

tinyML[®] Talks

Enabling Ultra-low Power Machine Learning at the Edge

“Oculi is putting the human eye in A.I.”

Charbel Rizk – Founder, CEO, CTO of Oculi Inc.

January 25, 2022



www.tinyML.org



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Additional Sponsorships available – contact Olga@tinyML.org for info

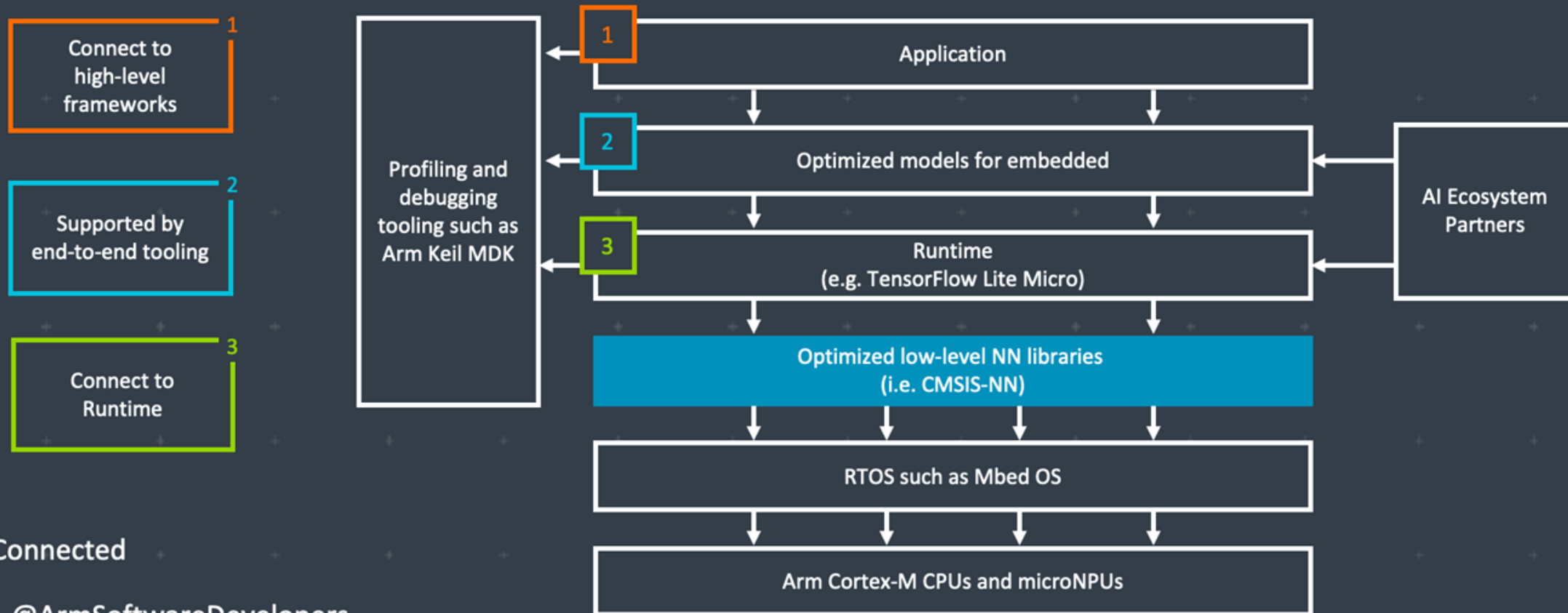
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Arm: The Software and Hardware Foundation for tinyML



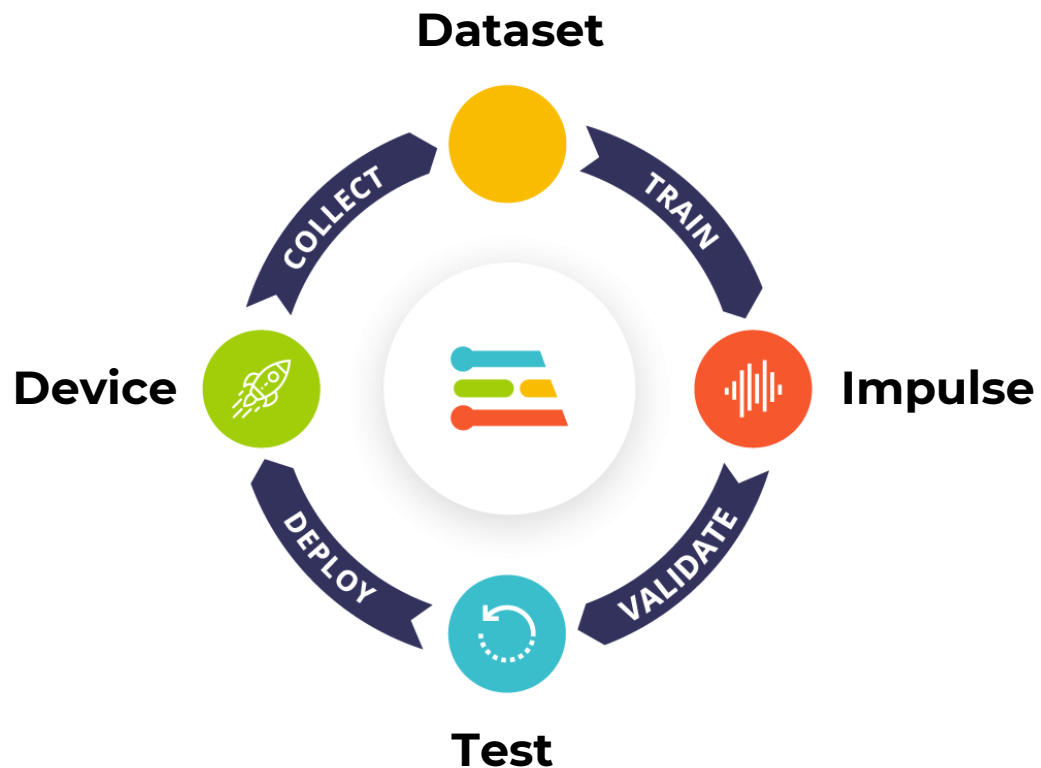
Stay Connected

 @ArmSoftwareDevelopers

 @ArmSoftwareDev

Resources: developer.arm.com/solutions/machine-learning-on-arm

EDGE IMPULSE The leading edge ML platform



www.edgeimpulse.com

The screenshot shows the Edge Impulse web interface for a "SPECTRAL FEATURES (CONTINUOUS GESTURES DEMO)" project. The interface includes a sidebar with navigation options like Dashboard, Devices, Data acquisition, Impulse design, EON Tuner, Retrain model, Live classification, Model testing, Versioning, and Deployment. The main content area shows the "Training set" configuration with parameters: Data in training set (18m 29s), Classes (6: drink, fistbump, idle, snake, updown, wave), Window length (2000 ms), Window increase (120 ms), and Training windows (6,873). A "Generate features" button is visible. To the right, the "Feature explorer (6,819 samples)" displays a 3D scatter plot with axes for accX RMS, accY RMS, and accZ RMS. The plot shows distinct clusters for different classes: drink (blue), fistbump (orange), idle (green), snake (red), updown (purple), and wave (brown). Below the plot, the "On-device performance" section shows a processing time of 11 ms and a peak RAM usage of 5 KB.

Qualcomm
AI research

Advancing AI research to make efficient AI ubiquitous

Power efficiency

Model design, compression, quantization, algorithms, efficient hardware, software tool

Personalization

Continuous learning, contextual, always-on, privacy-preserved, distributed learning

Efficient learning

Robust learning through minimal data, unsupervised learning, on-device learning

A platform to scale AI across the industry



Perception

Object detection, speech recognition, contextual fusion



Reasoning

Scene understanding, language understanding, behavior prediction



Action

Reinforcement learning for decision making



Edge cloud



Cloud



IoT/IIoT



Automotive



Mobile

SYNTIANT

End-to-End
Deep Learning
Solutions
for
TinyML & Edge AI



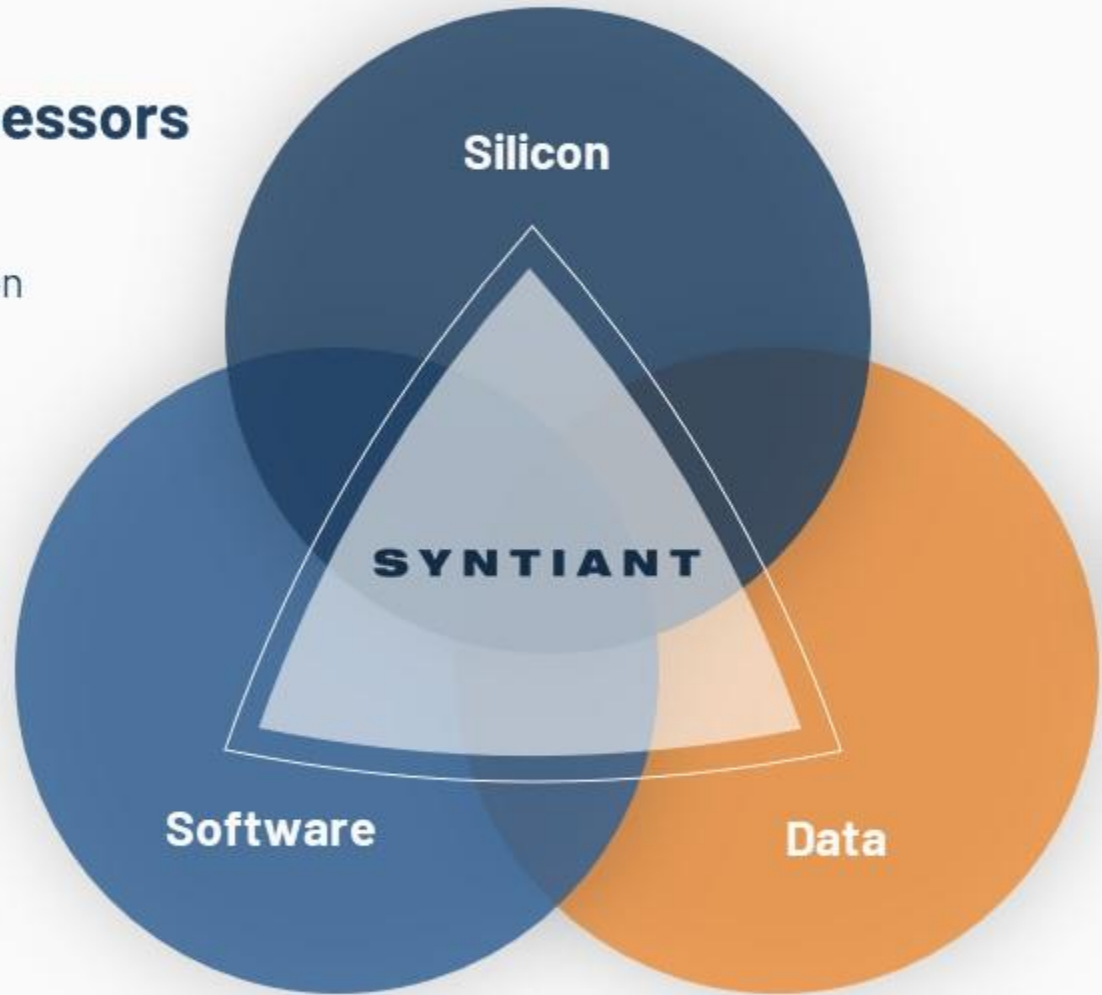
Neural Decision Processors

- At-Memory Compute
- Sustained High MAC Utilization
- Native Neural Network Processing



ML Training Pipeline

- Enables Production Quality Deep Learning Deployments



Data Platform

- Reduces Data Collection Time and Cost
- Increases Model Performance

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WE USE AI TO MAKE OTHER AI FASTER, SMALLER AND MORE POWER EFFICIENT



Automatically compress SOTA models like MobileNet to <200KB with **little to no drop in accuracy** for inference on resource-limited MCUs



Reduce model optimization trial & error from weeks to days using Deeplite's **design space exploration**



Deploy more models to your device without sacrificing performance or battery life with our **easy-to-use software**

BECOME BETA USER bit.ly/testdeeplite

mobilityXlab

arm





KLIKA · TECH

GLOBAL IOT SOLUTIONS



Reality AI[®]

Add Advanced Sensing to your Product with Edge AI / TinyML

<https://reality.ai>



info@reality.ai



[@SensorAI](https://twitter.com/SensorAI)



[Reality AI](https://www.linkedin.com/company/reality-ai)

**Pre-built Edge AI sensing modules,
plus tools to build your own**

Reality AI solutions

Prebuilt sound recognition models for
indoor and outdoor use cases

Solution for industrial anomaly detection

Pre-built automotive solution that lets cars
“see with sound”

Reality AI Tools[®] software

Build prototypes, then turn them into
real products

Explain ML models and relate the function
to the physics

Optimize the hardware, including
sensor selection and placement

BROAD AND SCALABLE EDGE COMPUTING PORTFOLIO

Microcontrollers & Microprocessors

Arm® Core



Arm® Cortex®-M 32-bit MCUs
Arm ecosystem, Advanced security, Intelligent IoT



Arm®-based High-end 32 & 64-bit MPUs
High-resolution HMI, Industrial network & real-time control



Arm® Cortex®-M0+ Ultra-low Power 32-bit MCUs
Innovative process tech (SOTB), Energy harvesting

Renesas Synergy™ Arm®-based 32-bit MCUs for Qualified Platform
Qualified software and tools

Renesas Core



Ultra-low Energy 8 & 16-bit MCUs
Bluetooth® Low Energy, SubGHz, LoRa®-based Solutions



High Power Efficiently 32-bit MCUs
Motor control, Capacitive touch, Functional safety, GUI



40nm/28nm process Automotive 32-bit MCUs
Rich functional safety and embedded security features

Core technologies

AI

A broad set of high-power and energy-efficient embedded processors

Security & Safety

Comprehensive technology and support that meet the industry's stringent standards



Digital & Analog & Power Solution

Winning Combinations that combine our complementary product portfolios

Cloud Native

Cross-platforms working with partners in different verticals and organizations

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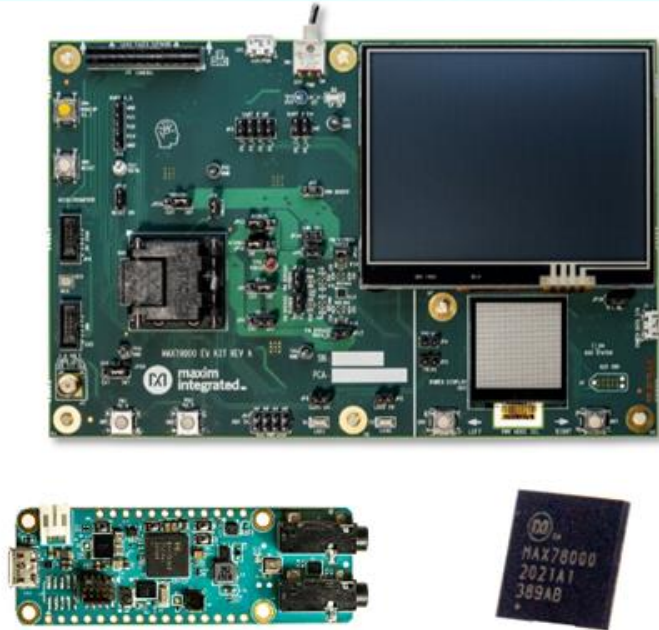


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Maxim Integrated: Enabling Edge Intelligence

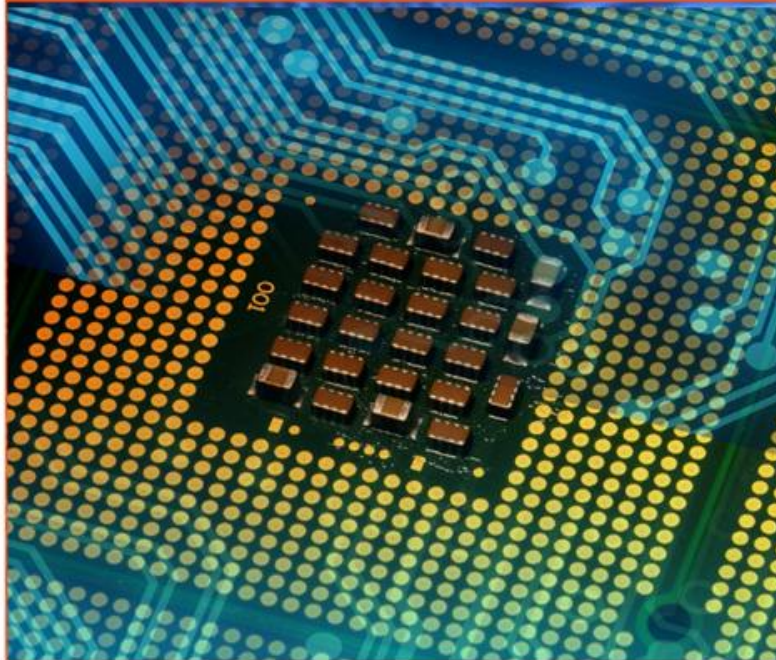
Advanced AI Acceleration IC



The new MAX78000 implements AI inferences at low energy levels, enabling complex audio and video inferencing to run on small batteries. Now the edge can see and hear like never before.

www.maximintegrated.com/MAX78000

Low Power Cortex M4 Micros



Large (3MB flash + 1MB SRAM) and small (256KB flash + 96KB SRAM, 1.6mm x 1.6mm) Cortex M4 microcontrollers enable algorithms and neural networks to run at wearable power levels.

www.maximintegrated.com/microcontrollers

Sensors and Signal Conditioning



Health sensors measure PPG and ECG signals critical to understanding vital signs. Signal chain products enable measuring even the most sensitive signals.

www.maximintegrated.com/sensors



Latent AI

Adaptive AI for the Intelligent Edge

[Latentai.com](https://latent.ai)



Micr .ai



NXP



seeed studio

The IoT Hardware Enabler



Build Smart IoT Sensor Devices From Data

SensiML pioneered TinyML software tools that auto generate AI code for the intelligent edge.

- End-to-end AI workflow
- Multi-user auto-labeling of time-series data
- Code transparency and customization at each step in the pipeline

We enable the creation of production-grade smart sensor devices.



sensiml.com

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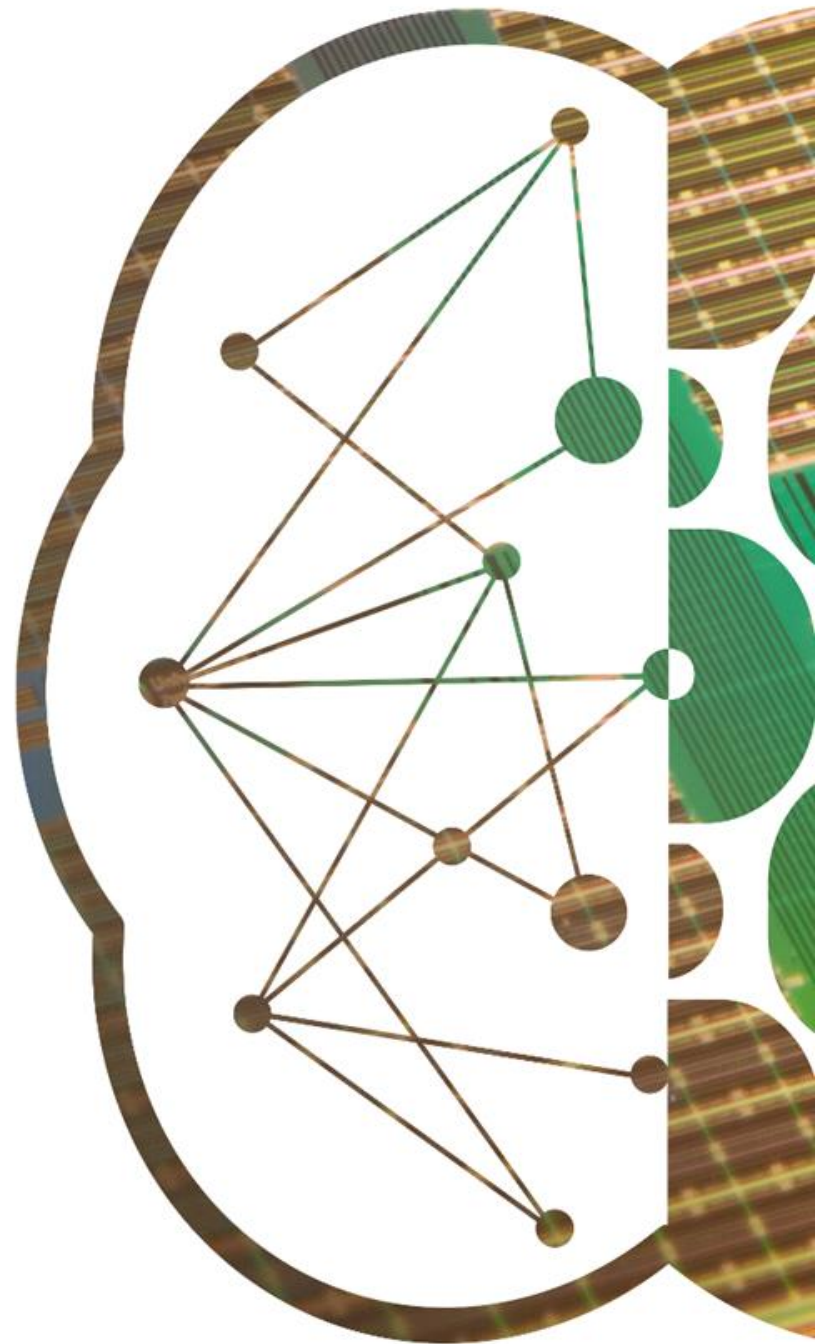
life.augmented



SynSense

SynSense builds **sensing and inference** hardware for **ultra-low-power** (sub-mW) **embedded, mobile and edge** devices. We design systems for **real-time always-on smart sensing**, for audio, vision, IMUs, bio-signals and more.

<https://SynSense.ai>



T I N Y



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AONdevices



Grovety Inc.





tinyML Summit 2022

Miniature dreams can come true...

March 28-30, 2022

Hyatt Regency San Francisco Airport

<https://www.tinymml.org/event/summit-2022/>

*The Best Product of the Year and the Best Innovation of the Year awards are open for nominations between **November 15** and **February 28**.*

tinyML Research Symposium 2022

March 28, 2022

<https://www.tinymml.org/event/research-symposium-2022>

More sponsorships are available: sponsorships@tinyML.org



tinyML Trailblazers Series

Success Stories with Joel Rubino
(CEO & Co-founder of Cartesium)

LIVE ONLINE February 2nd, 2022 at 8 am PST



Register now!





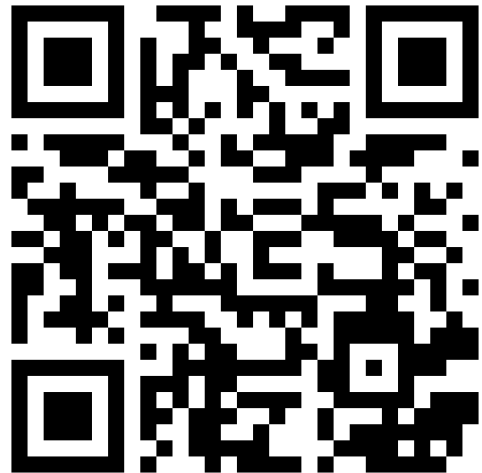
Join Growing tinyML Communities:



7.8k members in
42 Groups in 33 Countries

tinyML - Enabling ultra-low Power ML at the Edge

<https://www.meetup.com/tinyML-Enabling-ultra-low-Power-ML-at-the-Edge/>



2.5k members
&
4.4k followers

The tinyML Community

<https://www.linkedin.com/groups/13694488/>





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www.youtube.com/tinyML



tinyML
4.33K subscribers

5.9k subscribers, 337 videos with 170k views

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tinyML Summit 2021 tiny Talks: Person Detection... 18:26

tinyML Summit 2021 tiny Talks: Using Neural... 19:03

tinyML Summit 2021 Keynote: Adaptive Neural... 55:15

tinyML Summit 2021 Keynote: millJoules for... 99:43

tinyML Summit 2021 Market Opportunities for Edge AI 51:28



Next tinyML Talks

Date	Presenter	Topic / Title
Tuesday, February 1	Muhammad Shafique, New York University Abu Dhabi (NYUAD), UAE	Energy-Efficiency and Security for TinyML and EdgeAI: A Cross-Layer Approach

Webcast start time is 8:00 am Pacific time

Please contact talks@tinymml.org if you are interested in presenting



Reminders

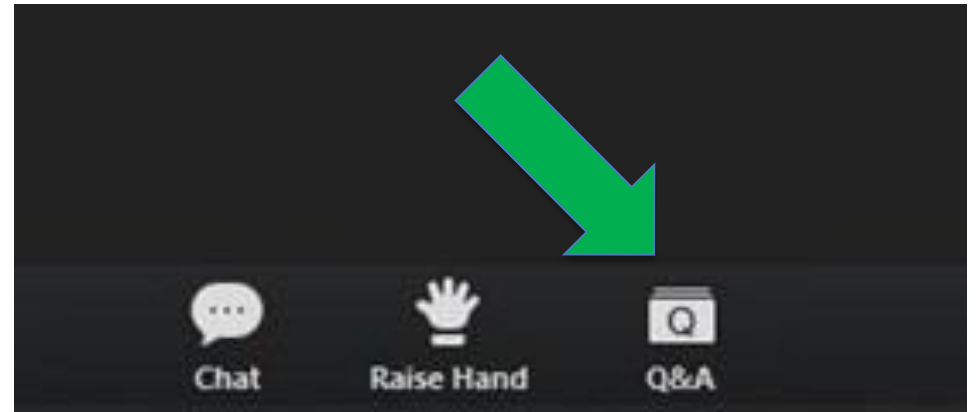
Slides & Videos will be posted tomorrow

Please use the Q&A window for your questions



tinyml.org/forums

youtube.com/tinyml

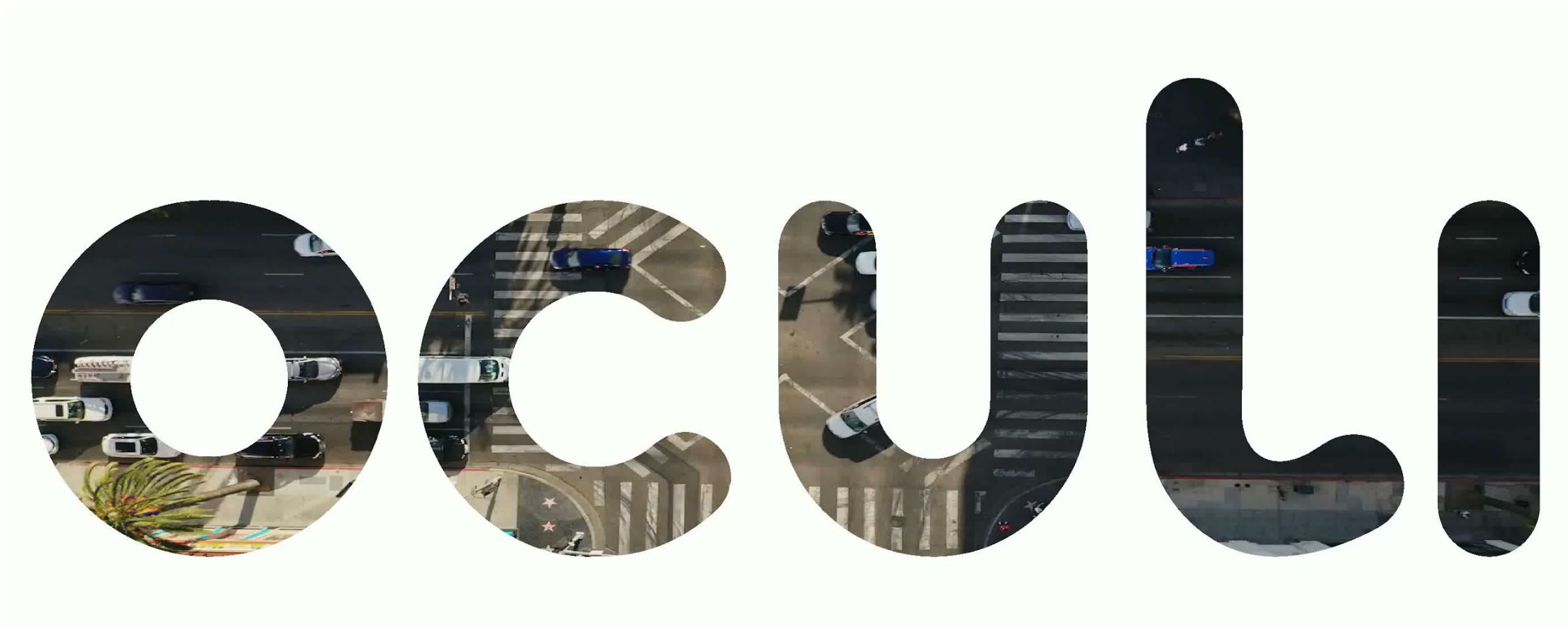




Charbel Rizk



Dr. Rizk is the Founder CEO, CTO of Oculi and an Associate Research Professor at Johns Hopkins ECE. He has been recognized as a top innovator, thought leader, and successful Principal Investigator / S&T manager. He was a pioneer in autonomous systems and led a small team that developed and demonstrated the first four-rotor (quad rotor) UAV system in the early 90's. Dr. Rizk has successfully collaborated with various FFRDC's, government labs, academia, and industry of various sizes. He is a senior member of IEEE, AIAA, and a member of AUVSI, EAA, and OSA.



REAL-TIME VISION INTELLIGENCE

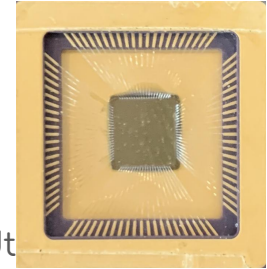
charbel.rizk@oculi.ai

www.oculi.ai



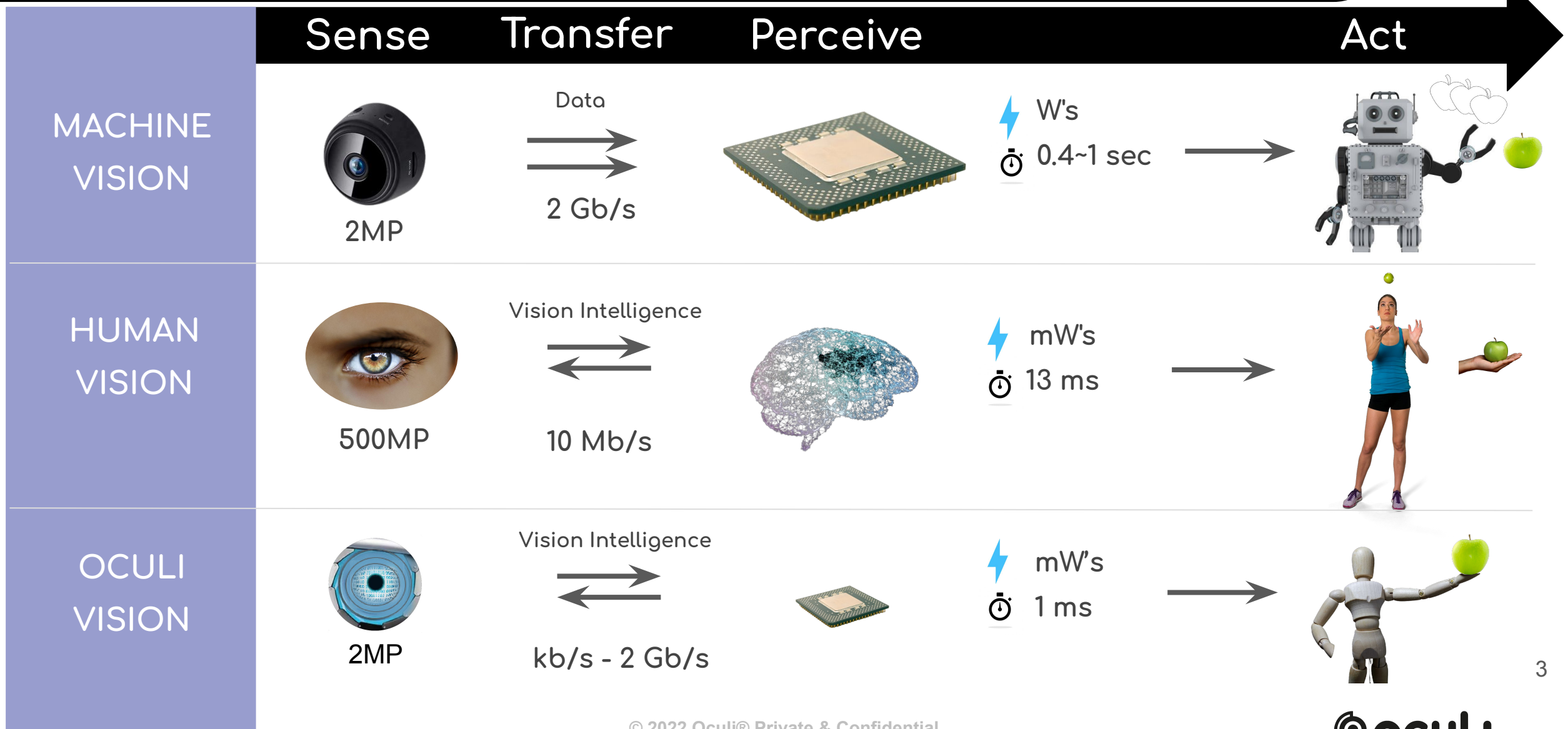
BOTTOM LINE

- OCULI SPU is the only software-defined vision sensor on a single-chip
 - Combines sensing + pre-processing at the pixel to deliver real-time vision intelligence
- Up to 30x better in energy-delay product
 - The most efficient architecture whether constrained by power, latency, processing, or bandwidth
- Proven technology with well protected IP
 - Functioning chips that have been delivered to partners for evaluation
- Initial focus on XR and smart/interactive display (B2B)
 - Can easily expand to other markets such as ITS, industrial, and automotive

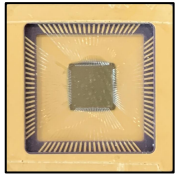


*OCULI SPU™
(Sensing and
Processing Unit)*

OCULI MIMICS HUMAN VISION



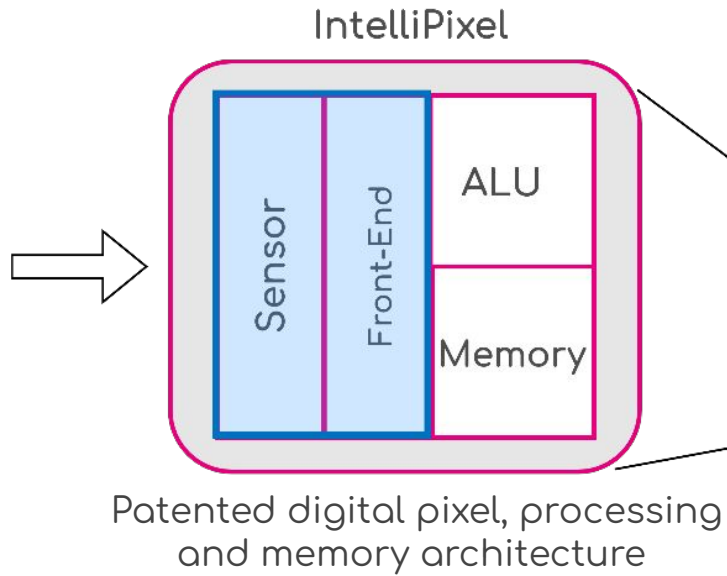
OCULI SPU ARCHITECTURE



SPU = Sensing and processing unit



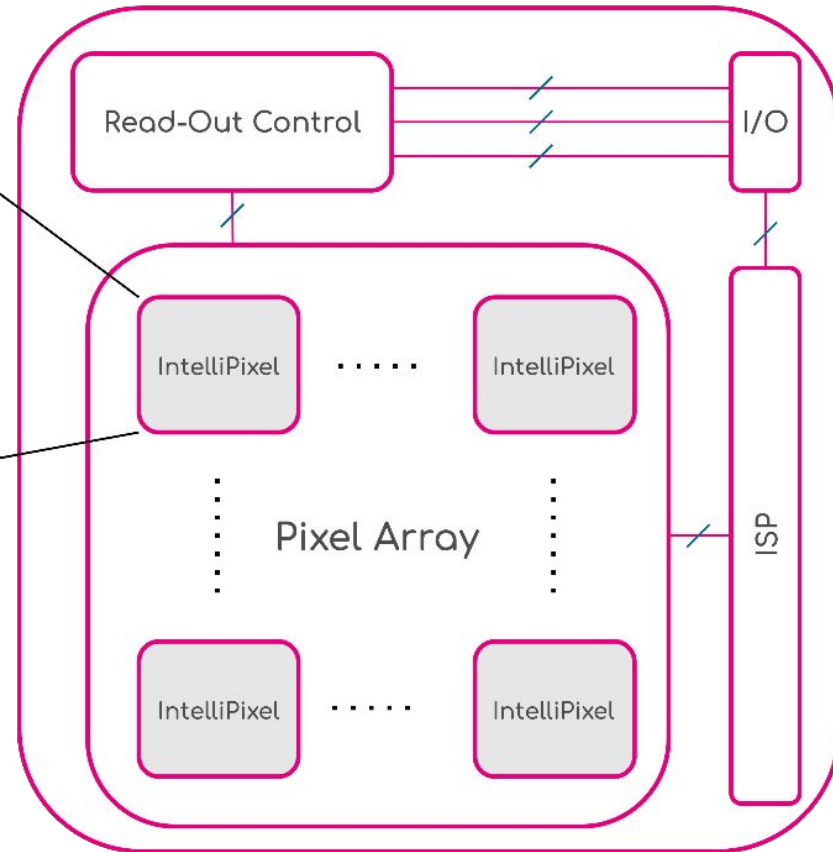
Scene



Patented digital pixel, processing and memory architecture

- Integrated neuromorphic sensing & processing
- Intellipixel = sensor+processing+memory
- Sensor Agnostic: works with conventional CMOS, DVS, infrared, depth/TOF, and multi-mode

OCULI SPU

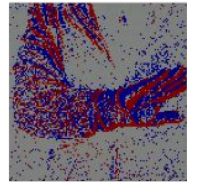


Oculi Outputs

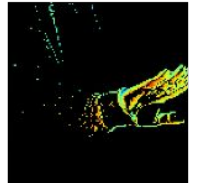
Full Frames



Events



Smart Events



Actionable Information

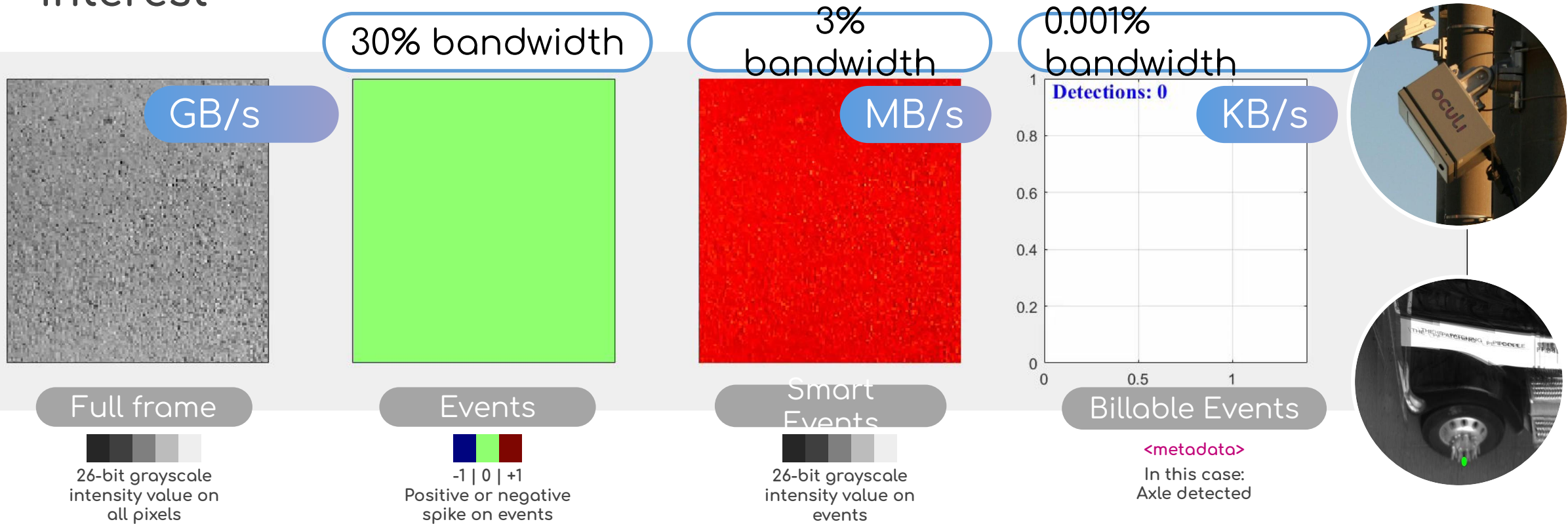


Unique to Oculi

FIELD DEPLOYMENT: INTELLIGENT TRANSPORTATION

Low Latency & Data Bandwidth

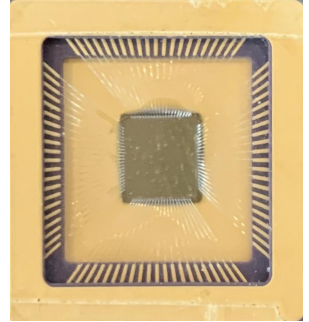
The OCULI SPU is dynamically programmed to deliver the signal of interest



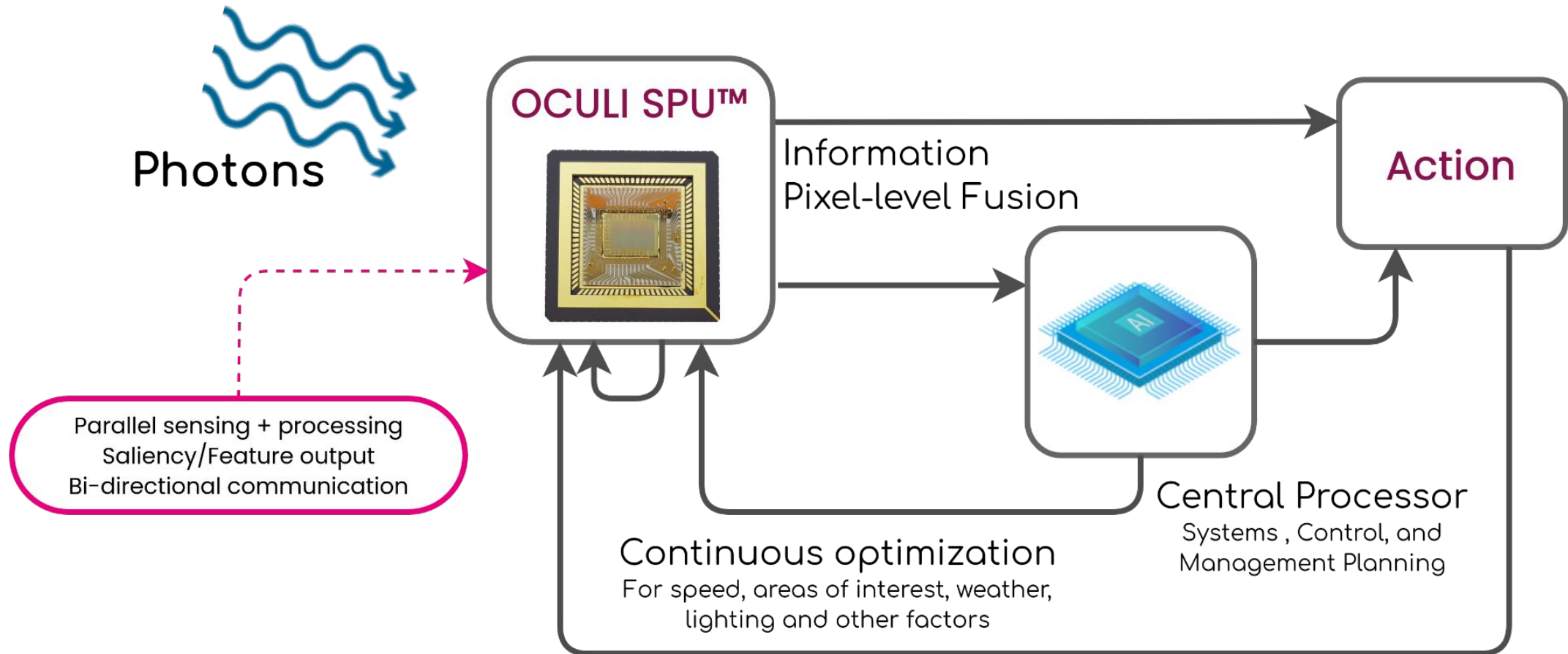
Customer validation with OCULI SPU S11 – first Oculi product
A complete vision solution on a single chip, ideal for edge applications

SINGLE CHIP SOFTWARE-DEFINED VISION SENSOR

- All key aspects are programmable to enable dynamic optimization
 - Native raw output: full frame, events, smart events, and actionable signal
 - Smart selectivity including spatial and temporal filtering
 - Sampling speed: Hz to MHz
 - In-pixel memory & compute
 - Sensitivity
 - Dynamic range
 - Quantization level
 - Bit depth and resolution
 - Sensing modality: color, depth, or both

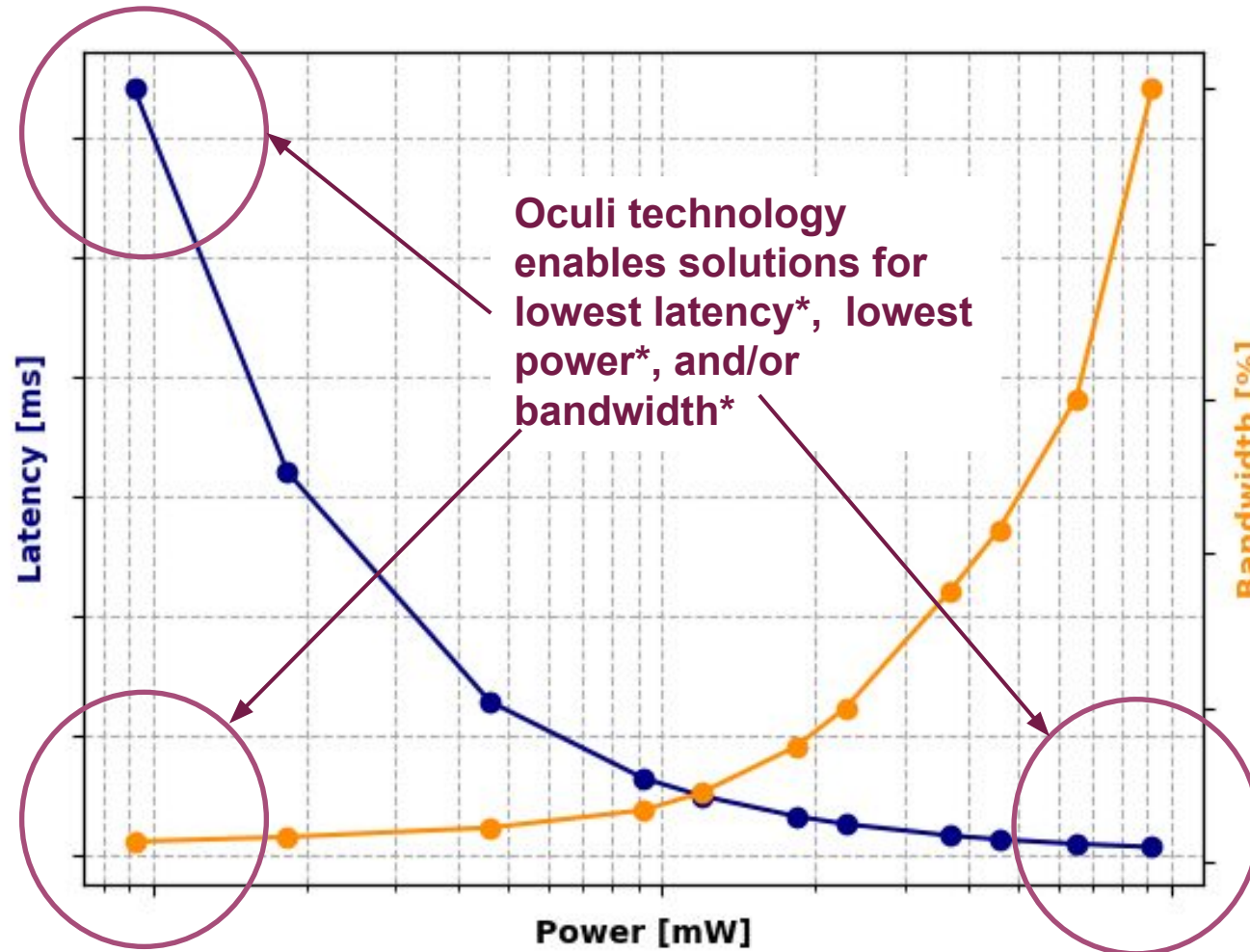


OPTIMIZED SYSTEM/SOLUTION ARCHITECTURE



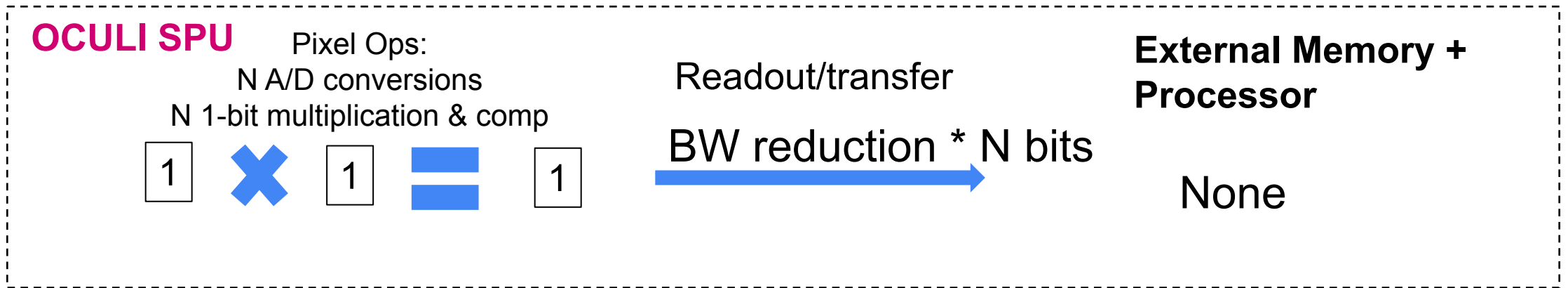
KEY VISION TRADE OFF: LATENCY (or BANDWIDTH) VS. POWER

Software-defined architecture delivers flexibility to operate and optimize in this trade space, enables economies of scale – same hardware product for multiple markets

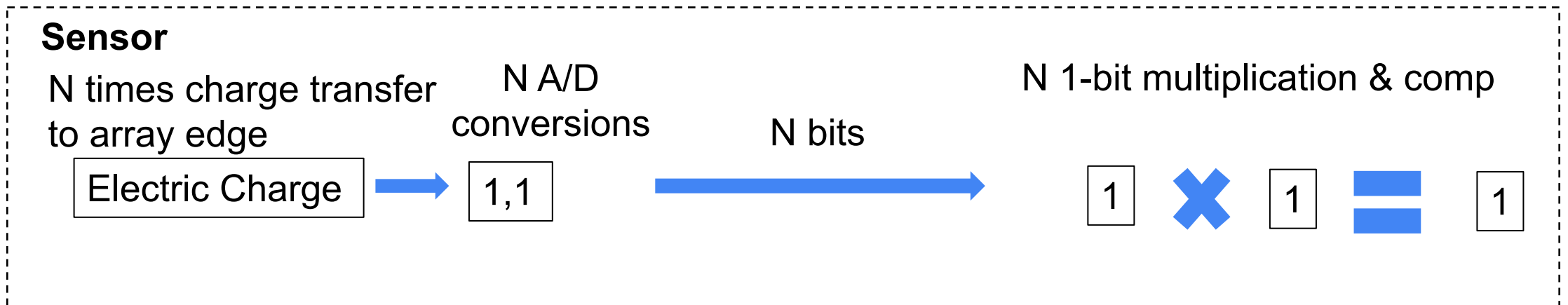


*When cost is the common denominator

INTELLIPIXEL REDUCES SYSTEM LATENCY & POWER

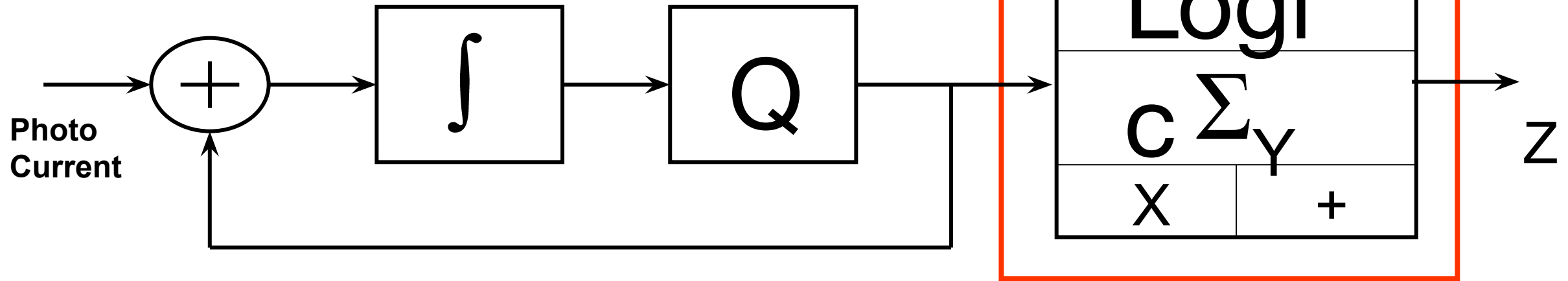


Binary Sensor with N pixels



OCULI INTELLIPIXEL

Oculi IntelliPixel™



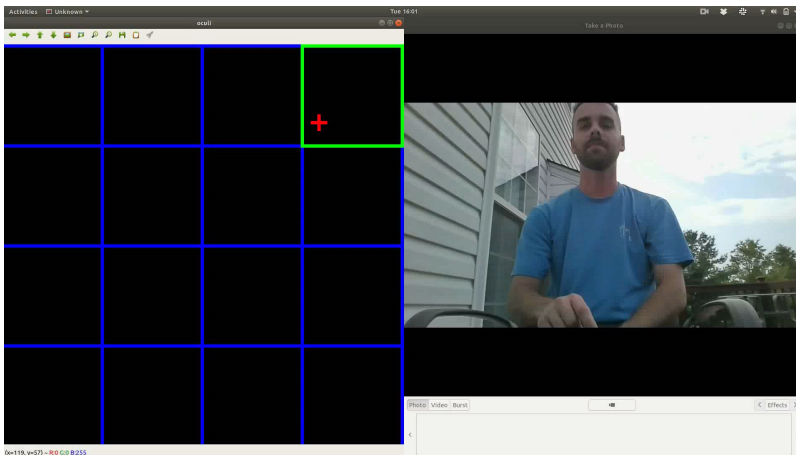
- $Z = A * / Y +- B$

- A & B are also programmable per pixel

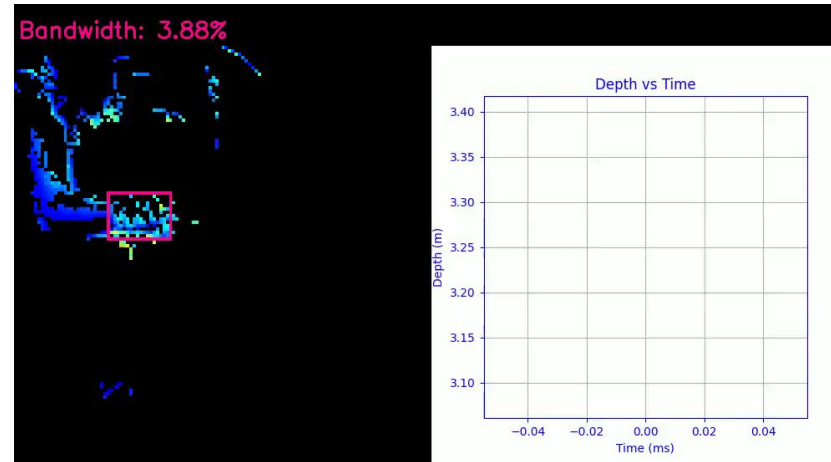
*J. H. Lin, P. O. Pouliquen, A. G. Andreou, A. C. Goldberg, C. G. Rizk. Flexible readout and integration sensors (FRIS): a bio-inspired, system-on-chip, event based readout architecture. In *Proceedings of SPIE: Infrared Technology and Applications XXXVIII Conference*, pages 8353-1N, May 2012. ii, 3, 4, 5, 10

EFFICIENT REAL-TIME GESTURE, EYE, & FACE TRACKING

Gesture Control

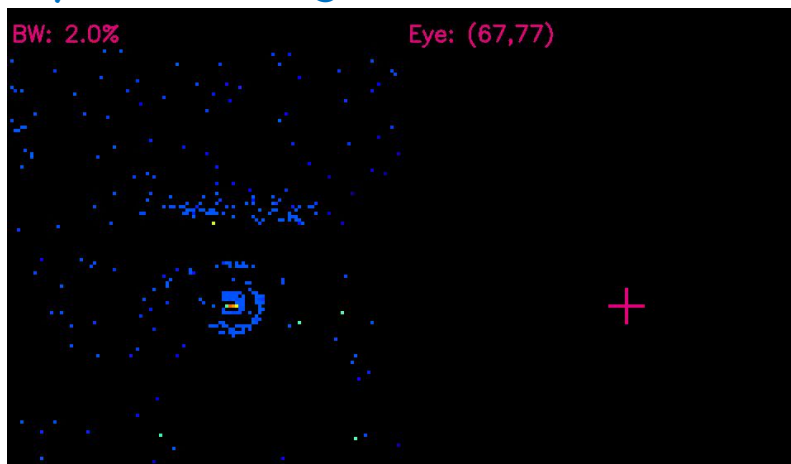


High speed depth sensing with stereo vision

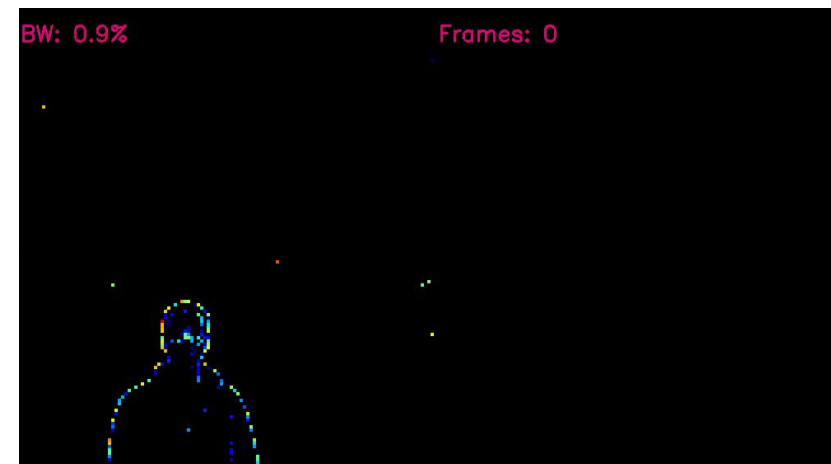


- A complete vision solution on a single chip
- Delivers near-zero lag & anonymous user analytics

Eye Tracking



Face Detection



PEOPLE DETECTION: SMART EVENTS VERSUS FULL FRAME

Full Frame

Smart Events



- ML Model was trained on full frames and used as is, no additional fine tuning
- ML Model evaluated using smart events as the input data (native raw output of the OCULI SPU)

PEOPLE COUNTING: SMART EVENTS VERSUS FULL FRAME

Full Frame

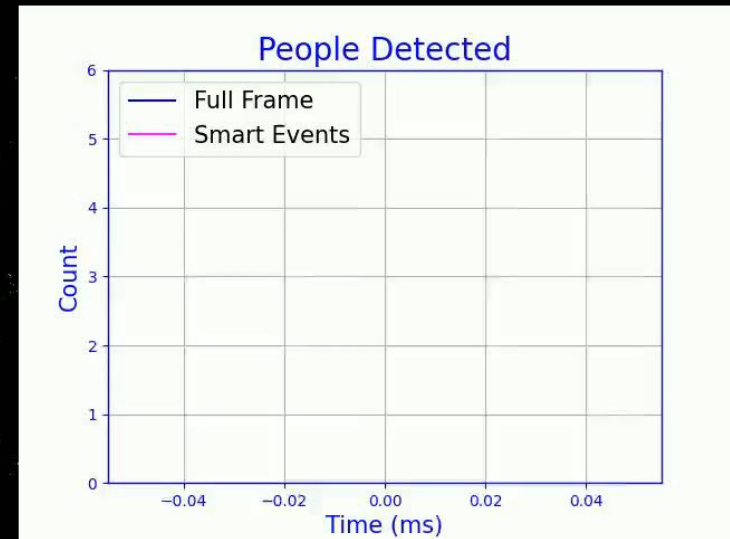
Smart Events

Full Frame

Smart Events

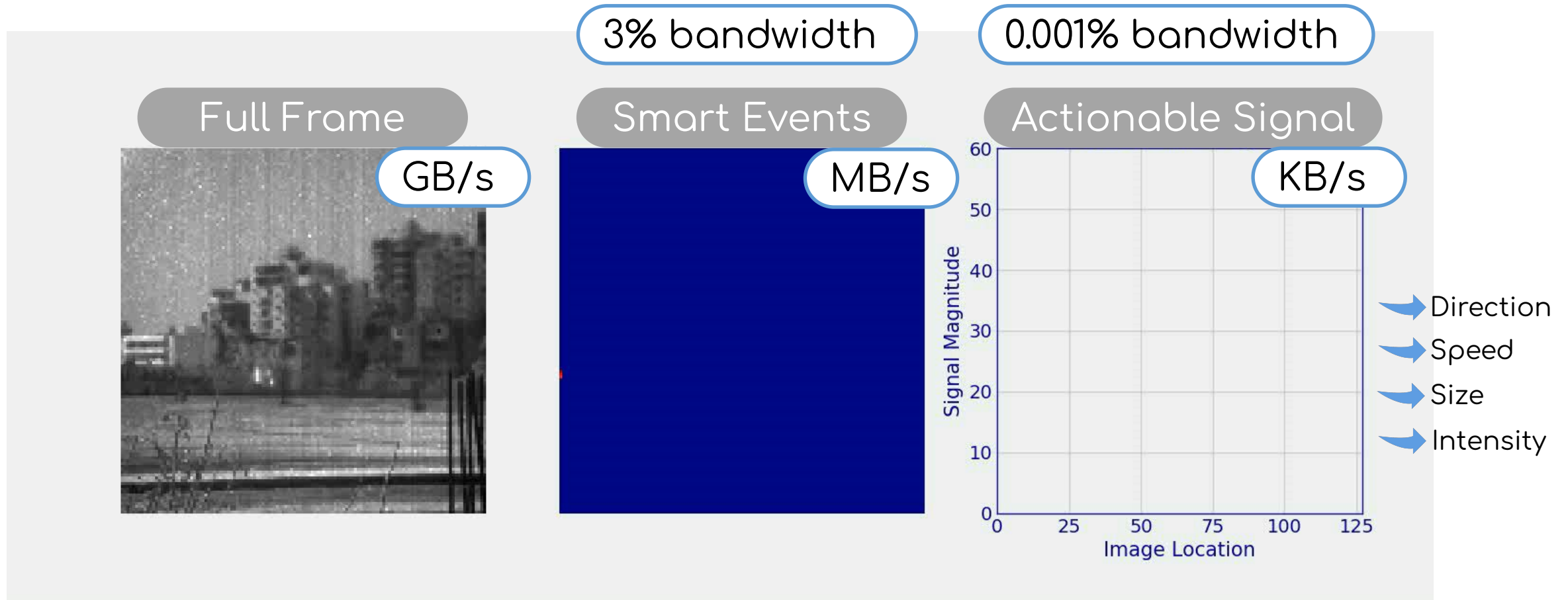
Bandwidth: 100.00%

Bandwidth: 1.91%



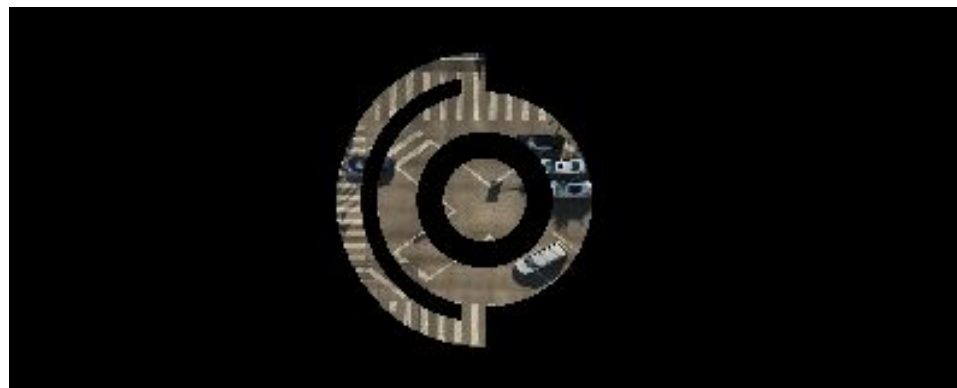
- ML Model was trained on full frames and used as is, no additional fine tuning
- ML Model evaluated using smart events as the input data (native raw output of the OCULI SPU)

LOW POWER ALWAYS ON WIRELESS SMART IMAGER APPLICATION



The OCULI SPU reduces bandwidth and external processing by up to 99% with zero loss of relevant data making it ideal for IoT and Edge Applications.

REAL TIME SPATIAL FILTERING WITH ANY PATTERN

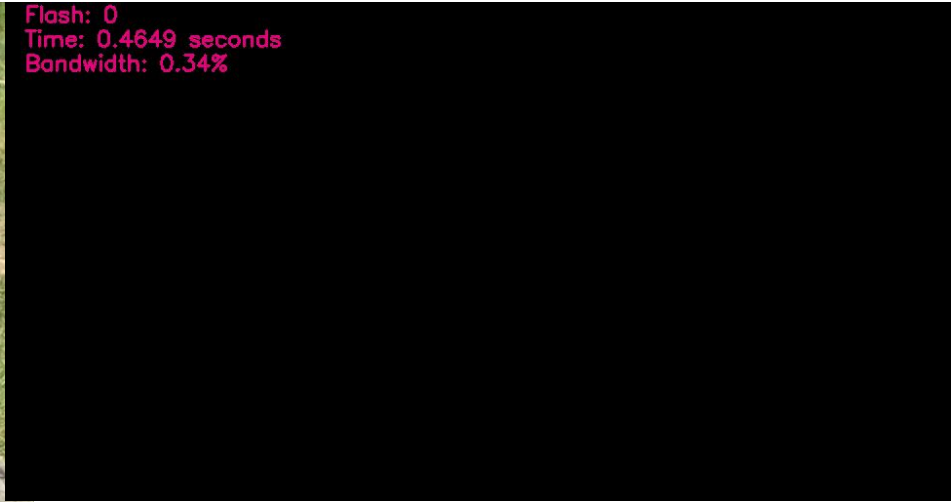


OCULI REMOVES THE SENSOR THROUGHPUT/BANDWIDTH/DATA CONSTRAINTS

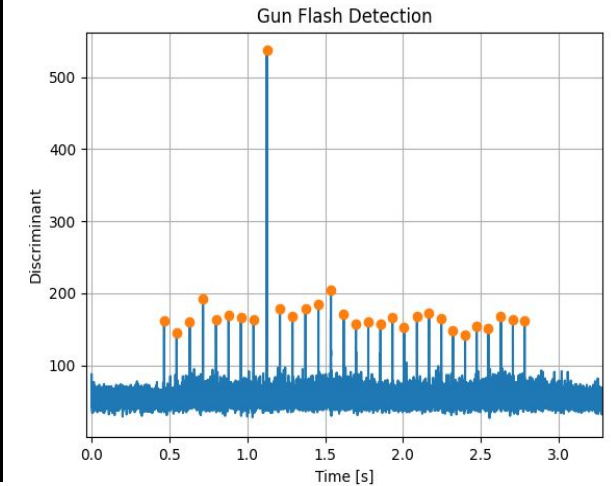
Full Frame (120 GB/s)



Smart Events (10 MB/s)



Actionable Signal (30 kB/s)



Oculi Technology Enables EFFECTIVE TinyML Solutions
Even for High Speed Imaging Applications

DUAL MODE IMAGING: COLOR & DEPTH



Smart Events
based on
rate of
change



Smart Events
based on value

In-pixel Sensor Fusion & Smart Selectivity Enables TinyML
Solutions for 3D Imaging Applications

USER FRIENDLY PLATFORM & SOFTWARE TOOLKIT



- Interactive GUI
- Interfaces with S11 SPU

GUI

Interactive GUI to collect data and visualize output from the OCULI SPU™ in various modes.

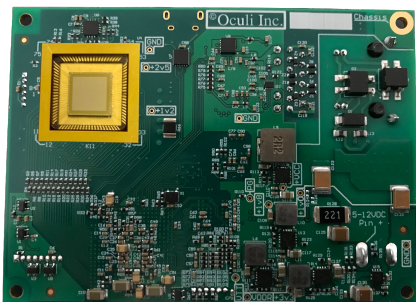
DEMOS

Comprehensive, out of the box demo applications including:

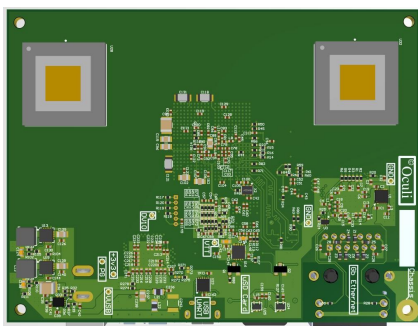
- Visualize: differencing, foreground extraction, intensity mode, full frames
- Scene reconstruction
- Anonymous face detection

SDK

Libraries (C++), code samples (C++/Python), and documentation.



- Oculi P11/P11B Platform
- Shipped to customers
- Used for all demos and pilot projects
- Includes S11 SPU



- Stereo Vision platform available Q1 2022
- Includes S11 SPU (x2)

REGISTRATION / TRADEMARK

OCULI SPU and other Oculi products referenced herein are products of FRIS Inc. (dba Oculi).

Oculi®

IntelliPixel®

OCULI SPU™

BionicVision®

LiDAR Lite™

Software-Defined Vision Sensor™

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For additional information please contact charbel.rizk@oculi.ai

REAL-TIME VISION INTELLIGENCE

- LOW POWER
- LOW BANDWIDTH
- LOW COST
- FAST RESPONSE
- SMALL / LIGHT WEIGHT

Charbel Rizk PhD, Founder CEO
charbel.rizk@oculi.ai



THANK YOU!

www.oculi.ai



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