The Fifth Annual Conference

Ground Vehicle Active Safety Systems

Huei Peng
Assistant Professor
Department of MEAM
University of Michigan
Active Safety is a Major Thrust of Intelligent Vehicle Techniques

- GPS
- Information
- Network
- AutoPC
- Radar
- System/Control techniques
- Modeling/Simulation
- Signal Processing/Warning
- Convenience
- Safety/security
- Quality
- Cleanness
Active Safety vs. Passive Safety

- Active safety: **Preemptive** measures to reduce the possibility of **crashes**.
- Passive safety: **Reactive** measures to reduce severity of **injuries**.

**Why active safety?**
- Passive safety techniques have seen dramatic **diminish in returns**.
- **Adverse trends** (weight, SUV) for passive safety.
- **Human errors**, a large contributing factor of crashes, cannot be mitigated by passive safety techniques.
Adverse Trend 1--Weight Reduction

- CAFÉ (and other environmental/economical factors) exerts a continuous pressure toward **reduced vehicle weight**.
- Weight reduction impacts safety adversely.
  - A 100-pound reduction in the average weight of all vehicles (both PCs and LTVs) would result in an estimated **increase of 10,543 incapacitating injuries** (DOT HS 808 575, January, 1997).

**Diminish in returns**

**Benefit of Airbag offset by weight reduction of 140 lb**

Source: IJVD v14 no2/3 1993
Adverse Trend 2--SUV/Light Trucks

UMTRI found that **2,000 fatalities** would have been prevented in 1996 if SUVs and light trucks/vans were replaced by same-weight passenger cars.

NHTSA reported (1999) that the probability of fatality is **2-4 times greater** when a car is struck by a SUV or light truck than by another car.

**Collision: Accord vs. Explorer**

Scenario: offset crash, both vehicles move at 35mph.
SUV/LT are more **aggressive** and are **not compatible** with cars
Human Drivers Could Benefit from Advance Warning

- **Human error** is thought to be the main factor for **75%** of all ground vehicle crashes. Even higher (80-90%) for commercial vehicles.
- **Human delays** (mean for brake reaction time ~0.75 sec) creates unwanted vehicle and traffic behavior.
  - It was found that 0.5 (1.0) second of advance warning could prevent 30-60% (60-90%) of the accidents.

Source: von Glasner AVEC’94 002 9437953
Active Safety Technologies

NHTSA’s vision
Active Safety Concepts

**Active Safety Experimental Vehicle**

- SOS vehicle stop switch
- Steering angle sensor (drowsy driving warning)
- Display inside instrument panel and HUD (next generation information)
- Fire extinguisher switch
- Gas sensor (fire alarm)
- Brake actuator (drowsy driving warning, collision reduction braking, SOS vehicle stop switch)
- Temperature sensor (fire alarm)
- Millimeter wave radar (headlight arrangement, collision reduction braking)
- Fire extinguisher nozzle (fire extinguishing)
- Head lamps (headlight arrangement)
- Thermal actuator for automatically releasing hood lock (fire extinguishing)
- CCD camera (blind corner)
- ECU for multiple systems
- "Crossing ahead" signal

**Alert and Warning System**

- "After you" signal (intervehicle information)
- Front stop lamp (headlamp based intervehicle information transmission system)
- Wheel speed sensor (fire pressure)
- Pulse sensor (drowsy driving warning)

**事故未然防止技術**

**事故回避技術**

**DELPHI Automotive Systems**
Collision Warning/Avoidance and Adaptive Cruise Control

Collision Warning/Avoidance

Time to Collision

Warning/Control distance

Adaptive Cruise Control

Mazda

Honda

Hedrick et al. SAE 09/98
CW/CA/ACC Development

S-class
Distronic

BOSCH
EATON
THOMSON-CSF
Lucas
VARITY

DELPHI
Automatic Braking
Throttle Control

AUTOMOTIVE RESEARCH CENTER

Vehicle Active Safety 11
What are the Critical Research Needs?

- **Status:**
  - Plenty of research/development efforts in product concepts/designs.
  - Products slowly trickle into the market *(cost? lack of confidence?)*
  - Arbitrary/ad hoc evaluation processes.
Real-World Performance of Active Safety Systems

--ABS example

• Fully modulating ABS for automobiles were first developed in the 1950’s
  – Ford: 1954 experimental Lincoln
  – Kelsey-Hayes: 1968 rear-wheel only system
  – GM (AC Electronics)” 1971 Olds Toronado rear-wheel only
  – Chrysler (uses Bendix system): 1971 Imperial 4-wheel ABS
ABS Penetration

- In 1997, 60% of new cars and 90% of new trucks in US have ABS.
Real-World Performance of ABS Systems

- NHTSA (1994, 1995)--Increase in fatal single vehicle crashes.
  Significant (~40%) increase in rollover crashes (passenger cars).
- GM (1995, 1996)--Slight increase in overall crashes
  Significant (~40%) increase in rollover crashes.
- FAA (1996)--Significant decrease in overall crashes
  No change in fatal crashes
- IIHS (1996)--Decrease in multiple-vehicle crashes
  Increase in single-vehicle crashes (rollover)
Lessons Learned from ABS Implementation

- It takes a long time for drivers to learn/adapt to vehicles with ABS.
- Adapted driver may develop more aggressive driving behavior.
- Improper steering converts one type of crash (collision) into another (rollover).
- Fear of Litigation/Liability issues is the main drag.
ARC Active Safety Research

• Worst-case Evaluation Method
  - Crazy teenage-driver simulator.

• Vehicle Motion Prediction Technique
  - Anticipating the threat from crazy drivers.

• Driving Simulators
  - Find out how crazy human drivers really are and how much they like our active safety designs?
A competing game

The **active safety system** is trying to **improve** vehicle safety.

The **crazy driver** (eval. signals) is trying to **degrade** vehicle safety.
Worst-Case Evaluation Method

- We have successfully generated rollover/jackknife on an articulated truck model at much reduced steering levels.

- Also, a VDC design which passed standard maneuver tests (J-turn, brake-in-a-J-turn, double lane change) were failed by the worst-case method at same steering/braking levels as those standard maneuvers.

Results presented in 1997 ARC conference
How the Worst-Case Method Helps

Worst-case maneuver

Possible benefits:
- Reduced cost/development time
- Legal/Liability

Design

Fleet test

Production

Modify/Patch

Standard maneuvers

Trial test
Vehicle Motion Prediction

- For many active safety systems, it is important to have a uniform "countdown" toward crash/threat.
- This count-down ticker can then be the basis of warning/control actions.
Example: Wheel Lift-Off Prediction

Input:
- Steering angle
- Roll Angle

Super-real-time:
- Simple model

Artificial Neural Network:

Output:
- Change of Roll Angle
- Final TTR

Straight line with slope of -1 vs. time
Rollover (Wheel Lift-off) Prediction

Steering angle

Ramp steering

Entering ramp

Obstacle avoidance

“Rollover”
The differential braking is turned on *up to 250msec earlier* than threshold (lateral acceleration or roll angle) based algorithms.
Other Roll Control Concepts

Rover/BMW ACE

Citroën Active Anti-Roll System (SC - CAR)

“ROP” by Palkovics et al.
Human-in-the-loop Simulation

- University of Iowa/NADS
- Oakland University

- Active safety algorithms (e.g., rollover prevention)
- Driver-vehicle interface
Conclusions

- Active Safety Research at ARC are focused on cross-cutting techniques targeting human-vehicle interactions.
- **Worst-Case Evaluation Method** helps to simulate the behavior of crazy drivers.
- **Motion Prediction Technique** accurately predicts impending threat. A TTR-based anti-rollover control was found to turn on the control action *up to 250msec earlier* than signal threshold (lateral acceleration or roll angle) based algorithms.
- **Future research**: integrate these techniques with the Driving Simulator capability of ARC to study the design/performance of active safety systems.