Research Connection:
“Cutting Edge” Transportation Safety Research

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Outline

• Active Safety, Defined
• “Leading Edge, High Visibility Research”
  – Vehicle-Infrastructure Integration (VII) → IntelliDrive (in California)
  – Intersection Safety
  – Networked Traveler – Situational Awareness
  – (Onboard Monitoring for Trucker Safety)
• Recap
Active Safety Defined
Safety Versus Time… (Kosch, 2007)

Foresighted and Active Safety

- Information
- Active Assistance
- Intervention

Passive Safety

- Collision
- Safety Systems
- Emergency Response

Potential

- Short Range Communication
- Broadcast, Cellular Systems

Probability for collision

Functionality

- Traffic Information
- Danger Warning
- Warning at mistakes e.g. stop sign

Emerald Response

- Restraint systems
- Emergency brake
- Airbag
- Crash-Cell

Foresighted Driving

- Road conditions
- distance, lane change

Examples

- e.g. stop sign
- Emergency brake

Source: C2C CC
Active Safety Roadmap

Figure adapted from NHTSA IVHS Plan (1992)
What is VII?

IntelliDrive (SM)

Basic Concept:

• All new vehicles will be equipped with DSRC radios at 5.9GHz, and GPS receivers.
• A nationwide, roadway-based communications network will be created.
• Wireless data will be exchanged between the vehicles and the roadside.
• A “Backhaul” network will transport this roadside data to/from a central location.
Vehicle-Infrastructure Cooperation

**Vehicle-Centric System**

**Intersection**

- **Vehicle**
  - On-Board Equipment
  - Vehicle Sensors
  - Driver-Vehicle Interface
  - DSRC Radio

- **Intersection**
  - Infrastructure sensors
  - CICAS SLTA, TSA processor
  - Signal controller system
  - Network Connection to VII and TOC
  - Driver Infrastructure Interface

**Messages**

**Vehicle-Centric System**
VII California Testbed Details

The Vehicle: Perhaps a dozen

The Infrastructure:
• 40 RSE Planned
• 12 Installed
Status of RSU 2, California at El Camino

Last report was Sun Jul 22 20:30:09 PDT 2007.

Full report

Report index

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backhaul IP Address</td>
<td>64.81.31.227</td>
</tr>
<tr>
<td>WRM Address</td>
<td>192.168.1.148</td>
</tr>
<tr>
<td>WRM Channel</td>
<td>Radio Frequency: 5890 MHz (IEEE 178)</td>
</tr>
<tr>
<td>WRM Data Rate</td>
<td>6</td>
</tr>
<tr>
<td>WRM Power</td>
<td>Transmit Power: 8 dBm, Current Transmit Output Power 16.0 dBm</td>
</tr>
</tbody>
</table>

Recent Signage Broadcasts

<table>
<thead>
<tr>
<th>First Observed</th>
<th>Last Observed</th>
<th>Message Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun Jul 22 13:05:10 PDT 2007</td>
<td>Sun Jul 22 20:20:09 PDT 2007</td>
<td>Driving time to Page Mill Ave. is 2 minutes</td>
</tr>
<tr>
<td>Sun Jul 22 13:15:09 PDT 2007</td>
<td>Sun Jul 22 20:20:10 PDT 2007</td>
<td>Driving time to Quarry Ave. is 4 minutes</td>
</tr>
<tr>
<td>Sun Jul 22 13:15:09 PDT 2007</td>
<td>Sun Jul 22 20:20:10 PDT 2007</td>
<td>Driving time to Sand Hill Ave. is 6 minutes</td>
</tr>
<tr>
<td>Sun Jul 22 13:03:10 PDT 2007</td>
<td>Sun Jul 22 20:20:09 PDT 2007</td>
<td>Driving time to Stanford Ave. is 2 minutes</td>
</tr>
<tr>
<td>Sat Jul 21 15:55:09 PDT 2007</td>
<td>Sun Jul 22 20:20:10 PDT 2007</td>
<td>Speed limit for CA-82 is 35 miles per hour</td>
</tr>
<tr>
<td>Sat Jul 21 14:30:09 PDT 2007</td>
<td>Sun Jul 22 20:20:10 PDT 2007</td>
<td>Test message at California</td>
</tr>
</tbody>
</table>

Recent Signal Messages

<table>
<thead>
<tr>
<th>Time Sent</th>
<th>Message Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>20:24:52.547</td>
<td>1: R: 55.8 2: G: 25.0 3: R: 61.0 4: R: 84.2 5: Y: 2.2 6: R: 36.8 7: R: 94.2 8: R: 73.0</td>
</tr>
<tr>
<td>20:24:52.746</td>
<td>1: R: 55.6 2: G: 24.8 3: R: 60.8 4: R: 84.0 5: Y: 2.0 6: R: 36.6 7: R: 94.0 8: R: 72.8</td>
</tr>
<tr>
<td>20:24:52.947</td>
<td>1: R: 55.4 2: G: 24.6 3: R: 60.6 4: R: 83.8 5: Y: 1.8 6: R: 36.4 7: R: 93.8 8: R: 72.6</td>
</tr>
</tbody>
</table>
System Features

- On-board curve prediction and dynamic curvature estimation using existing map (not enhanced high-accuracy map)
- Enhance and update map attributes via V-I communication
- Feedback and broadcast speed advisory for other vehicles through V-I communication

Curve prediction example results:

37~38 m

On-Ramp from Marsh Rd. to SB101

Dynamic curvature estimates using existing commercial map

-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10

East (m)

37.2 m
5th and El Camino Real

www.viicalifornia.org
Caltrans/PATH Signal Phase Software: History

- **170**
  - AB3418 (TSP Project, 2002)
  - Sniffer (Page Mill, 2006)
  - Current work with Kai Leung / BMW

- **2070**
  - NTCIP serial (Turner Fairbank, 2003; RFS, 2004)
  - AB3418 (ECR/Fifth, 2007)

- **Econolite ASC/3-2100**
  - NTCIP ethernet (World Congress, 2005)

www.viicalifornia.org
CICAS-SLTA (and –TSA)
Intersection Safety

- Cooperative Intersection Collision Avoidance Systems – Signalized Left-Turn Assistance (CICAS-SLTA)
CICAS SIGNALIZED LEFT TURN ASSISTANCE (SLTA) and Traffic Signal Adaptation (TSA)

Phase 1. Conduct Detailed Investigation
- Task 1.1 Develop Revised Test Plan
- Task 1.2 Investigate SLTA Gap Acceptance
- Task 1.3 Refine TSA
- Task 1.4 Develop CICAS Testbed
- Task 1.5 Interface with Standards

Phase 2 Assess Technical Feasibility
- Task 2.1 Develop and Implement DVI Concepts
- Task 2.2 Implement Testbed
- Task 2.3 Perform Field Measurements
- Task 2.4 Implement and Test SLTA Algorithms
- Task 2.5 Implement and Test TSA Algorithms
- Task 2.6 Interface with Standards
- Task 2.7 Recommendations of Next Steps

Phase 3 Assess Field Deployability (Optional)
- Task 3.1 Conduct SLTA Algorithm Tests
- Task 3.2 Conduct TSA Algorithm Tests
- Task 3.3 Develop FOT Plan
- Task 3.4 Interface with Standards
- Task 3.5 Prepare Final Report and Recommendations
A Project Focus at PATH - Unprotected SLTA

• Support driver making a left turn
• 27% of intersection crashes
• Type of Crashes
  – Head-On
  – Sideswipe
  – Other roadway users (pedestrians & bicyclists)

• Integration of CICAS within VII, emphasizing a vehicle-based solution
Signalized Left Turn Assist
CICAS-TSA Objective

Develop a system that detects a potential RLR-related conflict and dynamically extends the red clearance phase to prevent the collision.

Compatible with CAMP
CICAS-V: Addresses deployment and/or unequipped cars.

Extended red clearance
SLTA Driver Interaction Concept

**SV Maneuver Stage**

- Execute turn
- Wait for POV to clear
- Deceleration for intersection crossing
- Initial decision zone
- Deceleration for entering turn lane
- Approach

**Potential Interaction Between DVI-Driver**

- Can’t Use System for Collision Warning for Stopped SV
- Decision Support for Stopped SV
- Reactive Warning (SV Not Stopping)
- Preemptive Warning (Late Decision Support)
- Decision Support (Provided Before Braking)
- Too Early to Predict Vehicle Interactions Reliably?
Computer Vision-Based Pedestrian & Bicycle Detection and Tracking
Instrumentation Plan for Field Observation

Two Radar for Monitoring SV Traffic

Long-range Radar
POV Traffic Monitoring

Additional Equipment
- Video Image Capture
- GPS
- Data Acquisition Computer
- Infrared Camera

160° Laser Scanner
In-the-Box + All-direction Monitoring
Warning Algorithms Based on Trailing Buffer

- Trailing buffer is the time difference between
  - SV departure from POC (point of conflict), and
  - POV arrival at POC

- Trailing buffer is
  - A dynamic value that varies over time
  - A meaningful measure of “closeness to a crash”
  - A candidate criteria for warning algorithms
Representation of Time Gap Acceptance in LTAP-OD Scenarios

- Analysis of SV-POV interactions helps the understanding of driving behaviors and allows the estimation of gap/ lag acceptance.
PATH Intelligent Intersection Facility

Embedded Loop Detectors

Traffic Controller Cabinet

Traficon (30’ height)

RTMS (18’ height)

Signal Poles

60 Meters of 3M Microloops

Radar Poles
RFS Instrumented Intersection

- Instrumented for Driving Studies
- Prototyping Infrastructure Interfaces
- Technology Testbed
  - Sensor testing
  - Signal interface testing
  - Lighting
IDS RFS Intersection Experiments

From Driver’s Perspective

Driver Infrastructure Interface

DII

Off

Low Cycle

High Cycle

DVI

Pretrial

Trial Start

Warning On

Driver Vehicle Interface
SafeTrip-21: The Connected Traveler

Innovation for a Nation on the Move
Networked Traveler Services
We demonstrated these in NYC

- **Tell me about my trip**
  - *Trip Planner* (cell phone with Internet connectivity; multimodal services)
  - *Dynamic Route Advisory*
- **Tell me about the road**
  - *Traffic Signal Countdown* (as a safety and information enabler)
  - *Public Signage – Situational Awareness*
  - *Pedestrian Assistant* (location and other apps)
- **Watch out for me!**
  - *Heartbeat/watch out for me* (confederate driver near the bus; situational awareness, left/right?)
  - *Pedestrian Assistant* (safety apps)
- **System Operator / Agency Application**
  - *Transit Signal Priority* (LCD on bus with signal phase countdown)
  - *Dynamic Passenger Information* (On-board display, arrival countdown, and bus station, arrival time)
Milestones

• Demonstration at ITS World Congress November 2008

• Field Test
  – San Francisco Bay Area
  – Beginning in October
Safety

Situational Awareness is Key
Application 1. Situational Awareness

Concept of Advisory Services

Mapping to the Classic Driving Model Taxonomy

- **Strategic**
  - Safety Route Advisory

- **Tactical (Primary Focus)**
  - Situational Awareness Advisory

- **Control**
  - “Watch out for me!” Active Safety
Coverage Map (1/2):

About 1650 NAVTEQ triggers and more than 520 SpeedInfo triggers in Bay Area.
Coverage Map (2/2):
Alert Algorithm

Definitions:

**Subject vehicle**: Vehicle whose driver receives slow traffic ahead alert

**Alert location**: Upstream location where traffic is slow

**Trigger location**: Represented by GPS lat, long, and heading; about one mile (60 seconds of free flow speed) before alert location

**Suppose**:

- $V_s =$ Speed of the subject vehicle
- $V_f =$ Speed of the vehicles at the alert location

**Alert is issued if**:

1) $V_f \leq 50$ mph and
2) $V_s - V_f \geq 15$ mph and
3) Distance between trigger location and subject vehicle location $\leq 500$ ft
4) Difference between trigger location’s heading and vehicle’s heading $\leq 50$ deg
Validating End of Congestion Queue Algorithms (in progress)

- 3000 miles of late summer, early fall “shakedown” testing
  - 7 drivers
  - Analyzed GPS traces
    - Time (s)
    - Latitude (deg)
    - Longitude (deg)
    - Speed (mph)
    - Heading angle (deg)
    - Altitude (m)
    - Number of satellites
    - PDOP

- Isolated soft braking events
  - Braking (slowing distance)
  - Speed before slowdown
  - Speed differential (post facto speed data),

- Modeled the slowing distance as a third order polynomial
  - Speed and speed differential.
  - Calculated coefficients of the polynomial
    - f(driver, traffic, location)
Location of Top-Deck S-Curve Trigger Point
The ‘Onboard Monitoring System for Commercial Vehicle Safety’ (OBMS) System Prototype
Goal

Effective and lasting behavior change to safer driving behaviors for CMV drivers

- What is unsafe?
- How can feedback best be provided?
Core Behavioral Monitoring Categories

1. Speed Selection
2. Following Behavior
3. Attention (Inattention)
4. Fatigue
5. General Safety (Good Driving Practice)
Monitoring Apps: Speed

**Speed vs.**
1. Speed Limit (Violation)
2. Traffic Flow
3. Curve Speed (Curves Speed & Rollover Warning)
4. Road Surface
5. Grade
6. Hard Acceleration

**Real-Time Driver Feedback Elements**
1. Current Speed
2. Recommended Speed
3. Risk Factors (Why is that speed recommended?)
4. Event Recording in Progress (LED/Icon)
HHDD Warning  

Recommend 45 mph

Factors that may be influencing the recommended speed

Driver ID: B7244
HOS Remaining: 11 hrs
Alertness Index: 99

Icy
Components:
Camera Enclosure, Radar & Lidar, Road Surface Condition Monitor, Wheel Angle Sensor (String Pot), Gyro & Accelerometer
Prototypical Offline Feedback Format
Recap

• Summary
  – Vehicle-Infrastructure Integration (VII) → IntelliDrive (in California)
  – Intersection Safety
  – Networked Traveler – Situational Awareness
  – (Onboard Monitoring for Trucker Safety)

• We have been on the vanguard
  – Innovation
  – National spotlight

• Bridges near-term safety problems with potential mid-term safety solutions
Thank You

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