Build Smarter, Safer and Efficient Autonomous Robots and Mobile Machines

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Texas Instruments
Agenda

- Introduction
- Key challenges
- Key care-abouts
  - Sensing
  - System design and performance
  - Functional safety
- Development

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Introduction | Smarter, more efficient, safer

Autonomous mobile robots

Autonomous delivery robots

Construction, excavation, agriculture
Introduction | Technology enablers

3D perception

Artificial intelligence

Functional safety
Key Challenges
Key challenges | Safe operation

Collision Avoidance

- Detect humans and obstacles
- Navigate around them

Human Presence Detection

- Stop when people are in the safety bubble
- Resume when people are out of the safety bubble
Key challenges | Accurate & affordable sensing

**Radar**

**Pros:**
- Cheaper
- Works in all weather

**Cons:**
- Poor angular resolution

**Lidar**

**Pros:**
- Better precision and accuracy

**Cons:**
- Costly, consumes more power
- Poor results in bad weather
- 2D Lidar has poor resolution

**Vision**

**Pros:**
- Cheapest and best resolution
- Classify objects & scenes well

**Cons:**
- Computationally intensive
- Requires good light sources
Key challenges | System design and complexity

System challenges

• High-performance / low-latency processing at low-power
• Small form-factor, ruggedized design
• Cost-optimized design

Application challenges

• Programming of hardware accelerators
• AI development
• Functional safety software
Key care abouts
## Key care-abouts | Sensing with mmWave radar

<table>
<thead>
<tr>
<th>TI mmWave</th>
<th>Robotics Benefits</th>
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</table>
| 3D presence detection | • True 3D information (range, velocity and angle) of objects vs. LIDAR/ToF used mainly for distance measurement  
• Quickly detect and prevent possible collisions minimizing machine downtimes |
| Up to IEC 61508 SIL-2 compliant | • Helps enable human presence detection that has traditionally been solved by expensive safety certified LiDAR sensors |
| Accurate glass detection | • Improve reliable detection of glass walls/doors over existing sensors that “see” through them |
| Wide azimuth area coverage | • Create 360-degree detection zones around the robot to prevent collisions with humans to minimize injury and reduce machine downtimes |
| Robust in challenging environments | • Increase reliability over existing vision/LiDAR based sensors in conditions such as rain, dust, smoke, complete darkness or in the glare of sunlight |

Complement or displace established sensor solutions with up to SIL-2 certified TI mmWave sensors
Key care-abouts | System design with TDA4x

Enhanced Safety
- Hardware and software solutions enabling up to SIL-3 and ASIL-D designs

Energy efficient AI & sensor fusion
- Computer vision, deep learning accelerators & DSP cores delivering industry-leading performance at low power

Affordable design
- High levels of integration in a single chip reduces system complexity and cost.

Faster development
- Open-source software, tools, SOM and eco-system enable faster-time-to-market

ASIL-B and SIL-2
- Multi-core Cortex-A72
- Multi-core R5 (Lock-step option)
- C7x DSP
- 8 port 2.5Gb Ethernet switch
- Imaging and Vision accelerators
- Depth and motion accelerators
- Deep Learning accelerator
- Security accelerators
- Large Internal memory
- PCIe, 4x2L
- USB-3
- CAN-FDs

ASIL-D and SIL-3
- MCU Island
- Lock-step option
- Freedom from interference, power isolation

TDA4x

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Key care-abouts | System performance with TDA4x

- **Multi-core Shared Memory Controller**
- **Data Routing Unit (DRU)**
- **Data L3$ / large SRAM**
- **Multi-core Shared Memory Controller**

**Configurable HWA**
- Low level brute force pixel pre-processing
- Color filter array (CFA), color convert, wide dynamic range (WDR), filtering, scaling, depth, motion

**Programmable cores**
- Mid/hi level object processing, decision making & customer differentiation, feature extraction, classification

**Deep Learning and Perception**
- Highly Efficient (Significantly reduced DDR loading via SuperTiling, Low Power, High FPS per TOPS)

- **Image capture**
- Flexible RAW CFA
- Any 2x2 CFA pattern
- Flexible WDR format, 3 exposure
- Wide Dynamic Range (WDR/HDR)
- 12 bit pipe

- **Vision pre-processing**
- Pixel Remap / Distortion Correct
- Edge Preserving Noise Filter
- Image Pyramid: Luma + Chroma Fractional-integer Linear ROI Support
- 12 bit pipe

- **Distance & motion processing**
- Stereo Disparity: Depth
- Dense Optical Flow: Motion

- **Output**
- MPUs
- HWAs
- GPUs

- **Auxiliary MPU**

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# Key care-about Functional safety with TDA4x

## Architecture
- Independently certified safety development process for ISO 26262 and IEC 61508
  - ASIL-D/SIL-3 systematic capability
- Built-in hardware diagnostics
- Peripherals and architectures designed for end system safety capabilities

## Software
- Scalable across products
- TUV certified safety software process
- Safety diagnostic library
- Safety diagnostics reference and examples
- Self test libraries
- SW FMEDAs, code coverage, traceability reports
- Compliance support packages
- Compiler qualification kit
- FreeRTOS to SafeRTOS
- AutoSar and MCAL support

## Collateral
- Device safety manual
- Configurable FMEDA
- Safety analysis report
- Safety assessment certificate
- Trainings
- White papers and application notes
- Safety-enabled demos

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Easy development with industry standard frameworks

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<tr>
<td>3D perception</td>
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<tr>
<td>Localization</td>
</tr>
<tr>
<td>Obstacle detection</td>
</tr>
<tr>
<td>Object tracking</td>
</tr>
<tr>
<td>Navigation</td>
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</tbody>
</table>

Python and C++ programming

Industry standard APIs and frameworks

- ROS
- TensorFlow Lite
- ONNX Runtime
- TVM
- Docker
- GStreamer

TI tools and middleware for hardware acceleration

TI Edge AI processor

- Arm® Cortex®-A
- DSP
- Deep learning
- Imaging
- Vision
- Multimedia

Full software from TI makes applications development much easier!
TI Edge AI | Extensive tools from TI for faster DL model development and deployment

Free end-to-end TI proprietary tools for faster AI model development and deployment
Welcome to TI Edge AI Cloud

You are now connected to a Jacinto™ TDA4VM processor evaluation module.

Find your model

Learn performance statistics

Compare model performance

Find the model that best meet your performance and accuracy goals on TI Processor from TI Model Zoo. Learn current performance statistics of models such as FPS, Latency, Accuracy & DDR bandwidth.

Get model benchmarks

The following Notebooks let you access benchmarks for pre-compiled and custom models

Model performance

Using a pre-compiled model from TI Model Zoo, this example notebook lets you run inference on a TI Edge AI processor to get latency, FPS, DDR bandwidth and power benchmarks

Select task:
- Classification
- Detection
- Segmentation

Select runtime engine:
- TensorFlow lite
- ONNX runtime
- TVM

Open notebook

Model accuracy

Using a pre-compiled model from TI Model Zoo, this example notebook lets you run inference on a TI Edge AI processor to get accuracy benchmarks.

Custom models

This notebook lets you compile your own model and run inference on a TI Edge AI processor to get latency, FPS, DDR bandwidth, power and accuracy benchmarks.

Select runtime engine:
- TensorFlow lite
- ONNX runtime
- TVM

Open notebook

Open notebook

Open notebook

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Faster deployment with out-of-box demos and production ready components

3D perception and navigation

- ROS, ROS2 based, hardware and DSP accelerated demos
- Production ready GStreamer plugins, OpenVX and ROS nodes for offloading to hardware
- Functional safety complaint low-level drivers
- Community eco-system

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Autonomous navigation and collision avoidance video

Conclusion

- Autonomous machine co-existing with humans are increasing productivity in all spheres of life
- Key technology enablers are 3D perception, AI and functional safety
- TI’s functional safety compliant mmWave radar sensor increases reliability in seeing the obstacle where other sensors fails
- TI’s TDA4x processor enable energy-efficient, functionally safe compliant sensor-fusion ad AI powered autonomous mobile machines and robots.
Getting Started Resources
**Processor for practical edge AI**

- Jacinto™ TDA4x
- 2x A72
- 4x R5
- Safety MCU
- LPDDR4
- 2x A72
- DSP
- Imaging & Vision accelerators
- 2xR5
- Deep Learning Accelerator
- Video codec acceleration
- GPU
- Display
- Security Accelerator
- SPI bus
- 1.8V power
- Large internal mem, highspeed bus

**Energy efficient AI architecture**

<table>
<thead>
<tr>
<th>Type</th>
<th>TDA4VM</th>
<th>Batch size = 1</th>
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<tbody>
<tr>
<td>Object classification</td>
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<tr>
<td>MobileNet-v1</td>
<td>224 x 224</td>
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<tr>
<td>SSD-MobileNet-v1</td>
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<tr>
<td>Image classification</td>
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<td>ResNet50-v1.5</td>
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</tbody>
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Frames-per-second

**Learn with free cloud tool**

- ti.com/edgeaicloud

**Get started for free**

- Example scripts
- TI Model Zoo
- Training videos

**Build with 8 TOPS starter kit**

- P/N: SK-TDA4VM: $249

**Fast Development Cycle**

- Industry standard APIs
- 3P Eco-system

**Development | Open-source software & tools**

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<th>Development</th>
<th>TDA4x processors</th>
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| **Edge AI evaluation** | https://dev.ti.com/edgeai  
                        | https://dev.ti.com/edgeaicloud  
                        | https://dev.ti.com/edgeaiprojects |
| **Full development** | Product Folder: https://www.ti.com/product/TDA4VM  
                        | Starter Kit: https://www.ti.com/tool/SK-TDA4VM  
                        | TDA4 EVM: http://www.ti.com/tool/TDA4VMXEVM |
| **Software development kits** | TI Processor SDK for edge AI – Seamlessly reuse and migrate Linux,  
                                | https://www.ti.com/tool/download/PROCESSOR-SDK-LINUX-SK-TDA4VM#downloads  
| **Support** | https://e2e.ti.com |

Learn on https://training.ti.com/process-monthly-webinar-series
Evaluation modules

- IWR6843 ISK (60 GHz)
- IWR6843 AOP (60 GHz Antenna on package)
- IWR1843 BOOST (77 GHz)

Reference examples/labs

- Sense and avoid lab for collision avoidance
- 360° safety bubble with ROS lab for safe human presence detection

Accelerate path to production with 3P network

- Designing TI mmWave made easier using 3rd party ecosystem
- Industrial mmWave third-party search tool