Accidents amount (%)	Death (%)	Injury (%)
89.8%	**87.4%**	**90.6%**

Accident Cause



Driver's operation to avoid collision

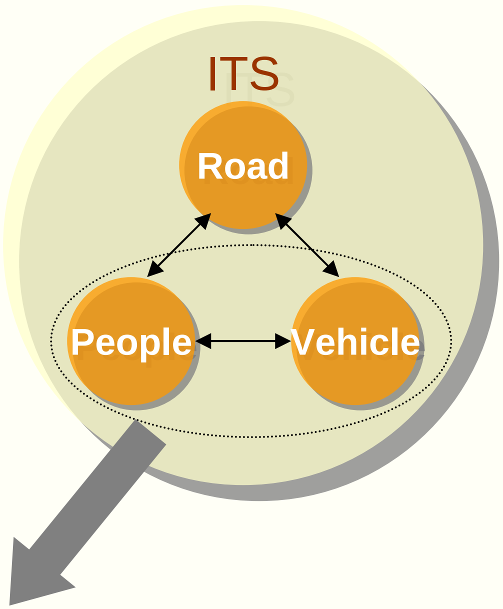


- **About 90% accidents are caused by drivers' mistake**
- **About 40% drivers take no operation when collision will happen**

Intelligent Transportation Systems

Technology fields —— Computer, Information, Communication, Control, Sensor Technology, etc.

Target—— To solve the problems such as road accidents, traffic jams, environment pollution, and energy consumption.



Subsystems

Advanced Traffic Management Systems, ATMS
Advanced Traveler Information Systems, ATIS
Advanced Vehicle Control and Safety Systems, AVCSS
Commercial Vehicle Operations, CVO
Advanced Public Transportation Systems, APTS
Advanced Rural Transportation Systems, ARTS

Driving Safety Support Systems

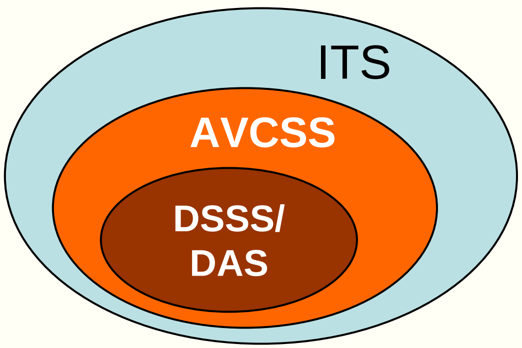
Driving Safety Support Systems, DSSS

Concept ——

A subsystem of Universal traffic Management Systems (UTMS) launched by National Police Agency, Japan

The main concept of the system is “Support of safe driving ”.

Similar system —— Driver Assistance Systems, DAS



Advanced Vehicle Control and Safety Systems

The Second Level——Automated Vehicle

The First Level —— DSSS

Driving Safety Support Systems

Main function of Driving Safety Support Systems

Acquire vehicle parameters and traffic environment, and provide necessary information to drivers.

Detect latent danger and warn drivers.

Control the vehicle to avoid collision automatically in an emergency

Help drivers to finish partial driving work to reduce drivers' workload.

Some application of DSSS

Frontal Collision Avoidance

Side Obstacle Collision Avoidance

Collision Warning

Lane Keeping Support

Speed Headway Keeping

…….

DSSS is an effective technology which could improve road traffic safety and avoid drivers' mistake.

This research including:

Frontal Collision Avoidance/Warning

Lane Keeping Support

Speed Headway Keeping

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Driver Experiments

Experiment Purpose —— To research drivers' behavior and acquire drivers' characteristic parameters

Experiment Objects —— 40 drivers, age range: 28 to 56 years old;
driving experience: 2 to 37 years;
sex ratio: 35:5。

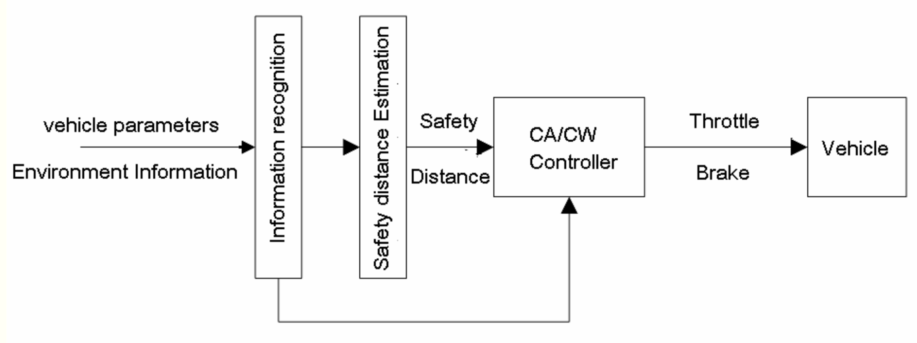
Experiment Project —— 2 test vehicles,
car following
vehicle speed range:
20 to 80km/h

Data Record —— vehicle speed, distance,
relative speed,
following vehicle's acceleration,
brake signal, throttle position, etc.

Driver safety distance model

Safety distance ——

The key parameter used to estimate Vehicle's safe state



Safety distance based on driver

$$D_s = \frac{v_r^2}{2\delta_a} + d_{fl}$$

δ_a ——driver's anticipant relative acceleration d_{fl} ——the distance while the following car's speed is equal to the leading car during braking

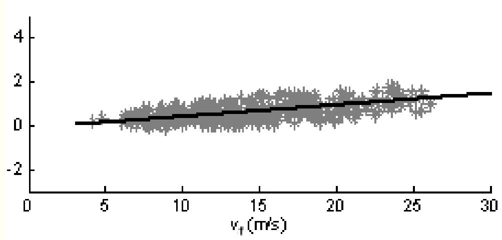
polynomial expression

$$D_s = \frac{v_r^2}{2\times(0.0524 v_c - 0.1215)} + 0.8509(v_c + v_l) + 1.6109$$

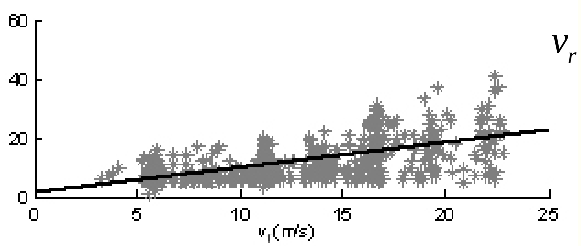
v_f ——Following car speed

v_l ——Leading car speed

v_r ——Relative speed



δ_a (m/s²)—v_f (m/s)



d_{fl} (m)—v_l (m/s)

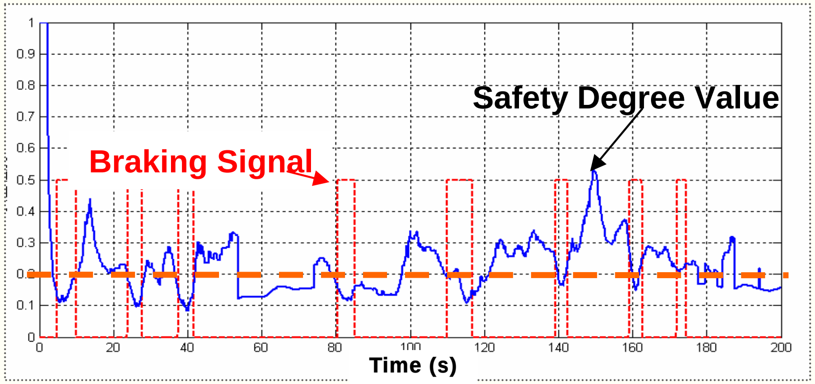
Driver braking behavior

Define safety degree value C_{safe} based on typical braking process

$$a_l \le a_{LM} = \frac{(v_f + v_r)^2}{2(-d_0 + \frac{v_f^2}{2a_{Max}} + v_f(T_r + T_{sys}))}$$

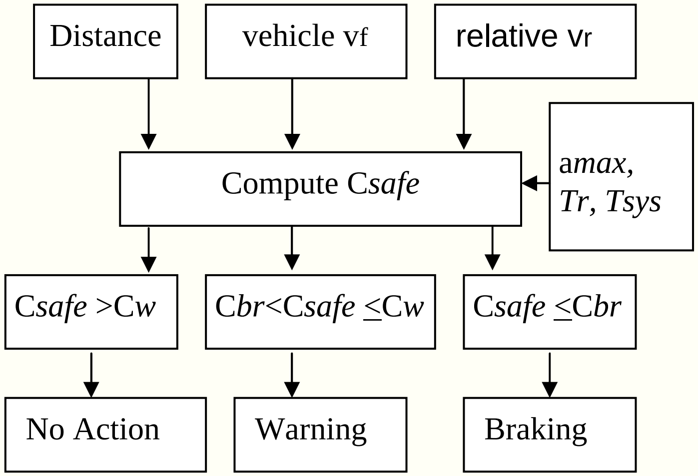
$$C_{safe} = \frac{a_{LM}}{a_{Max}}$$

—— figure out the driver's estimation of safety and braking behavior

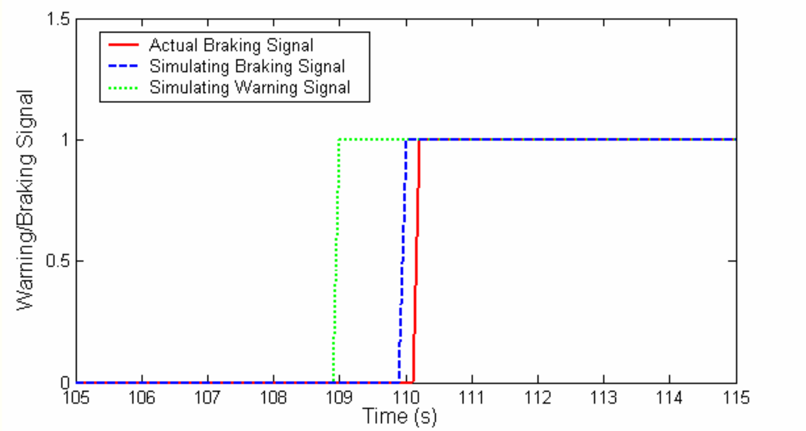


Driver's safety degree value during car following

Warning Strategy based on C_{safe}



Structure of warning strategy



Simulation result of warning strategy

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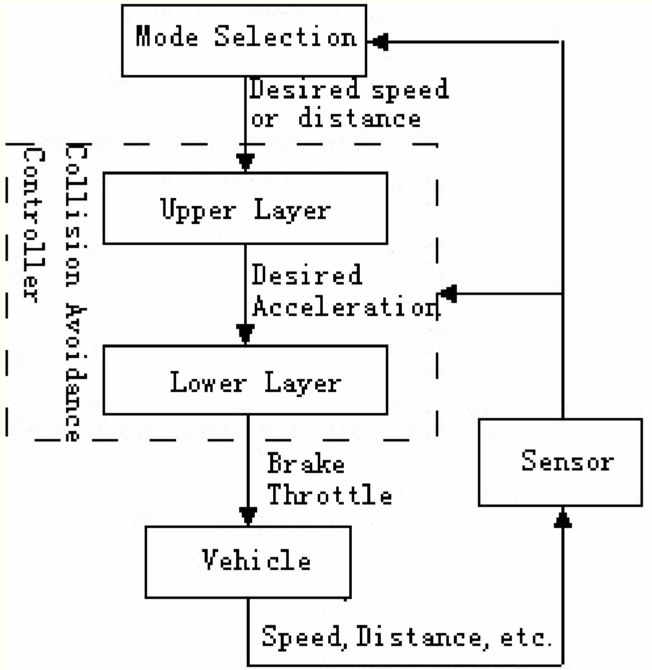
Controller Design

Hierarchical control system

Mode selection——
Working mode, which includes automatic mode and assistant mode, is selected by the driver.

Upper layer——
Determining desired acceleration by control algorithm according to working mode, safety distance and vehicle state.

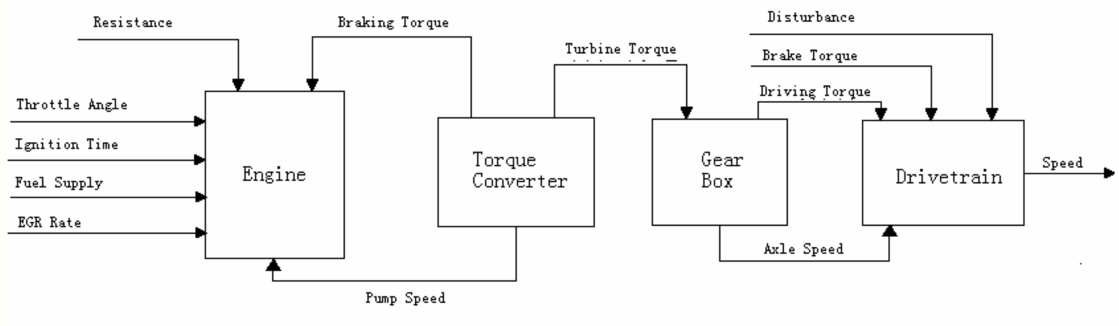
Lower layer——
Determining throttle/brake commands required to track desired acceleration.



Controller Design

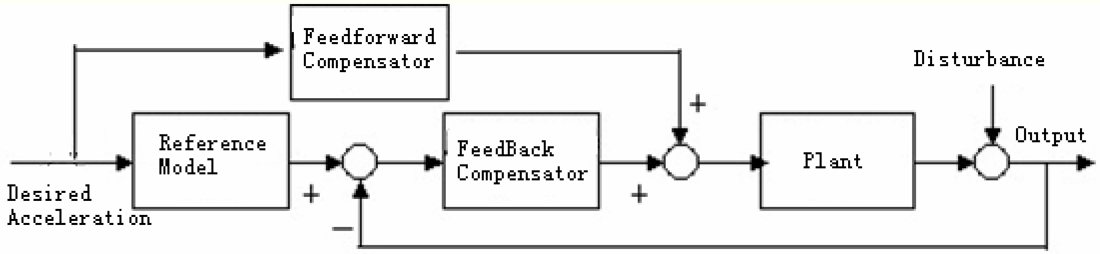
Key Technologies:

Vehicle longitudinal model



Upper layer controller—— A hybrid algorithm by combing LQ and TEM method

Lower layer controller—— Two degree of freedom control method based on MMC and $\mathbf{H}_\infty$ control theory



Lower layer controller

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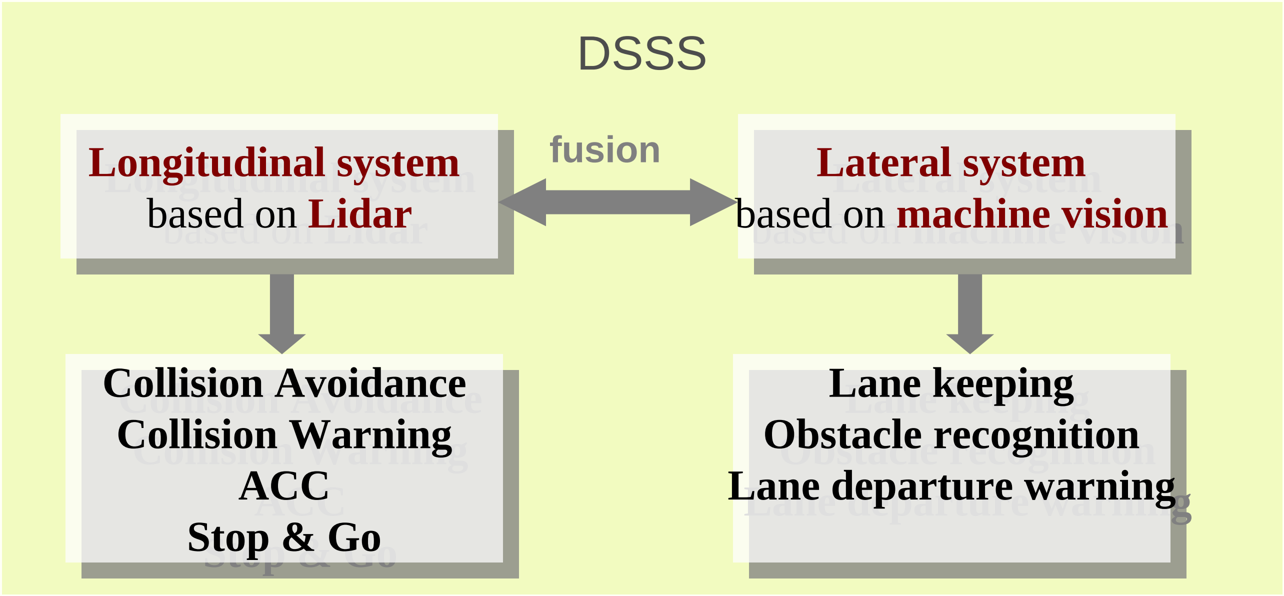
Experimental Platform

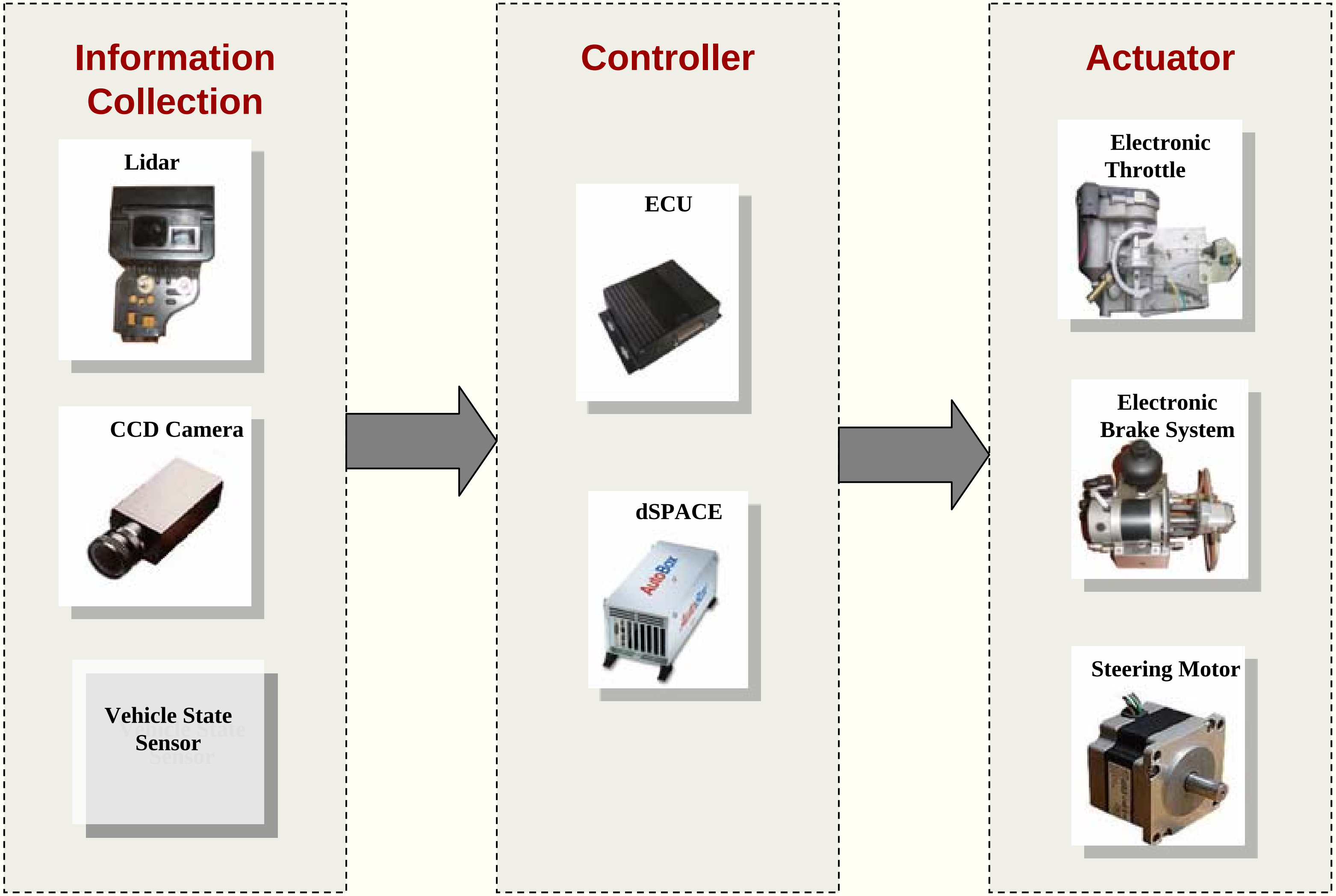
Design and refit based on normal vehicle

The information, parameters and control signal are transferred through CAN bus

Modular design
3 main modules including information collection, controller and actuator

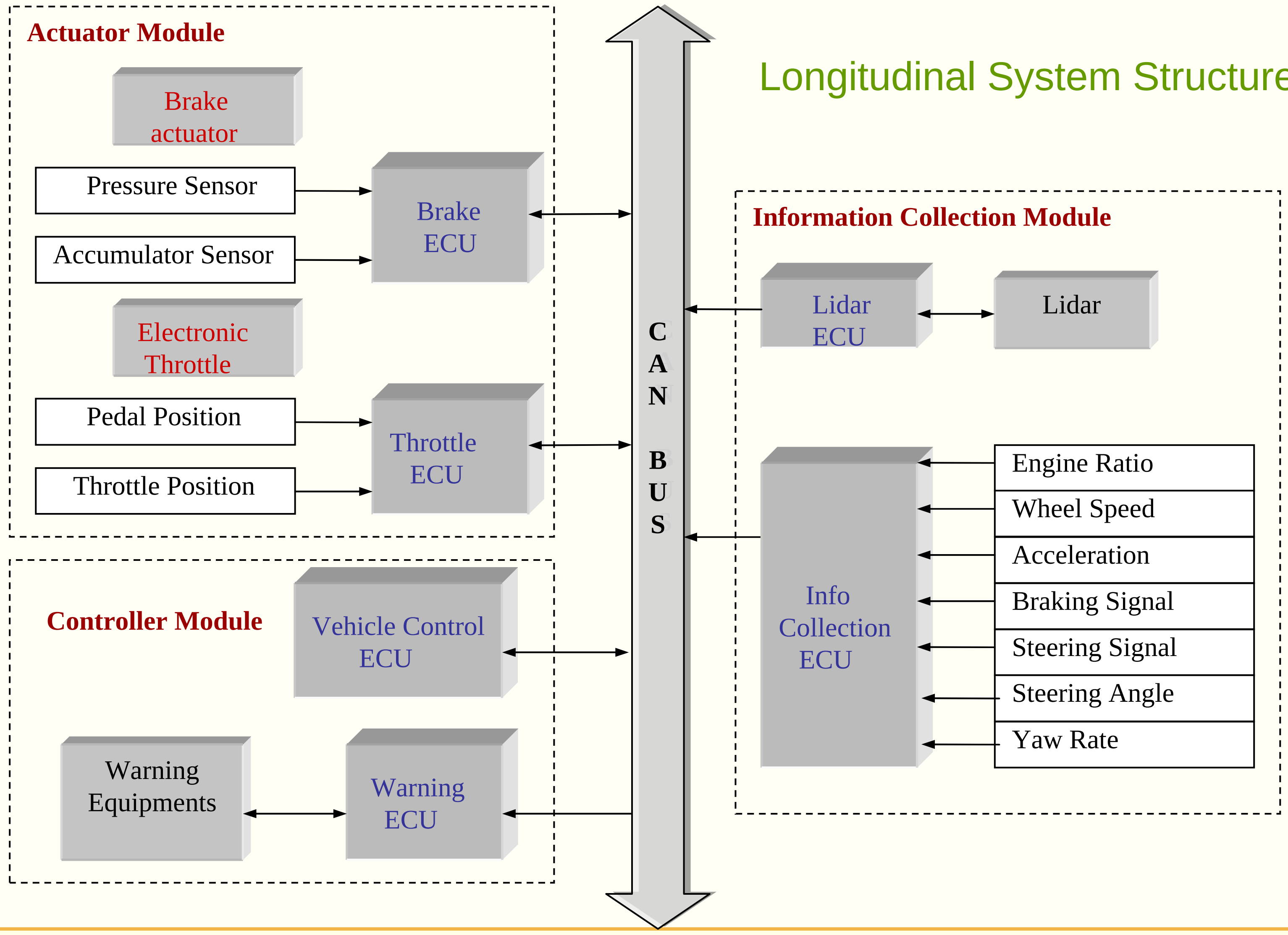


Experimental Platform



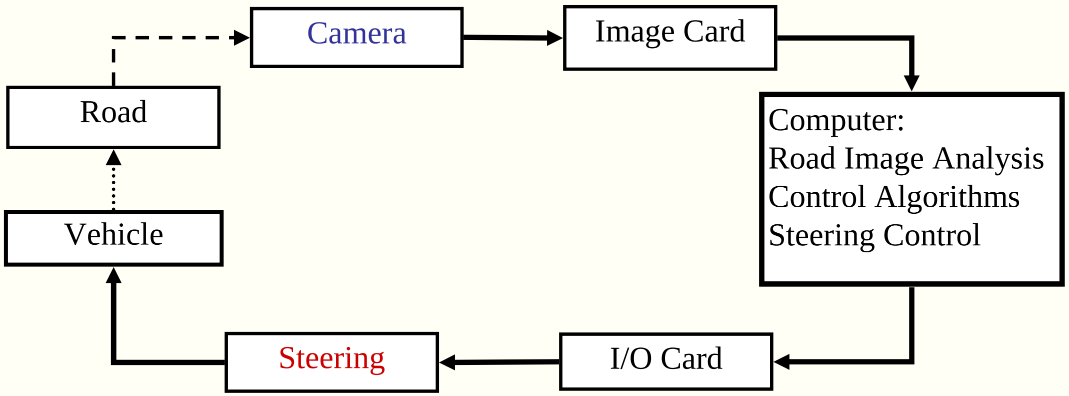
Experimental Platform

Longitudinal System Structure

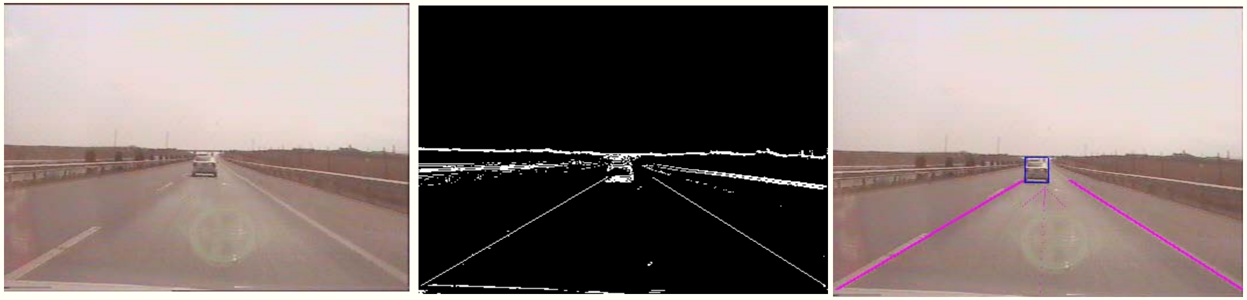


Experimental Platform

Lateral System Structure



Lane recognition and Obstacle recognition



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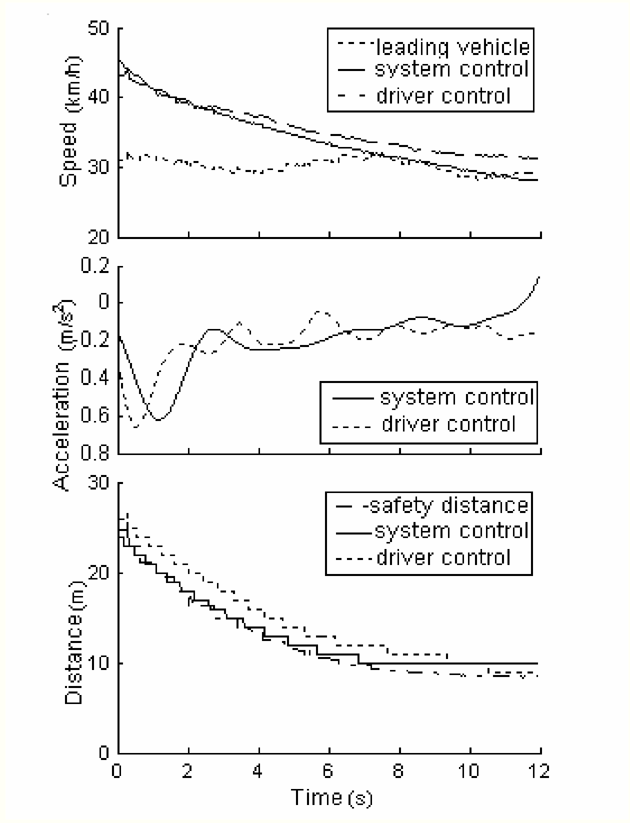
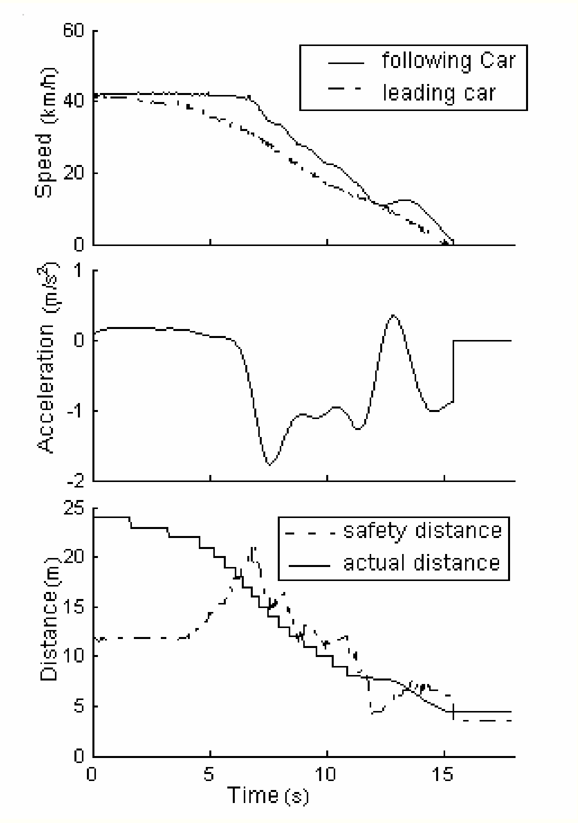
Experiment result of DSSS

1. Experimental results of Collision Avoidance Systems on normal road



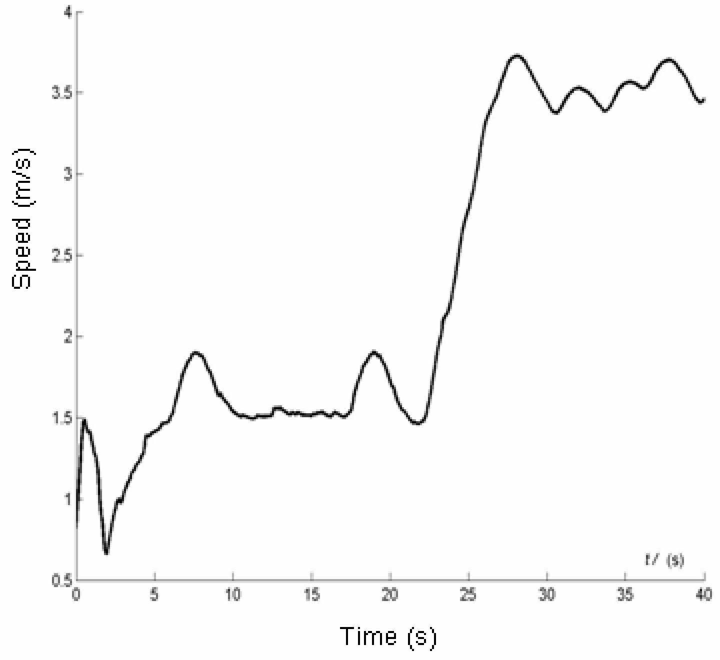
(a) Approaching



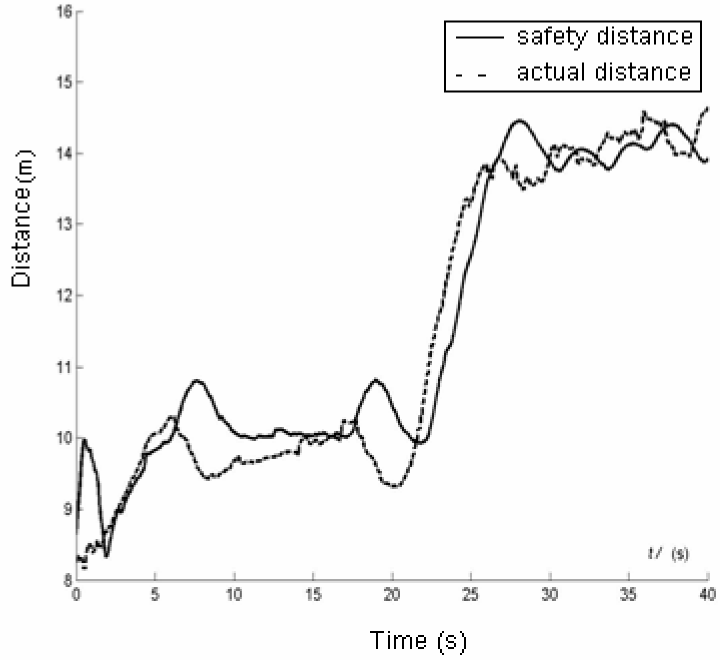
(b) Leading car braking suddenly

Experiment result of DSSS

1. Experimental results of Car-Following systems on normal road



(a) Test car's speed response



(b) Distance response

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Technologies of Driving Safety Support Systems are developed to avoid collision accidents and drivers' mistake.

A driver safety distance model is established based on vehicle following and braking experiments.

An experimental platform of Driver Safety Support Systems is constructed and the functions including collision warning/avoidance, vehicle following and lane keeping are implemented.

The simulation and experimental results show that the systems could support the drivers and raise road traffic safety effectively.

The End

Thank You for Your Attention