Tensilica Processor Cores Enable Sensor Fusion for Robust Perception

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Cadence

Cadence Tensilica Processor and DSP IP Business

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TENSILICA® CUSTOMERS

>50B
Processors
SHIPPED

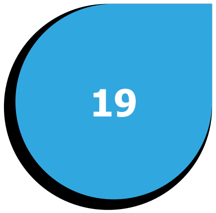
DSP LICENSING REVENUE

#1 DSP IP
LICENSING
REVENUE

PROCESSOR LICENSING REVENUE

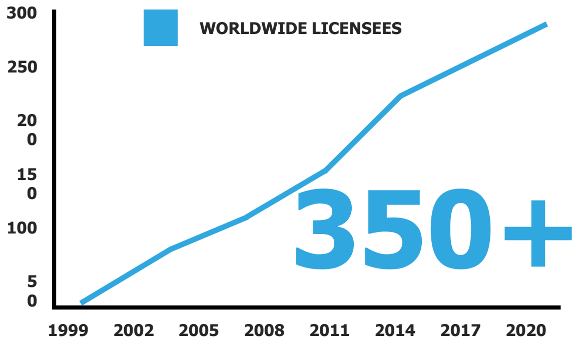
#2 Processor IP
LICENSING
REVENUE

SEMICONDUCTORS



19 of the Top 20
SEMICONDUCTOR
VENDORS
USE
TENSILICA IP

TENSILICA LICENSEES

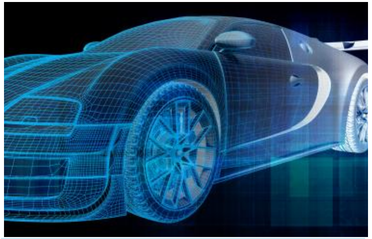


GLOBAL ECOSYSTEM

200+ ECOSYSTEM
PARTNERS

Target Markets for Cadence Tensilica DSPs

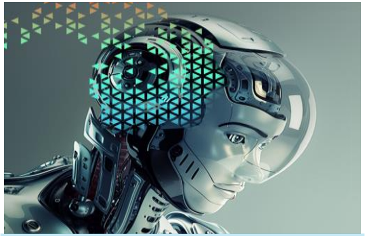
AR/VR



Automotive

IoT

Mobile



Robotics/Drone

IP Camera

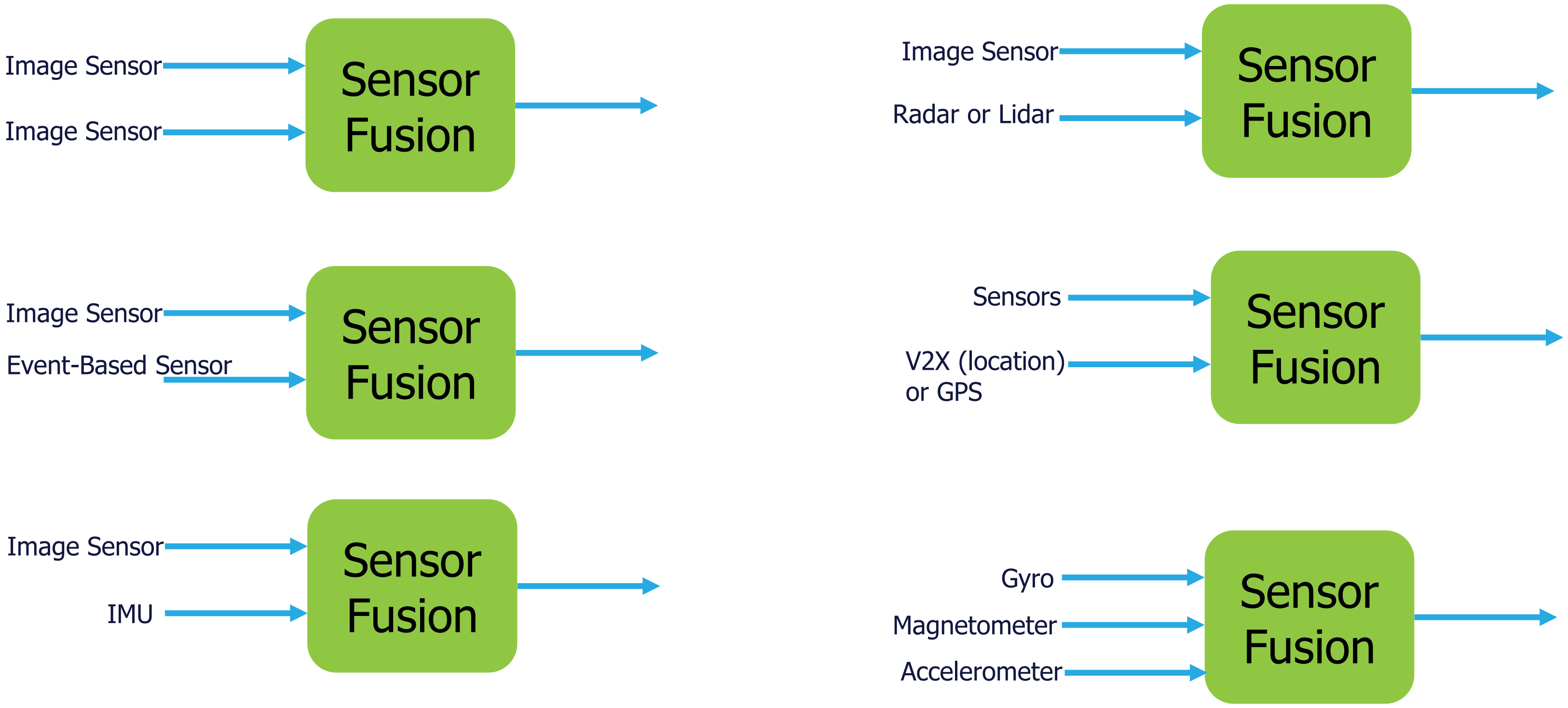
Data Center

Consumer Electronics

Why Sensor Fusion?

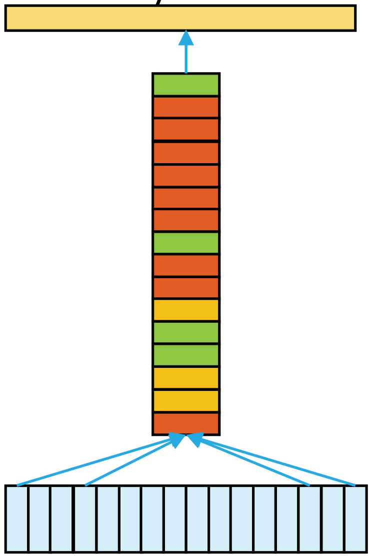
- Better quality
  - Have multiple sensors of same kinds
  - Two different type of sensors to compensate for the error generated by one sensor
- Better reliability
  - Redundancy: if one fails other works
- Measuring what is not possible with one sensor
  - Image sensor + Radar: may not work well at nighttime so add a radar
  - Image Sensor + IR Sensor
  - Short distance, Mid distance, Long distance
    - Image Sensor, Lidar, Radar
- Utilize each sensor’s strength and minimize their weakness

Types of Sensor Fusion



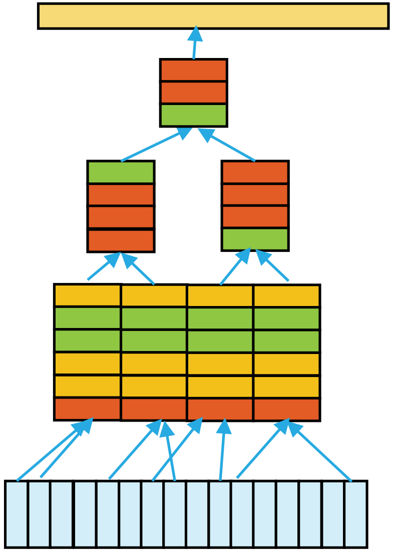
Types of Sensor Fusion

Early Fusion



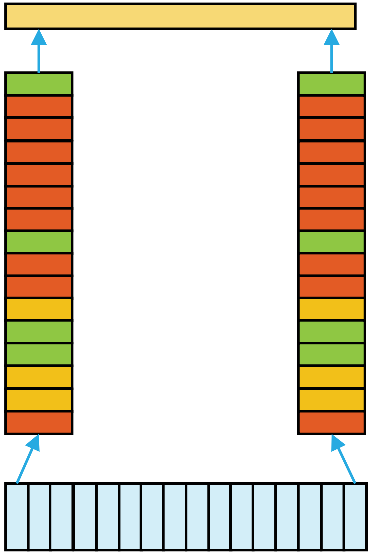
Fusing at point of data
Example: Stereo sensors

Mid Fusion



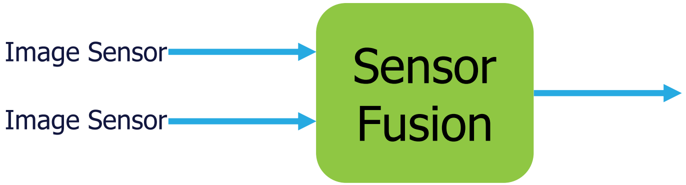
Feature level
Example: Image and radar doing feature extraction

Late Fusion

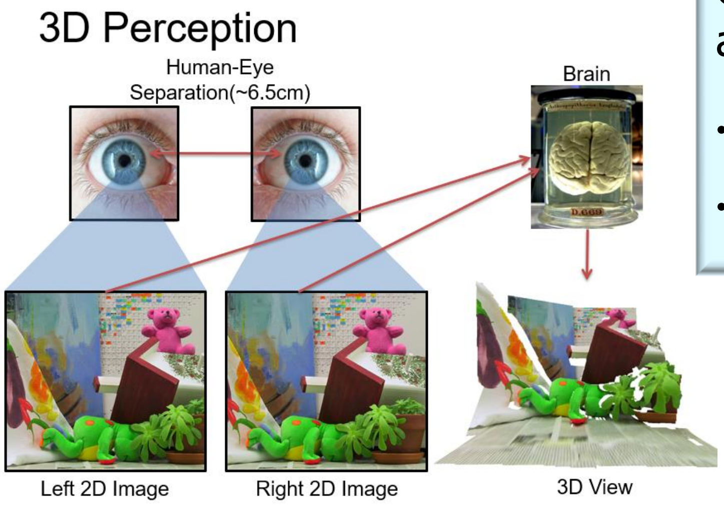


At result level
Example: Image and radar both identifying object

Stereo Sensors



- Single (Mono) visible camera can not measure the distance to an object
- Add a second sensor (Stereo) and use sensor fusion to measure distance

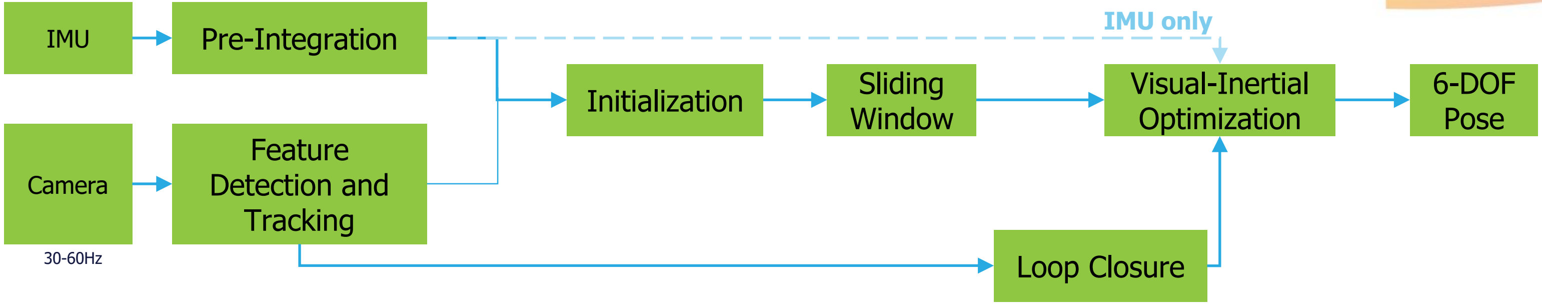


One such algorithm, Semi Global Matching, assumes left and right images are rectified

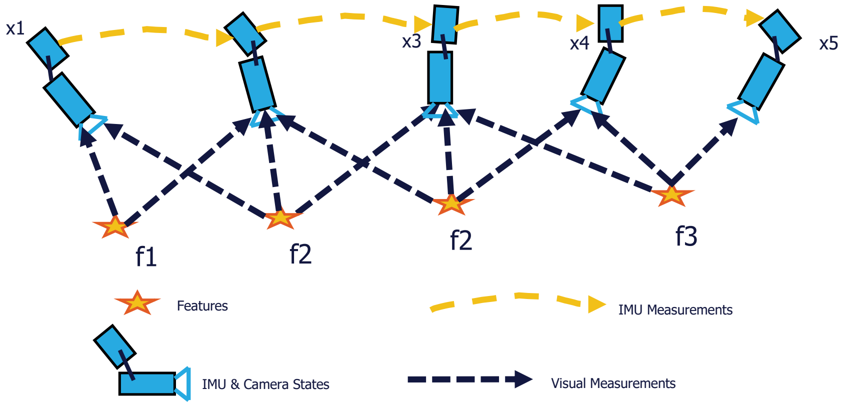
- PixelWise cost compute uses **Birchfield Tomasi** and later box filter of BT for **3x3 window** around point (x,y)
- Disparity refinements: Involves uniqueness find, quadratic interpolation, disparity of right image and disparity validation

- Classical image processing algorithm
- Requires processing on each pixel

Sensor + IMU: Classical Sensor Fusion



https://pub.mdpi-res.com/sensors/sensors-19-03747/article_deploy/html/images/sensors-19-03747-g001.png?1568249905



https://www.mdpi.com/sensors/sensors-19-01624/article_deploy/html/images/sensors-19-01624-g001.png

Benefits

- Implemented in conjunction with one or more cameras
- IMU provides refresh rates of 1kHz+, camera at 30-60 fps
- SLAM calculation and pose estimates at refresh rate faster than camera
- Able to track movements more accurately
- Can compensate if camera is unable to find good features to track

Radar + Camera: Using Kalman Filter and GNN

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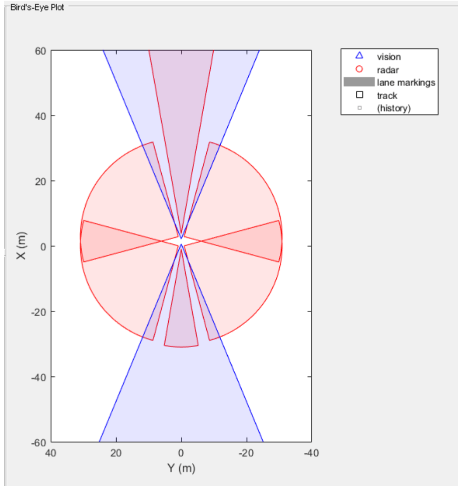
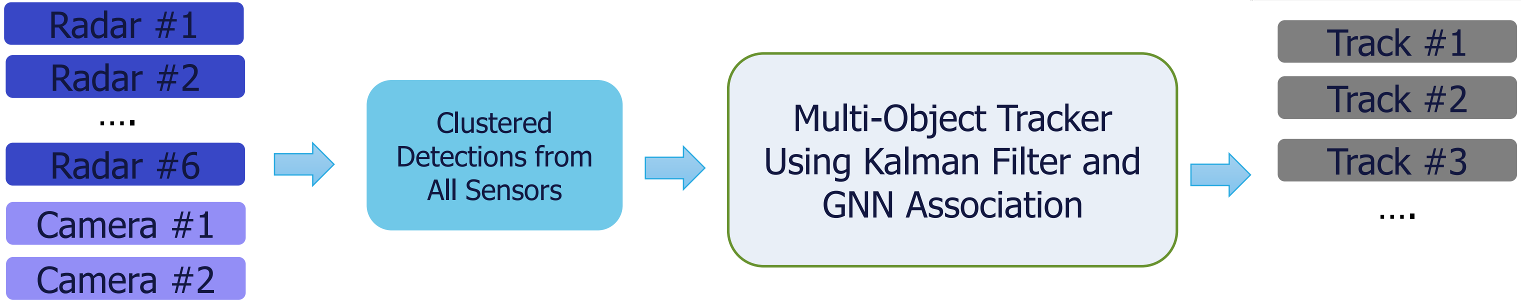
- Inputs:
  - Multiple camera and radar sensors mounted on Ego vehicle would provide multiple detections clusters received from numerous surrounding objects
- Outputs
  - Assigned tracks for the detection clusters along with internal state of those tracks for updates for next frame





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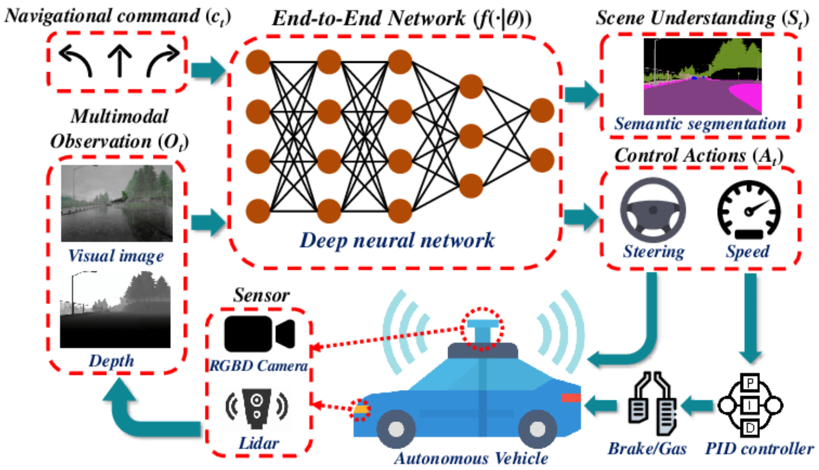
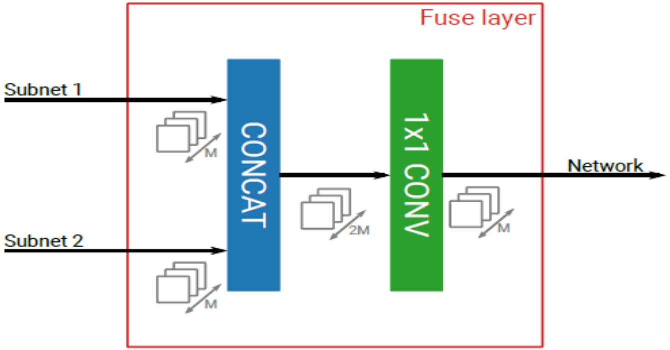
AI and Sensor Fusion?

- A lot of sensor fusion relies on classical approaches: Kalman filter, etc.
- For large and complex systems, scalability is a big problem
  - Inefficient to manually code “rules” for each corner case
  - Over time, these rules will become difficult to maintain or improve
- AI:
  - Achieve higher levels of automation
  - Scalability
- Past decade, majority of speech and **image/video processing has transitioned to neural networks for better performance/accuracy**
  - **Now radar and lidar-based classification and object detection is moving to AI, also**
- For AI to work well, we need data, lots of it
  - Image + radar + lidar data is limited at the moment, short-term problem



RGB + Depth Fusion with AI for Robust Object Detection



- Using Single Shot object / pedestrian detection with only RGB or only depth data can have limitations
  - Example: Detecting objects in group, occluded objects

- Remarkable detection accuracy improvements can be obtained by fusing features from subnets processing <u>RGB and depth data – followed by a single network for fused data</u>

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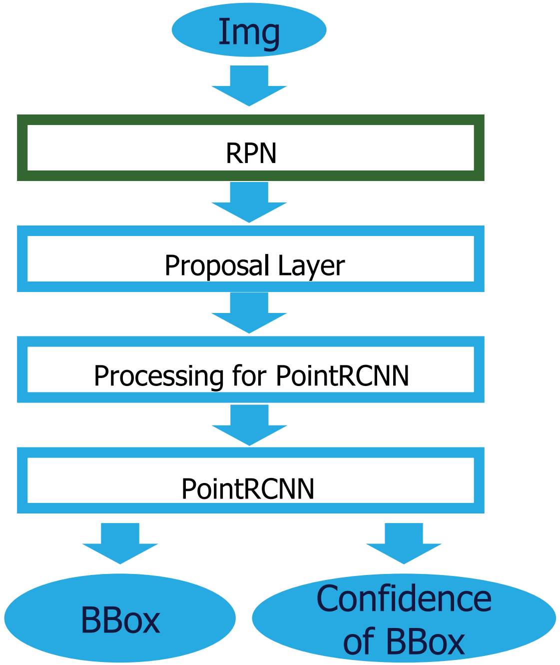
Lidar + Camera: Using EPNet

- Sensor fusion-based 3D object detection
- Has 2 subnets
    - RPN (Region Proposal Network)
    - PointRCNN
    - Some additional processing (pre and post)
- Fusion of features from pointcloud and image is done in RPN
- RPN generates bounding box (BBOX) data which is further fine-tuned by PointRCNN



Sensor Fusion Summary

- Used in various markets: consumer, automotive, …
- Definition depends on type of sensors being used
- Different sensors require different processing
- Traditional digital signal processing algorithms are still being used
- Various AI-based algorithms are being experimented
- Amount of processing depends on size of sensors and type of sensors
- Your solution still needs both traditional digital signal processing and AI processing

Tensilica DSPs

ISO 26262
Road Vehicles - Fuctional Safety

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Performance

	Vision	Radar / Lidar / Comms	Floating Point
Xtensa NX — High Performance	Vision Q7, Q8	ConnX B10, B20	Floating Point KQ8, KQ7
Xtensa LX — Low Power	Vision P1, P6	ConnX 120, 110	Floating Point KP6, KP1

Vision

- Image/Vision Processing
- On Device AI
- AR/VR
- ADAS
- Mobile
- Sensor Fusion

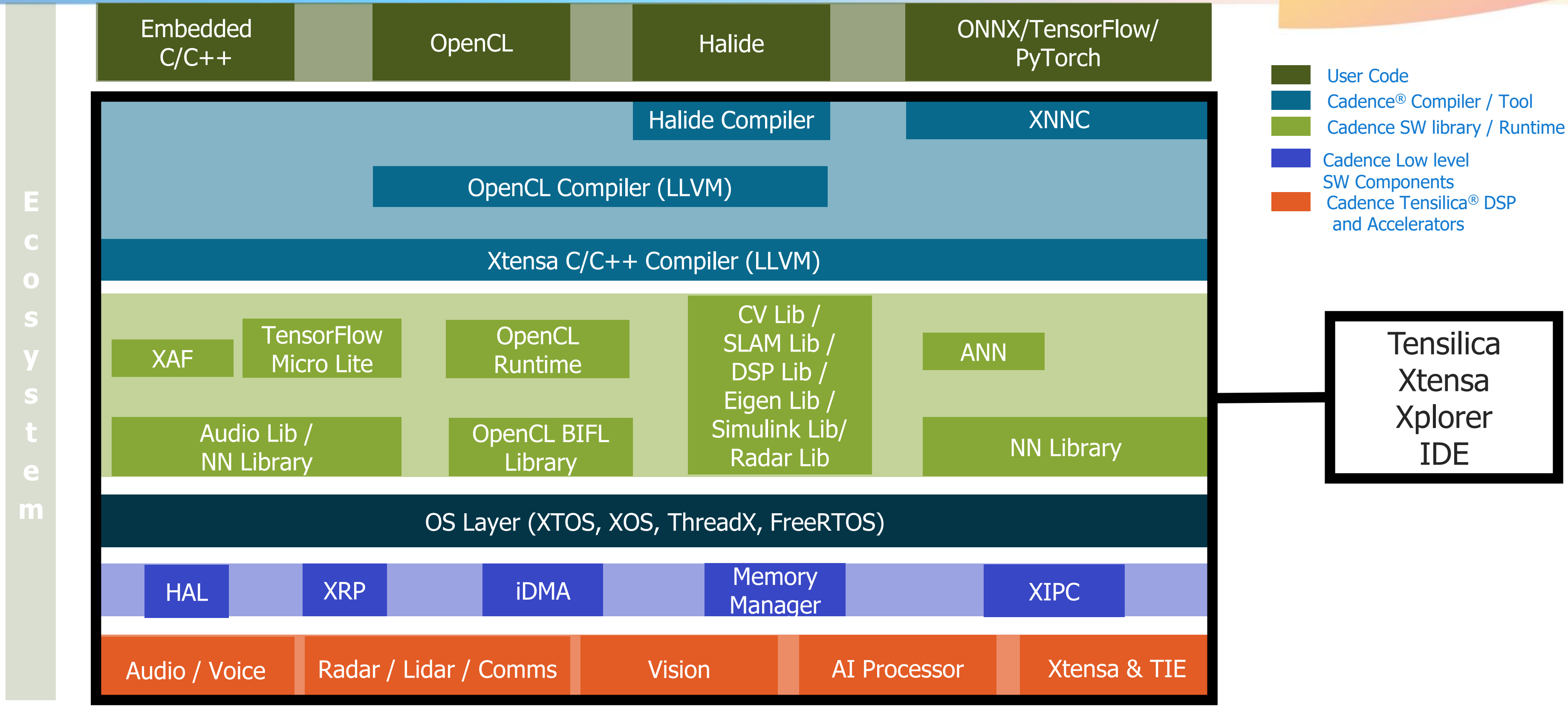
Radar / Lidar / Comms

- Automotive Radar/Lidar
- Sensor Fusion
- V2X, 5G, LTE, Wireless
- WiFi, Smart Grid
- Infrastructure and Terminals

Floating Point

- AI/ML
- Motor Control
- Sensor Fusion
- Object Tracking
- AR/VR
- HPC

Cadence Tensilica: Comprehensive Software Solutions



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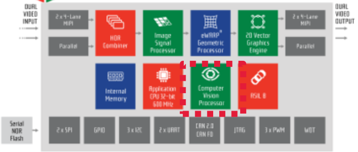
Cadence DSPs for Sensor Fusion

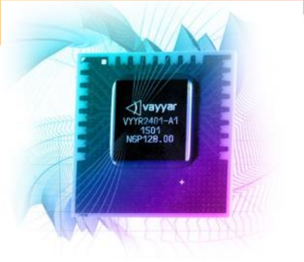
Sensor Fusion Need		Cadence Offering
Domain-Specific Sensor Processing	→	Vision, Radar, Audio/Voice DSPs
Processing Capacity	→	400GOPS to 3.2TOPs processing capacity
Different Data Types	→	(8,16,32 bit) fixed point, complex, (16,32,64 bit) FP data type support
Traditional Digital Signal Processing + AI	→	Traditional DSPs with optimized instruction set >2TOPS AI processing
SW Tools and Library	→	Various optimized library, NN complier, NN-lib

Tensilica DSP Customer Success



GW5400, Automotive Smart Viewing Camera Processor

Black Sesame Technologies' A1000 (HS2)



SemiDrive

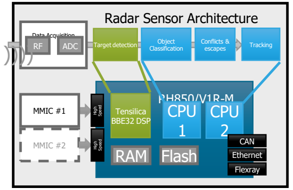
X9: Automotive Applications Processor
V9: Automotive Processor

Kneron KL720

Visconti

NXP S32R45/41
4D Imaging Radar

Andes Automotive Radar SOC



Renesas RH850/V1R-M

Summary

Cadence Tensilica Group is a leading supplier of IP for edge device sensor processing with on-device AI

Cadence® Tensilica® DSPs are well-suited for sensor fusion

Tensilica DSPs and AI solutions for automotive-grade products are already in production

Rich environment of third-party solution providers and partners

One Last Thing…

Cadence® Tensilica®
Vision Q8 and Vision P1 DSPs
www.cadence.com/go/VisionQ8P1

AI-Based Sensor Fusion
https://cariad.technology/de/en/news/stories/sensor-fusion-introduction.html

Vision DSP Video
https://www.youtube.com/watch?v=eXegAFLqz-g

Come visit our booth #117

- See demonstrations of our customers' products in real-world automotive, smart camera, and IoT applications