Driving Safety Support Systems based on Driver Behavior

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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

<table>
<thead>
<tr>
<th>Accidents amount</th>
<th>Death Toll</th>
<th>Injury Toll</th>
</tr>
</thead>
<tbody>
<tr>
<td>517889</td>
<td>107077</td>
<td>480864</td>
</tr>
</tbody>
</table>

Statistical result of Vehicle collision accidents

<table>
<thead>
<tr>
<th></th>
<th>Accidents amount (%)</th>
<th>Death (%)</th>
<th>Injury (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head-on Collision</td>
<td>23.9%</td>
<td>29.6%</td>
<td>26.7%</td>
</tr>
<tr>
<td>Side Collision</td>
<td>38%</td>
<td>27.9%</td>
<td>38.8%</td>
</tr>
<tr>
<td>Rear-end Collision</td>
<td>15.5%</td>
<td>14.4%</td>
<td>12.6%</td>
</tr>
<tr>
<td>Total</td>
<td>77.4%</td>
<td>71.9%</td>
<td>78.1%</td>
</tr>
</tbody>
</table>

Deaths due to traffic accidents per 100 million vehicles

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>USA</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>110</td>
<td>220</td>
<td>4000</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Accidents amount (%)</th>
<th>Death (%)</th>
<th>Injury (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>89.8%</td>
<td>87.4%</td>
<td>90.6%</td>
</tr>
</tbody>
</table>

Accident Cause
- Recognition Mistake: 74.5%
- Judgment Mistake: 17.8%
- Operation Mistake: 6.3%
- Others: 0.9%

Driver’s operation to avoid collision
- No operation: 39%
- Brake: 44%
- Steer: 9%
- Steer and Brake: 20%

- 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 First Level —— DSSS

The Second Level —— Automated Vehicle
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

\[ D_s = \frac{v_r^2}{2\delta_a} + d_{\beta} \]

\( \delta_a \) —— driver’s anticipant relative acceleration
\( d_{\beta} \) —— the distance while the following car’s speed is equal to the leading car during braking

polynomial expression

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

\( v_f \) —— Following car speed
\( v_l \) —— Leading car speed
\( v_r \) —— Relative speed

\( \delta_a (\text{m/s}^2) - v_f (\text{m/s}) \)

\( d_{\beta} (\text{m}) - v_l (\text{m/s}) \)

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Driver braking behavior

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

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

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

figure out the driver’s estimation of safety and braking behavior

Warning Strategy based on $C_{\text{safe}}$

Distance \hspace{1cm} vehicle $v_f$ \hspace{1cm} relative $v_r$

Compute $C_{\text{safe}}$

$a_{\text{max}}, T_r, T_{\text{sys}}$

$C_{\text{safe}} > C_w$ \hspace{1cm} $C_{\text{br}} < C_{\text{safe}} \leq C_w$ \hspace{1cm} $C_{\text{safe}} \leq C_{\text{br}}$

No Action \hspace{1cm} Warning \hspace{1cm} Braking

Structure of warning strategy

Driver’s safety degree value during car following

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 $H_{\infty}$ control theory
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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

DSSS

Longitudinal system based on Lidar
- Collision Avoidance
- Collision Warning
- ACC
- Stop & Go

Lateral system based on machine vision
- Lane keeping
- Obstacle recognition
- Lane departure warning

Collision Avoidance
Collision Warning
ACC
Stop & Go

Longitudinal system based on Lidar

Lateral system based on machine vision

fusion
Experimental Platform

**Information Collection**
- Lidar
- CCD Camera
- Vehicle State Sensor

**Controller**
- ECU
- dSPACE

**Actuator**
- Electronic Throttle
- Electronic Brake System
- Steering Motor

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Experimental Platform

Lateral System Structure

Lane recognition and Obstacle recognition
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1. Experimental results of Collision Avoidance Systems on normal road

(a) Approaching
(b) Leading car braking suddenly
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