From Detection to Classification: The Next Generation of Automotive Radars

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Outline

• Status of Automotive Radar
  – Market Trends
  – Advanced Driver Assistance (ADAS)
    vs.
    Highly Automated Driving (HAD)
• Improving the Performance of Radar Sensors
• Central versus Edge processing
• Conclusion
Market Trends

- ADAS Radar sensors are dominating the market.
- HAD occupies a small, but increasing fraction of the Radar market.

*Based on data from Yole Developpement*
Driver Assistance vs. Automated Driving

ADAS Sensors

- Built for specific applications like
  - Adaptive Cruise Control
  - Automatic Emergency Brake
  - Vulnerable Road user protection
- High volume, cost sensitive
- Usually a standalone sensor

HAD Sensors

- Not limited to a specific application scenario:
  - Provide the best sensing performance in all circumstances
  - Sensor fusion with Video and Lidar is important
- Currently low volume, reduced cost sensitivity
- Often uses centralized processing
Driver Assistance vs. Automated Driving

**ADAS Sensors**
- Only tens to a few hundred reflexes
- Optimized for a certain use-case
- Only basic classification

**HAD Sensor**
- Thousands of reflexes creating high-resolution Radar “images”
- Enables dependable object classification
- Video-like update rates
What to Classify?

Video sensor capabilities

- Street lane detection
- Free space estimation
- Reconstruction and Segmentation
- Traffic light detection, road signs
- Object Detection and Classification (e.g. vehicles, persons)

Feasible using Radar?

- Yes
- No
- Question mark
Improving Sensor Performance

Raw sensor performance
• Distance resolution and accuracy:
  Modulation bandwidth, SNR
• Velocity resolution and accuracy:
  Measurement time, SNR
• Angle resolution and accuracy:
  Number of antenna channels, SNR

Classification performance
• Dynamic Range
  – SNR, antenna beam focusing, improved distance, velocity and angle separation to achieve “image”-like data,
• Improved feature extraction
  – Additional processing steps (Microdoppler, SAR, Machine Learning)
Improving Performance: Frontend

Improve range separation
Allow a better separation between peaks in the receive spectrum and also improve detection of weak peaks.

- Reduce VCO phase noise
- Improve PLL linearity
Improving Performance: Frontend

Improve distance range
• Higher transmit power
• More transmit channels for MIMO and phased array operation

Drawbacks
• Higher power consumption
• More self-interference
• More RF package pins required
Improving Performance: Frontend

Improve dynamic range and angle separability

- Higher sensitivity
- IQ receivers
- More receive channels for MIMO operation

Drawbacks

- A MIMO multiplexing scheme beyond TDM is required.
- Additional processing power required for each additional channel
- More RF package pins required
Improving Performance: Algorithms

Synthetic Aperture Radar

- Allow very high side-looking angle resolution

Drawbacks

- Storing of raw data required for coherent integration.
- High compute performance required for backprojection algorithm.

Range processing (per chirp)

Backproject each chirp into SAR image

Accumulate coherently all projections

SAR image
Improving Performance: Algorithms

Machine Learning based Classification

• Classification at spectrum level
• Based on trained models using measured and labeled data

Drawbacks

• Higher compute bandwidth for neural networks working on raw data
• Memory for coefficients
Improving Performance: Interference

- Make sure high-resolution images are not distorted due to other Radars

- Example:
  - Highway scene with 60 cars, each equipped with 3 radars

- Approaches
  - Local (receiver hardening, signal healing algorithms)
  - Cooperative (common avoidance behavior like moving inside the allowed frequency band)
  - Connected (coordinated avoidance using a data connection)
Local vs Centralized Processing

Standalone Sensors

- All radar-related processing is done in the sensor, only high-level data is exchanged
- Standalone operation possible
- Low-speed bus connection

Radar Head Only

- Most processing is done in a central unit
- Algorithms with high requirements on compute and memory feasible
- Fusion between sensors and different sensor modalities (Lidar, Video) possible
- High-speed bus connection from sensor to central processing unit required
Edge or Central Processing

- Where do we put the interface between local and central processing?

Example values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td># of receive channels</td>
<td>8</td>
</tr>
<tr>
<td># of samples per chirp</td>
<td>1024</td>
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<tr>
<td># of chirps per frame</td>
<td>1024</td>
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<tr>
<td>ADC quantization Bits</td>
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Conclusion

• Two driving forces in Automotive Radar:
  – Advanced Driver Assistance
  – Highly Automated Driving

• Get most out of a Radar
  – Hardware improvements
  – Advanced Algorithms

• Compute distribution
  – Local processing with edge computing
  – Central processing for highest performance