Intel's Neuromorphic Research Chip Loihi

Technology:	14nm
Die Area:	60 mm2
Neuro cores:	128 cores
x86 cores:	3 LMT cores
Max # neurons:	128K neurons
Max # synapses:	128M synapses
Transistors:	2.07 billion
Memory:	33 MB
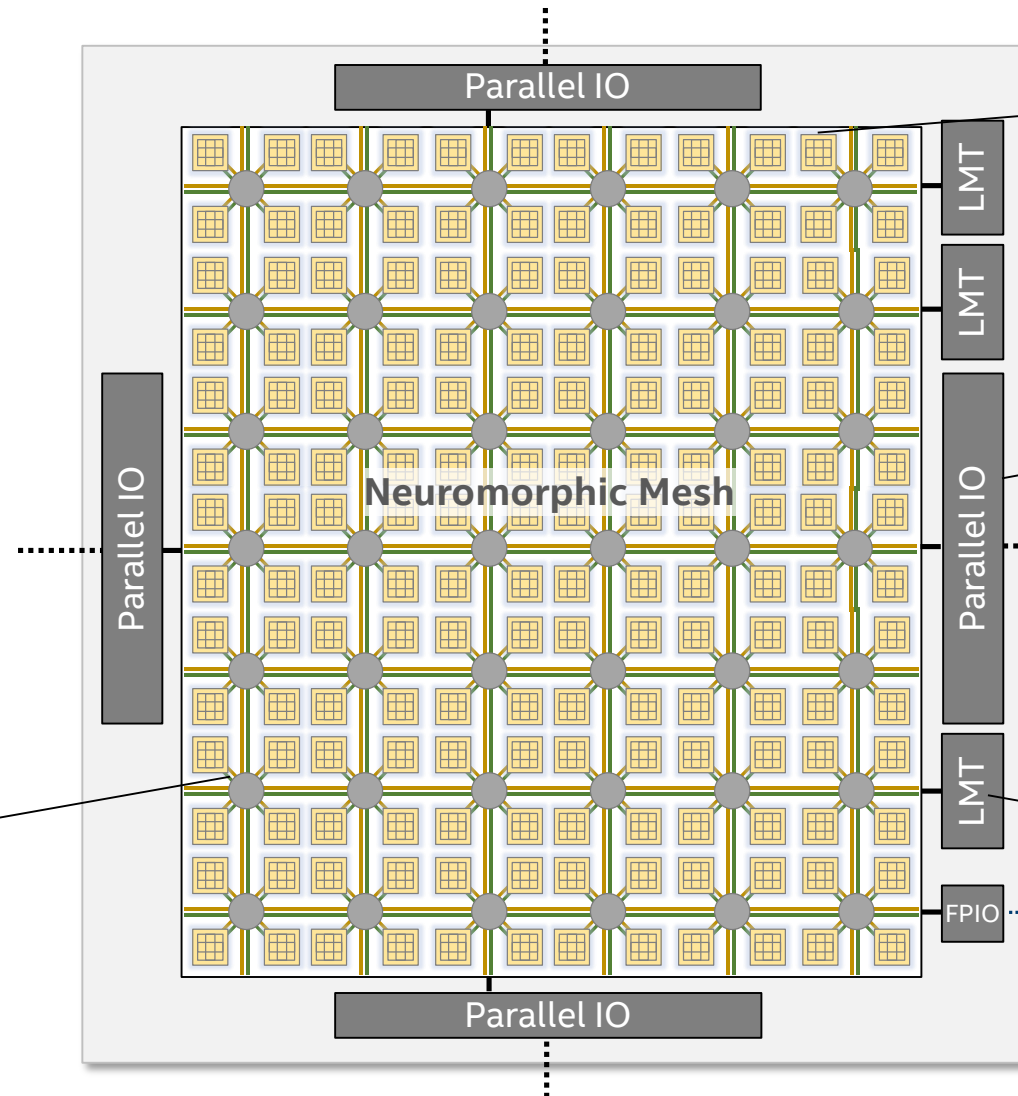
Neuromorphic core
- Leaky integrate-and-fire neuron model
- Programmable learning
- 128 KB synaptic memory
- Up to 1,024 neurons
- Asynchronous design

Parallel off-chip interfaces
- Two-phase asynchronous
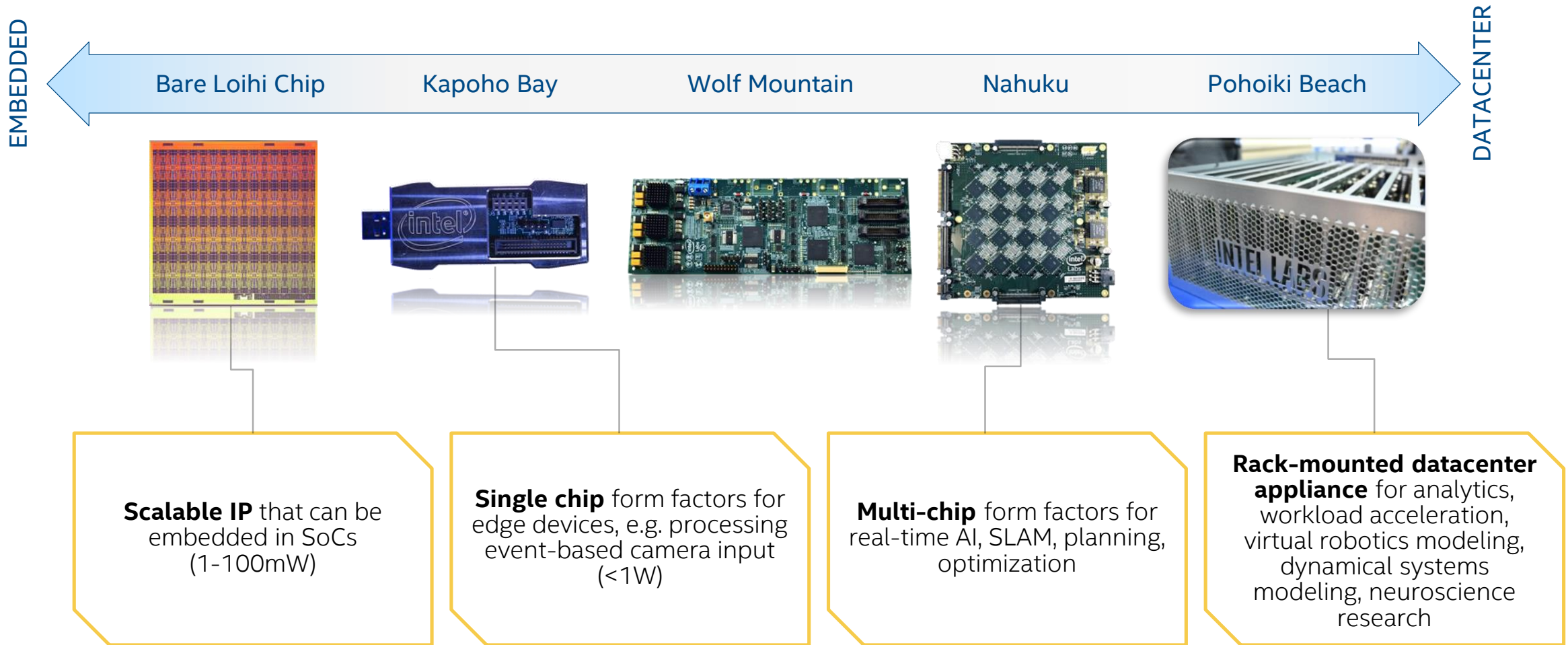- Single-ended signaling
- 100-200 MB/s BW

Embedded x86 processors
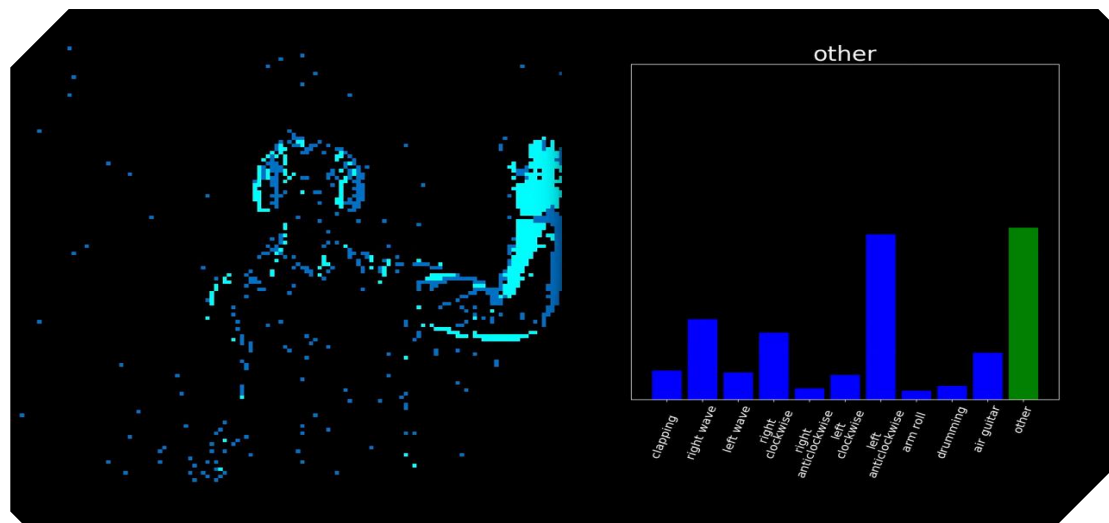- Efficient spike-based communication with neuromorphic cores
- Data encoding/decoding
- Network configuration
- Synchronous design

Low-overhead NoC fabric
- 8x16-core 2D mesh
- Scalable to 1000's cores
- Dimension order routed
- Two physical fabrics
- 8 GB/s per hop

Parallel IO

Parallel IO

Parallel IO

Parallel IO

LMT

LMT

LMT

FPIO

Neuromorphic Mesh

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Loihi: form factors

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| Bare Loihi Chip | Kapoho Bay | Wolf Mountain | Nahuku | Pohoiki Beach |

Scalable IP that can be embedded in SoCs (1-100mW)

Single chip form factors for edge devices, e.g. processing event-based camera input (<1W)

Multi-chip form factors for real-time AI, SLAM, planning, optimization

Rack-mounted datacenter appliance for analytics, workload acceleration, virtual robotics modeling, dynamical systems modeling, neuroscience research

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Loihi and event-based vision

SLAYER networks

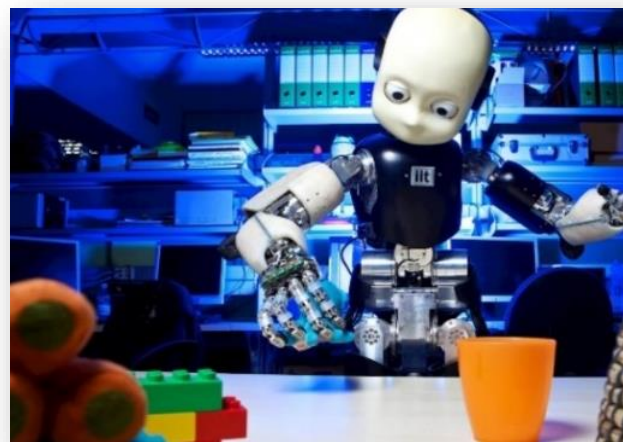**DAVIS240C***
5mW static
5mW dynamic
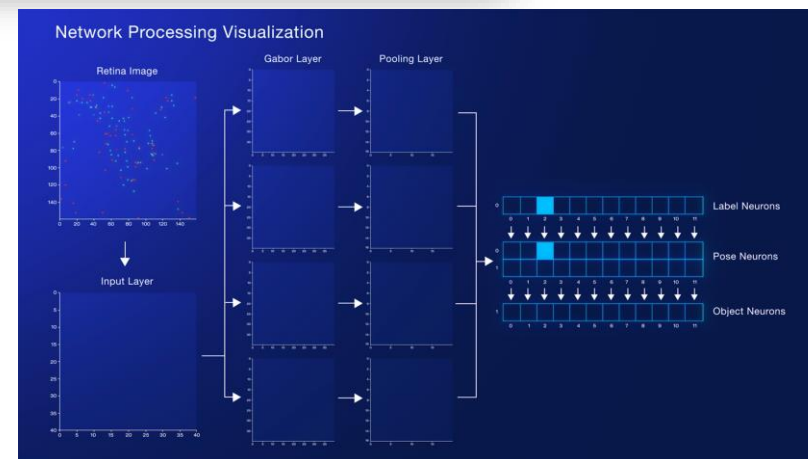1ms latency

Loihi[†]
36mW static
7mW dynamic
<10ms latency

Deep SNN trained in an event-based manner

See also: K. Stewart, G. Orchard, E. Neftci, On-chip Few-shot Learning with Surrogate Gradient Descent on a Neuromorphic Processor. arXiv:1910.04972, November 2019.

Fast object learning
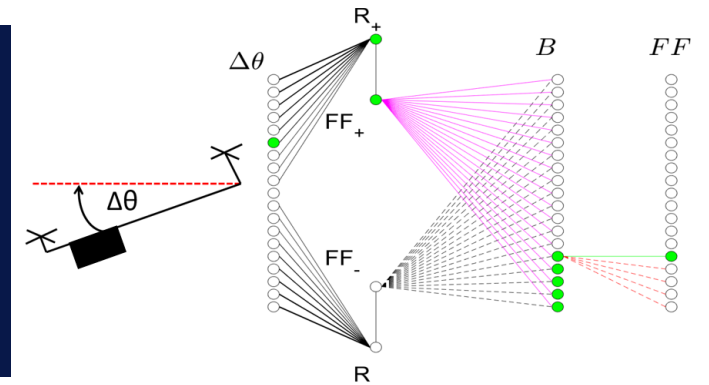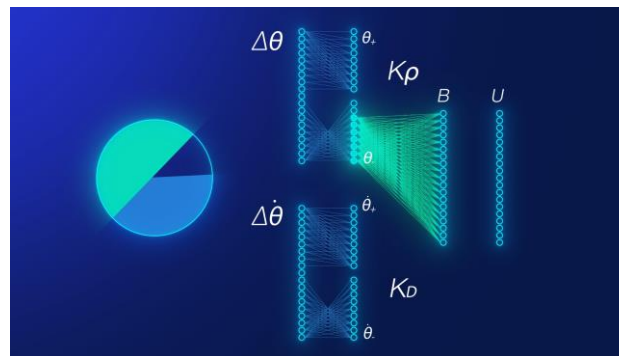

- Attention
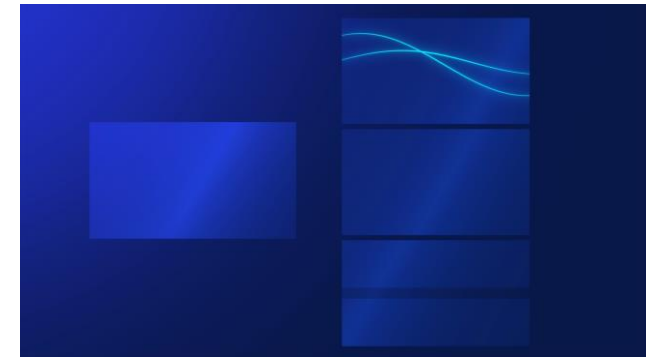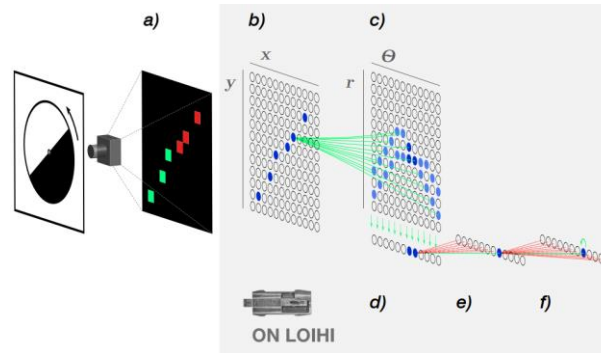- State machine
- Spatial memory
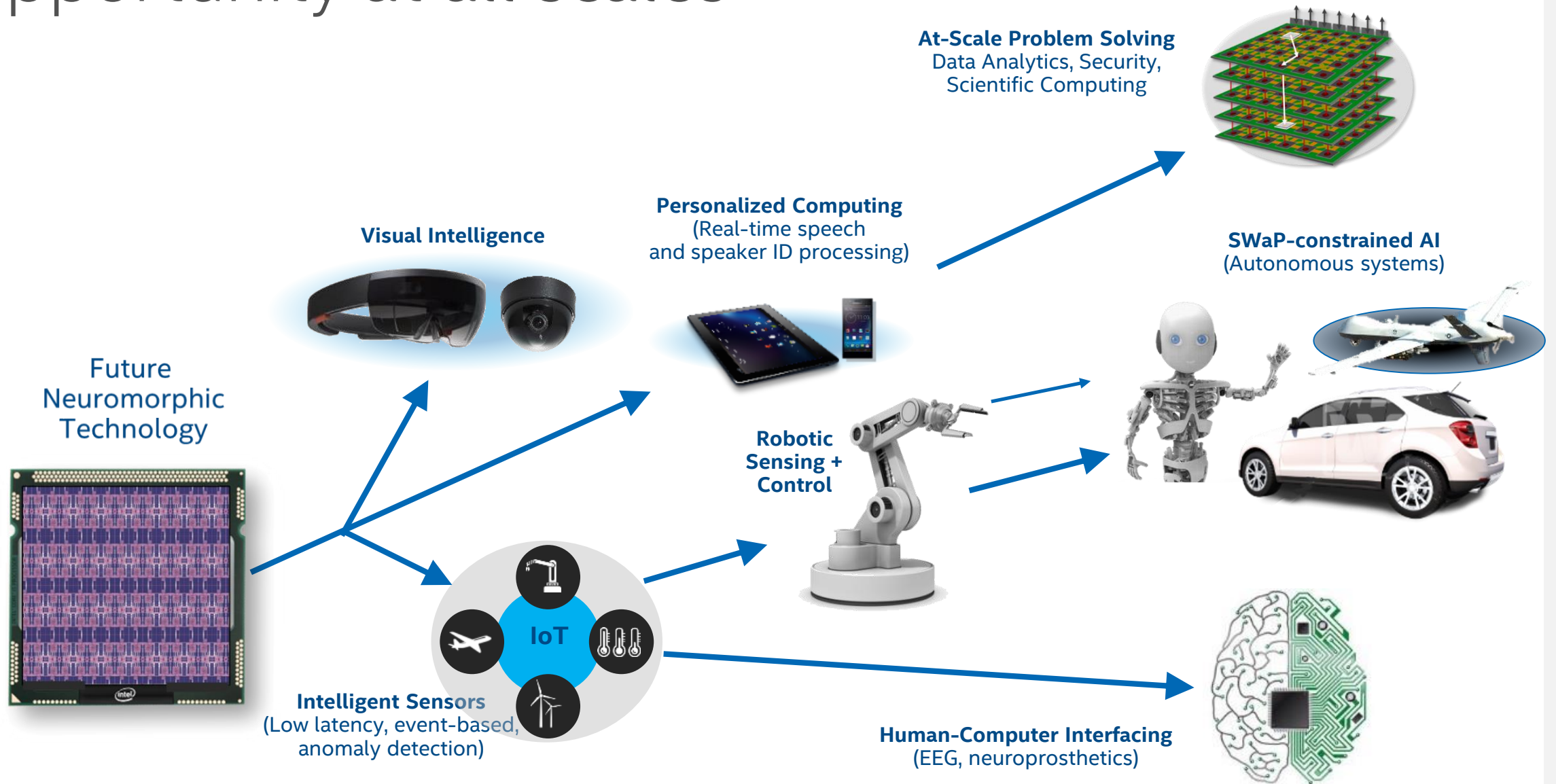
Adaptive motor control

- Enabling the full pipeline from sensing to control on chip
  - Event-based sensing (line tracking) on chip: <200 mks
  - SNN-based control: up to 20kHz vision-driven control rate

Towards Low-Latency High-Bandwidth Control of Quadrotors using Event Cameras. Robotics Perception Group, University of Zurich
https://www.youtube.com/watch?v=KfY9j3XAiDU&feature=youtu.be

Opportunity at all scales

Visual Intelligence

Personalized Computing
(Real-time speech
and speaker ID processing)

At-Scale Problem Solving
Data Analytics, Security,
Scientific Computing

SWaP-constrained AI
(Autonomous systems)

Future
Neuromorphic
Technology

**Robotic
Sensing +
Control**

IoT

Intelligent Sensors
(Low latency, event-based,
anomaly detection)

Human-Computer Interfacing
(EEG, neuroprosthetics)

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Intel Neuromorphic Research Community

THEORY

SENSORS & ACTUATORS

ALGORITHMS

PROGRAMMING MODELS

APPLICATIONS
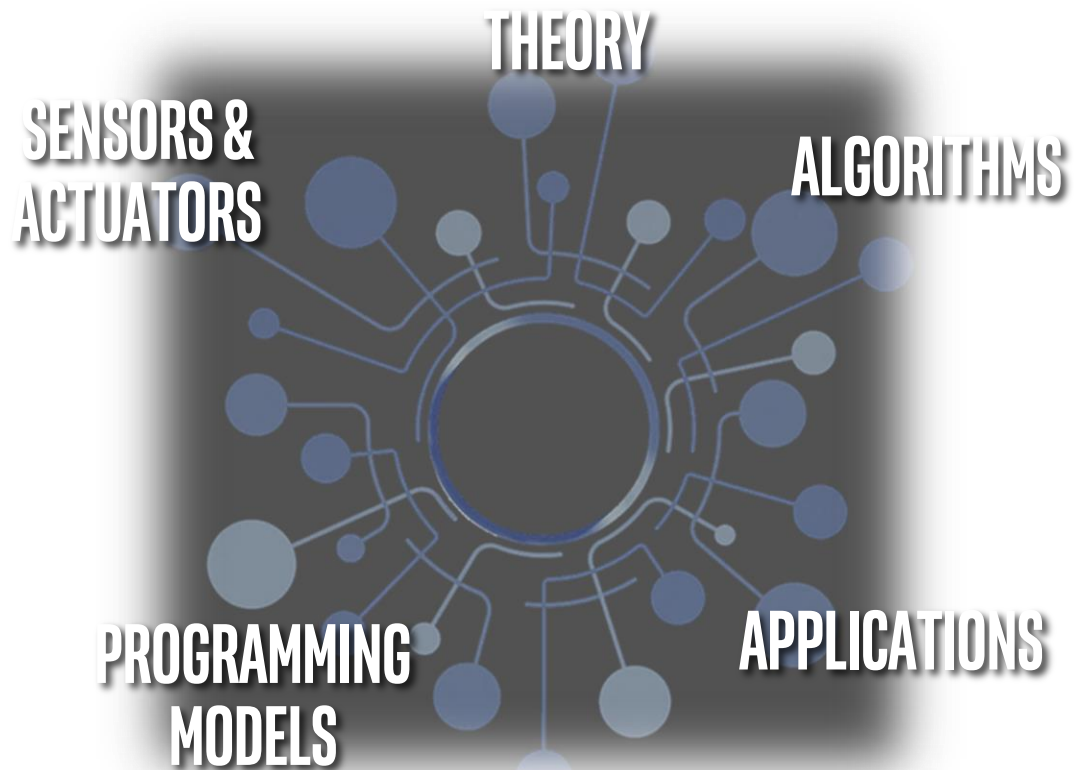
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