GPS-Based Navigation & Positioning Challenges in Communications-Enabled Driver Assistance Systems

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GM Vehicle-to-Vehicle (V2V) Technology and Demo Fleet

(5 min video)
GM Vehicle-to-Vehicle (V2V) Technology Development

• Demo fleet first demonstrated in 2005
• Fleet of 6 communicating vehicles
• 360 degree collision warning system
• Demonstration platform for DSRC-based active safety features
• Public demonstrations in more than 10 U.S. cities

Vehicle capabilities:
• Automatic braking
• Directional seat vibration system
• Motorized seatbelts
Vehicle-to-Vehicle Activities in Europe

- Fleet of 4 communicating vehicles
- Demonstration platform for DSRC-based active safety features
- Public demonstrations in 8 European countries
Dedicated Short Range Communication (DSRC)

• Dedicated to ITS (Intelligent Transportation Systems) applications
  • Allocation of 75 MHz around 5.9 GHz in U.S.
  • Potential allocation of 30 MHz around 5.9 GHz in Europe

• Supports low-latency line of sight and non-line of sight applications

• Provides multiple channels for broadband, real-time, long-range, bi-directional, secure communication

• Facilitates the development of ad-hoc V2V network architectures

• Standards development in the following communities
  • IEEE 802.11p – lower layer wireless protocols
  • IEEE 1609 – upper layer wireless protocols + security
  • SAE J2735 – wireless messaging standards
GM in V2V Collaborative R&D

Crash Avoidance Metrics Partnership (CAMP)

VSC-A: Vehicle Safety Communications – Applications
- Developed under a cooperative agreement with USDOT
- Interoperable and scalable architectures that enable future deployment.
- Emphasis on resolving current communication and positioning issues
- 3 year project (December 2006 to November 2009)
Interoperable Application Development in VSC-A

- Emergency Electronic Brake Light (EEBL)
- Forward Collision Warning (FCW)
- Intersection Movement Assist (IMA)
- Blind Spot Warning + Lane Change Warning (BSW + LCW)
- Do-Not-Pass Warning (DNPW)
- Control Loss Warning (CLW)
Extending V2V Technology to Vehicle-to-Infrastructure (V2I) Systems

- Similar to V2V technology except:
  - Sender is a fixed entity
  - Intersection sends local maps (with lane, stop line markings, etc.) and traffic signal states

- Vehicles position themselves to lane level and informs/warns drivers on:
  - Traffic signal state changes
  - Possible signal violations
  - Even direct lane changes if necessary
GM in V2I Collaborative R&D

Crash Avoidance Metrics Partnership (CAMP)

CICAS-V: Cooperative Intersection Collision Avoidance System
- Developed under a cooperative agreement with USDOT
- Avoid violations at Traffic Signals and Stop Signs
- 4 year project (December 2006 to June 2010)

- Two functional intersections in MI and CA
  - RTK-based GPS with RTCMv3.0
  - Better than 0.5 m positioning accuracy achieved

5th/ El Camino (CA) & 10 Mile/Orchard Lake (MI) CICAS-V Intersections
VSC-A & CICAS-V Positioning
Requirements & Scope

- CICAS-V
  - Absolute positioning requirements:
    - Lane Level: <1 m (95%) open-sky conditions

- VSC-A
  - Relative positioning requirements:
    - Lane Level: <1 m (95%) open-sky conditions
  - Absolute positioning accuracy: < 5 m (95%)

- GPS is the technology of choice to meet these requirements
Concept of Operation

Available Positioning Information
- Vehicle GPS information
  - Standalone Position, Heading
- Relative vectors to other vehicles and infrastructure GPS
  - V2V and V2I (red) vectors
  - Accurate to better than 1 m
- Location of infrastructure GPS
  - Pre-surveyed and accurate Lat, Lon

Modes of Operation
- CICAS-V
  - Estimate vehicle position
  - Better than 1 m absolute accuracy
- VSC-A
  - Estimate across and along distances
  - Better than 1 m relative accuracy
- CICAS-V & VSC-A
  - Better than 1 m relative & absolute accuracy
SAE Standards – Current Status

SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary

(I): Periodic Heartbeat Message (required)
(II): Variable Rate Message (optional)
   a. Event Notifications
   b. Vehicle Trail
   c. Vehicle Path Prediction
   d. Raw GPS
(III): Proprietary (optional)

- VSC-A actively involved in standard development regularly attend SAE meetings
- VSC-A is working with SAE DSRC Committee members to:
  - Ballot the next revision
  - Improve standard for trial testing
RTK (Real-Time Kinematic) engines are included in:
- GPS Receiver (1)
- Relative Positioning Module (20)
- All 10XX messages shown are RTCM V3.0 messages
A Common Positioning Architecture for V2V and V2I

- Equipped vehicles *talk* to each other when they are within DSRC range (i.e., 300 m):
  - share positioning and other V2V data

- V2I intersections broadcast intersection dependent data:
  - A *master GPS station* may be used by a cluster of intersections
  - Each intersection may add own signal timing and map information to master GPS data
DSRC Transceiver Devices

**Standalone** – GPS-based device

**Integrated** – GPS-based device with vehicle network interface

**Passive** – Standalone or Integrated device that broadcasts vehicle position data to other network users

**Active** – Standalone or Integrated device that executes V2V features

**Personal** – Small device that provides visibility enhancement to pedestrians, cyclists, etc
GM V2X Transponder Demo Video

(2 min)
Ongoing Research and Development

- Further development of relative positioning
- Defining future enhancements
  - New GPS signals, L2, L5 and GPSIII
- Hardware dependency of performance
  - Tests with multiple receiver types
- Tests with applications and other algorithms
- Enhancement possibilities for challenging GPS environments
Thank You!

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Backup Slides
VSC-A Performance

Host System Output: Across Distance to Target

Driving Scenario: Host and Target Driving in Same and Adjacent Lane
CICAS-V Performance

Using Right Lane

Changing Lanes to Go Through

Turning Left on to Inside Lane
V2X Safety Applications

Communications Between Vehicle and Infrastructure
- Blind Merge Warning
- Curve Speed Warning
- Emergency Vehicle Signal Preemption
- Highway/Rail Collision Warning
- Intersection Collision Warning
- Intersection Crossing Assistance (Electronic Button)
- In-Vehicle Signage
- Left Turn Assistant
- Low Bridge Warning
- Low Parking Structure Warning
- Pedestrian Crossing Information at Intersection
- Road Condition Warning
- Stop Sign Movement Assistance
- Stop Sign Violation Warning
- Traffic Signal Violation Warning
- Work Zone Warning

Communications Between Vehicles
- Approaching Emergency Vehicle Warning
- Blind Spot Warning
- Cooperative Adaptive Cruise Control
- Cooperative Collision Warning
- Emergency Electronic Brake Lights
- Highway Merge Assistant
- Lane Change Warning
- Post-Crash Warning
- Pre-Crash Sensing
- Vehicle-Based Road Condition Warning
- Vehicle-to-Vehicle Road Feature Notification
- Visibility Enhancer
- Wrong Way Driver Warning

NOTE: Highest ranking applications based on safety benefit estimates are highlighted in yellow
Source: Task 3 CAMP VSC1 Project Institute of Navigation Alberta Section June 2 2009
GM OnStar

- GPS location & clock are critical enablers for all OnStar services

**OnStar Monthly interactions (Avg. May-July ’07)**

<table>
<thead>
<tr>
<th>Service</th>
<th>Interactions per Month</th>
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<tbody>
<tr>
<td>Airbag Notification</td>
<td>800</td>
</tr>
<tr>
<td>Good Samaritan</td>
<td>6,100</td>
</tr>
<tr>
<td>Roadside Assistance</td>
<td>35,000</td>
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<tr>
<td>Remote Diagnostics (on demand)</td>
<td>68,000</td>
</tr>
<tr>
<td>Advanced Automatic Crash Notice</td>
<td>900</td>
</tr>
<tr>
<td>Stolen Vehicle Location</td>
<td>700</td>
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<tr>
<td>Route Support</td>
<td>351,000</td>
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<tr>
<td>Emergency Services</td>
<td>10,000</td>
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<tr>
<td>Remote Unlock</td>
<td>66,000</td>
</tr>
<tr>
<td>OnStar Hands-Free Calls</td>
<td>Over 15.0 Million</td>
</tr>
<tr>
<td>OnStar Vehicle Diagnostics</td>
<td>More than 3.0 Million</td>
</tr>
</tbody>
</table>

- In addition, OnStar uses GPS to be an effective advocate against crime
  - Targeted Amber alert with the National Center For Missing Children
  - Stolen Vehicle location
  - GM and Red Cross partner to provide information to those in crisis

- OnStar currently has over 5 million active subscribers
- OnStar will be standard across all General Motors retail vehicles in the U.S. & Canada (~4 Million per year)
Concept of Operation

Sequence of Operation

- Vehicles broadcast VSC-A over-the-air (OTA) message
  - GPS measurement data

- Infrastructure broadcast CICAS OTA messages
  - GPS measurement data
  - Map & timing information

- Vehicle software
  - Receives GPS data from others
  - Generates RTK vectors to others
  - Performs positioning functions
  - Output:
    - Across/Along other vehicles
    - Precise absolute position
Research & Development Challenges

- Strict relative (V2V) and absolute (V2I) positioning requirements
- A *common language* for Over-The-Air data: SAE J2735
- Technology penetration, particularly for V2V

- Infrastructure support for V2I
- Reliability of communications and positioning
- Ensuring privacy, security, and scalability