Technology Trends for Automotive Safety

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Automated “Train” of Cars
Outline

• The Safety Problem
• Active Safety Systems
  – **Motivation**
  – **Examples**
    • Advanced Snowplow
    • Transit Frontal Collision Warning
• Vehicle-Infrastructure Integration
  – **Cars and Roads that Talk to Each Other, Defined**
  – **Examples**
    • Cooperative Collision Warning
    • Cooperative Intersection Collision Avoidance Systems
• Last Words
Analysis of the Safety Problem

- Rear-End: 29%
- Intersection Crossing Path: 26%
- Single Vehicle Road Departure: 21%
- Lane Change/Merge: 9%
- Other: 15%
Causal Factor Distribution

- Driving Task Error: 76%
- Road Surface: 8%
- Vehicle Defects: 3%
- Driver Physiological State: 14%
The motivation for Active Safety Systems

– Each year, more than 6 million vehicle crashes occur on our nation's highways. Crashes kill more than 41,000 people, injure approximately 3.4 million others, and cost more than $150 billion per year.

– Driver error is the primary cause of about 90% of reported crashes involving passenger vehicles, trucks, and buses.
Advanced Snowplow

Changes for ASP 2:
Two radar sensors
Better sensor bracket
ASP Driver Interface

- Simple
- Minimal glance time
- Control dynamics
Development of a Prototype Frontal Collision Warning System for Transit Buses
Frontal Collision Warning System
Requirements Definition
Transit Bus Collision Warning System
Driver Vehicle Interface on Bus
Frontal Collision Warning System

Driver's decision

Multi-Target w, acc/dcc, v, L

Driver’s perception

Multi-Target w, acc/dcc, v, L

Road geometry, Traffic & environment

Relative speed

Relative dist

Desired speed

Traffic

Road Preview

Video Camera

Real-time Image processing

GPS Proc.

Subject-Veh. model

Frist Layer Radar & Lidar Data Fusion

Data Fusion Between Radar-Lidar, Video Camera & Vehicle Sensor

Warning Algorithm - Optimal Decision Making

Warning System

DVI

Frist Layer Radar & Lidar Data Fusion

Target w, acc/dcc, v, L

Target w, acc/dcc, v, L

Target w, acc/dcc, v, L

Vehicle Sensor measure

Multi-Target w, acc/dcc, v, L

Multi-Target w, acc/dcc, v, L

Multi-Target w, acc/dcc, v, L
Therefore Wireless has become attractive .......

- **Prior Approach**: Needs multiple sensors and significant cost to achieve 360° coverage
- **Wireless Approach**: One transceiver per vehicle to achieve 360° awareness
We are cognizant of the substantial efforts by both government and non-government entities to develop, in response to Congress’ transportation legislation, a national ITS plan and Architecture addressing ways of using communication technologies to increase the efficiency of the nation’s transportation infrastructure. The record in this proceeding overwhelmingly supports the allocation of spectrum for DSRC based ITS applications to increase traveler safety, reduce fuel consumption and pollution, and continue to advance the nation’s economy.

FCC Report and Order, October 22, 1999, FCC 99-305
DSRC as per FCC Ruling in 2004

- DSRC has 75 MHz Spectrum (1 control channel, 6 service channels)
- DSRC supports the non-exclusive geographic area licensing
  - Each licensee can operate any of the service channels
  - A license is for an area-of-operation (e.g., county, state…)
- Control channel is for safety messages and service announcements
  - Three levels of priority: Safety of Life, Safety, Non-Safety
- The service channels are used for non-safety related data traffic (e.g. e-commerce, infotainment)
- ASTM standards committee voted in 2000 to base it on 802.11a
  - Now IEEE 802.11p
DSRC Applications and Constituencies

- Vehicle-vehicle/roadside-vehicle safety messages
  - Automotive OEMs
    - Formed VSCC under CAMP (NHTSA)
  - DOTs
    - Formed Infrastructure Consortium (FHWA)
    - Justifies free spectrum and a DOT role
- Traffic Management, Signal priority or preemption, tolling
  - Thruway authorities, DOT’s, Toll tag industry (DSRC Industry Consortium)
- Drive-by Electronic Commerce, Infotainment
  - Gas stations, McDonalds, …
  - Want licensed operation for cheap
WAVE Radio Module Interfaces

- SMA Antenna Connector
- Ethernet Connector
- Power Connector
- Cigarette Lighter Plug
- 12V Power Adapter
- SMA Antenna Connector

**US:** 5.25-5.35 GHz, 5.725-5.850 GHz
**US DSRC:** 5.85-5.925 GHz
DSRC OBE And RBE Connectivity

ON BOARD UNIT (OBU)

In-vehicle devices

ROAD SIDE UNIT (RSU)

COMPUTER

ISP?

INTERNET And/or TMC

ROAD SIDE EQUIPMENT (RSE)

WIRELESS LINK
Current Hardware Installation

- PC104 computer running QNX6 real-time Operating System
- Denso Wireless Access in Vehicular Environment (WAVE) Radio Module (WRM)
- Currently no outside communication outside except WRM (no backhaul)
Cooperative Collision Warning
Now: Wireless for Active Safety Systems

- **Conventional Approach**: Needs multiple sensors – and significant cost – to achieve 360° coverage
- **Wireless CCW Approach**: One transceiver per vehicle to achieve 360° coverage
CCW System: Components and Architecture (2)

Vehicle A

- Safety Applications
  - Forward Collision Warning
  - Blind Spot /Lane Change Assistant
  - Intersection Assistant
  - Neighboring Vehicle Map
  - Wheel speed, steering angle, yaw rate, GPS

Vehicles B, C, D, E

Vehicle Data Exchange Protocol
Communication Protocol
Demonstrated CCW decision support to driver

*Forward direction*

Extendible to 360° decision support through symmetry

*Right-side*
In-Vehicle Display

- State of Other CCW Vehicles
- Position of CCW Vehicles
- Self State
- Heading
- Warning Diagnostic
- Satellites Received
Blind Spot/Lane Change Assistant
Cooperative Intersection Collision Avoidance Program
Infrastructure based sensors

Vehicle

• Infrastructure state information (e.g. intersection type, signal state, etc);
• Vehicles state information (e.g. speed, position, etc);

Driver Interfaces

Outputs

DII manager

Drivers

Signal controller

• Traffic Signal
• Traffic sign. contr.
• Traffic sign. manag.

Predictors

Gap predictor
Stop predictor
Conflict predictor

State Map Generator

State map

Future State

Future State Predictor

In-vehicle sensors

In-vehicle display devices

Signal controller

Infrastructure based sensors
A Focus Area: Left Turn Across Path / Opposite Direction (LTAP/OD)
Schematic of California Approach

Characterize Intersection Driving
- Roadside Observations
- Driver Observations

Develop Wireless Communication System
Evaluate COTS Technologies

Design IDS Alert System

Implement RFS Test Intersection

Develop Simulation Tool

Develop DII
Driving Experiments At RFS Intersection
Observations and Experiments

- Characterizing Driver Behavior at Intersections
  - Four sites
    - Two in Berkeley
    - Pinole
    - Burlingame (near SFO)
    - San Francisco
  - Two approaches
    - Roadside
    - In-Vehicle
  - At least three warning algorithm approaches
    - Dynamic (Shladover)
    - “BMI-based”/Statistical (Ragland)
    - Neural net (Misener)
  - Transcends LTAP/OD
Instrumented Ford Taurus for Driving Data Collection

- **Wireless connection from laptop to PC104 in traffic signal control cabinet**
- **Intended Field data collection and controlled tests at RFS**
MLK Turning Left onto University (+/- 15 m from stop bar & < 2 m/s)
Implementation at the PATH Intelligent Intersection
Elements of Cooperative System at the PATH Intelligent Intersection

- **40-ft Bus at PATH/RFS**
  - DVI at driver console, with identical display for passengers
  - Wireless implementation of simultaneous DII and DVI
    - In practice, need not be simultaneous – a tricky research item
  - Demonstrated to Barbara Sisson, Associate Administrator for Research, FTA
‘State Map’ of Intersection at Controller

We know the status of every communicating entity
Vehicle-Intersection Wireless Testing – Current Status

- Wireless infrastructure used to communicate between vehicles and intersection (DSRC)
- DSRC test radios installed in vehicles and at intersection
- Messages exchanged with approaching vehicle
Providing Vehicle Information to Intersection

- GPS receivers installed in vehicles to obtain speed, position, and heading information
- Information transmitted to intersection to be relayed and used in alert generation
- Left turn alert issued by intersection in response to data received from vehicles and sensors placed at intersection
Relay of Traffic Signal Status to Vehicle

- Real time traffic signal status is relayed to vehicle
- Video shows display inside vehicle
Vehicle-Infrastructure Integration ↔ Vehicle-Highway Cooperation

- Emerging *US DOT* + *State DOT (AASHTO)* + *Automotive Industry* Collaboration – VII
- “Revolution” in ITS services
  - Traffic and highway management
    - Use of probe vehicles (traffic, weather, road surface condition)
  - Active safety warning systems
    - “Cooperative” safety (intersections, curves)
  - Crash and incident response
    - Immediate response and situational assessment
  - In-vehicle travel information
    - Dynamic route advisory, advance warning information, highway-rail intersection safety

Enabled by evolving communications technologies and standards – DSRC