AUTONOMOUS VEHICLE DETECTION

Intelligent Transportation Society of Maryland
2016 Annual Meeting

by

Osman D ALTAN, Ph.D., EE
Office of Operations Research and Development
Federal Highway Administration

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U.S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION
• Concept of Automated Vehicles – building blocks
• Basic principle of object detection
• Object detection sensors
• GPS and DSRC
• Application videos
CLASSIFICATION

OBJECT REPORTED OR ALERT ISSUED (OUTPUT)

T

FALSE ALARM
False Positive

TRUE POSITIVE

F

TRUE NEGATIVE

F

MISSED DETECTION
False Negative

T

OBJECT PRESENT OR ALERT WARRANTED (INPUT)
IDEAL SENSING

Rate

Missed Detection

Acceptable Region

System Works Perfectly in this Region

False Alarm

Sensitivity / Threshold

5
PRACTICAL SENSING

Rate

Acceptable Point

Missed Detection

False Alarm

System Imperfect but Acceptable Operating Point

False Negative Rate

False Positive Rate

Sensitivity / Threshold
AUTONOMOUS SYSTEMS
Sensors based on different technologies are used:
- Radar
- Lidar
- Camera with image/machine processing

Sensor fusion utilized to improve robustness and reliability of object detection. Especially, (radar – camera) or (lidar – camera) combinations are common.

Each technology has its advantages and disadvantages. e.g., lidar cannot measure range rate, camera cannot measure range and range rate. These parameters need to be computed.

Sensors are capable of detecting objects within a specified ‘solid angle’ within a finite range (volume). Basically, the solid angle is defined in simpler terms as azimuth angle and elevation angle. e.g., radars have a fuzzy detection boundaries. Range and solid angle defines the detection volume.
# RADAR

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Radar Type</th>
<th>Band Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>76GHz – 77GHz</td>
<td>Long Range Radar</td>
<td>Narrow Band</td>
</tr>
<tr>
<td>22GHz – 29GHz</td>
<td>Short Range Radar</td>
<td>Ultra Wide Band</td>
</tr>
<tr>
<td>77GHz – 81GHz</td>
<td>Short Range Radar</td>
<td></td>
</tr>
<tr>
<td>24GHz</td>
<td>Medium Range Radar</td>
<td>Ultra Narrow Band - ISM</td>
</tr>
</tbody>
</table>
AUTONOMOUS SYSTEMS

Note: This is a slice of detection area in a given elevation angle.

Note: For every object in the detection cell, there is range rate with a given resolution.

Angular Resolution (Azimuth)
Detection Cell
Range Resolution
Field of View
Sensor
LIDAR

360° Horizontal Field of View
0.08° Angular Resolution (azimuth)
< 2cm Range Accuracy
LIDAR

Lidar Image from Google Car
Mono Vision - single camera
Stereo Vision - two cameras (for depth perception)
Contextual Information
Medium Field of View
Object Classification
Poor in Range Measurement (except stereo vision)
No Range Rate Measurement
Impacted by Environmental Conditions
<table>
<thead>
<tr>
<th></th>
<th>Radar</th>
<th>Lidar</th>
<th>Mono Camera</th>
<th>Stereo Camera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>Good</td>
<td>Good +</td>
<td>None</td>
<td>Good</td>
</tr>
<tr>
<td>Range Rate</td>
<td>Good</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Azimuth</td>
<td>Medium</td>
<td>Good +</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Object Classification</td>
<td>None</td>
<td>Good +</td>
<td>Good +</td>
<td>Good +</td>
</tr>
<tr>
<td>Environmental</td>
<td>Good</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Cost</td>
<td>Medium</td>
<td>High +</td>
<td>Low</td>
<td>Medium</td>
</tr>
</tbody>
</table>
GPS and DSRC – NEW PARADIGM

GPS

GPS Antenna

DSRC Radio
(Dedicated Short-Range Communications)
DSRC radios exchange a basic safety message, which includes a car’s POSITION, direction, speed, brake status, size, and more.

They also can exchange messages related to infrastructure and traffic management.
<table>
<thead>
<tr>
<th></th>
<th>OBJECT DETECTION SENSORS</th>
<th>GPS / DSRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Update Rate</td>
<td>10 Hz or more</td>
<td>GPS 1 Hz (special units up to 10 Hz)</td>
</tr>
<tr>
<td>Range</td>
<td>None to very accurate</td>
<td>Not accurate</td>
</tr>
<tr>
<td>Range Rate</td>
<td>Some sensors measure, otherwise computed</td>
<td>Computed from speed and direction</td>
</tr>
<tr>
<td>Direction</td>
<td>Accurate to moderately accurate</td>
<td>Relative direction not accurate</td>
</tr>
<tr>
<td>Cold Start</td>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td>Environmental</td>
<td>Moderately impacted depending on sensor type</td>
<td>Moderately impacted</td>
</tr>
<tr>
<td>Operating Medium</td>
<td>All</td>
<td>Reduced performance at urban canyons, wooded areas</td>
</tr>
<tr>
<td>Field of View</td>
<td>Narrow to 360°</td>
<td>360°</td>
</tr>
</tbody>
</table>
SENSOR PERFORMANCE

- Currently GPS is not sufficiently accurate for many applications, especially real-time control related apps.
- On-board sensors are much more accurate, especially ‘sensor fusion’ improves the performance significantly with only marginal cost impact.
- GPS black-outs are common in locations such as urban canyons, wooded areas, tunnels, long underpasses, etc.
- On-board sensors are functional under the above conditions, although some of them have limitations under certain environmental conditions.
- Update rate of low-cost GPS is not sufficient for real-time applications.
- On-board sensors have a minimum of 10Hz update rate.

Sensor fusion between GPS data and on-board sensor data is not recommended, GPS data contaminates the accurate on-board sensor data.

GPS still serves as very useful input in many applications, and even in real-time control apps from a different perspective depending on the application.
How Do We Get There?

NHTSA’s Five Levels of Vehicle Automation

- Level 0. No Automation
- Level 1. Function-Specific Automation
- Level 2. Combined Function Automation
- Level 3. Limited Self-Driving Automation
- Level 4. Full Self-Driving Automation
Extreme Challenges

Source: http://www.youtube.com/watch?v=AfA-Ytg2XxU
Could Today’s Automated Vehicles Have Avoided This Crash?

Advanced automation technologies and features:
- Radar, Lidar, Sonar, Machine Vision
- Adaptive cruise control
- Automatic brake assist
- Lane centering
- Lane change assist

Could Today’s Automated Vehicles Have Avoided This Crash?
DSRC and cellular connectivity

- Pedestrian Safety (V2X/X2V)
- Eco-Driving (I2V)
- Speed Harmonization (I2V)
ECO APPROACH/DEPARTURE

Application Overview

- Collects signal phase and timing (SPaT) messages and MAP messages using vehicle-to-infrastructure (V2I) communications
  - Receives V2I and V2V (future) messages, the application performs calculations to determine the vehicle’s optimal speed to pass the next traffic signal on a green light or to decelerate to a stop in the most eco-friendly manner
  - Pre-cursor to this Project: Provides speed recommendations to the driver using a human-machine interface or sent directly to the vehicle’s longitudinal control system to support partial automation
ECO APPROACH/DEPARTURE
SLOW DOWN SCENARIO
Automated vehicle technologies are revolutionary

A connected, automated transportation system is the next revolution
We Want You: Be a Part of the Next Revolution!

Universities
- Exploratory Advanced Research (EAR) Program
- National Science Foundation

Researchers
- National Research Council (NRC) Fellowships
- Eisenhower Research Fellows
- FHWA Student Internships
- Intergovernmental Personnel Act Agreements (IPA)

Industry
- Connected Vehicle PlugFests
- OEMs (Crash Avoidance Metrics Partners, LLC)
To Learn More

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• FHWA Office of Operations Website: http://ops.fhwa.dot.gov/

• Turner-Fairbank Highway Research Center Website: http://www.fhwa.dot.gov/research/tfhrc/offices/operations/

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Contact

– osman.altan@dot.gov