Ultra-low Power
Always-On
Computer Vision

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Outline

1. Background
2. Use Cases
3. Our Approach
4. Product
5. Future
Goal
Ultra-low power always-on computer vision

- Ultra-low power for always-on: **System power** less than 1mA on standard lithium cell
- Low latency with typical frame rate of 1-30 fps
- Computer Vision: Insight and information from sensor

Historically
- Image sensor takes 10mW to Ws
- Image processing takes 100mW to Ws
Vision will enhance many use cases across numerous verticals

**Smartphone**
- Face-based auto-wake and auto-sleep
- Always-on trigger for other use cases
- Always-on trigger for iris authentication (removes multiple steps and user initiation)

**Smart watch**
- Face-based auto-wake and auto-sleep
- Always-on gestures

**Tablets**
- Simple gaze tracking for advertising attribution
- Improved landscape/portrait screen orientation

**Virtual reality**
- Low power gaze tracking (foveated rendering)
- Low power visual odometry for 6 DoF

**‘Intelligent’ occupancy trigger**
- Distinguish humans from other objects
- Add data layer to trigger: How many? Where?
- Trigger on particular events or objects

**‘Intelligent’ interactivity trigger**
- Face detection as a trigger for interactivity
- Smart appliance can react when a user approaches to engage it

**Standalone intelligent data sensor**
- Heat maps of how a space is occupied
- Privacy advantages - data only, no images captured
Our always-on vision research and innovation

Integrated vision sensor & processor, independent of main processor

Lens

Sensor
- Low Power Pixels
- Low Power Custom HW

CMOS Image Sensor
Very low power QVGA

Processor
- Low Power CPU
- Dedicated HW Blocks

Digital Processor
Trainable algorithms

Memory

Main Processor
- App & OS Software

Metadata output of scene understanding

Commands/Queries
Use Cases: Our silicon can support many use cases

Half body

Full body

3/4 body

Change Detection

Multiple orientation
Use Cases: Our silicon can support many use cases

Simple Gesture (e.g. Left-Right-Left)

2-D Marker Or Logo

3-D Rigid Body (Toy)

Analytic use case:
(1) Shelf Status
(2) Customer Engagement
Successful detection in challenging light scenarios

- Detection scenario at distance and low light is challenging
- Model and algorithm must be resilient to these scenarios
- Sensor also sensitive to 850 nm IR
## What needs to be done for Always-on Computer Vision

<table>
<thead>
<tr>
<th>Our Approach</th>
<th>Traditional Approach</th>
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<tbody>
<tr>
<td>Image itself is secondary to information</td>
<td>Image quality paramount</td>
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<tr>
<td>Monochrome works in most cases. ≤ 8-bit sufficient</td>
<td>Color &amp; wide bit-depth preferred</td>
</tr>
<tr>
<td>Focus can be good enough in most cases</td>
<td>Focus, autofocus, Bokeh important</td>
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<tr>
<td>Adequate pixel count for applicable distance</td>
<td>Higher pixel count</td>
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<tr>
<td>System power optimized including sensor</td>
<td>Sensor &amp; algorithm/model often split</td>
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<tr>
<td>Images shot in challenging lighting</td>
<td>Camera &amp; subject posed for best image</td>
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<tr>
<td>Inference is heavily weighted</td>
<td>Balance between training &amp; inference time</td>
</tr>
<tr>
<td>Algorithms redesigned with memory &amp; power in mind</td>
<td>Built upon available technologies</td>
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<tr>
<td>Metrics may be event-based</td>
<td>Typical metric is frame-based</td>
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Our System Approach for Always-on Computer Vision

• Favor algorithms with adaptive compute
  ◦ Only perform computer vision when image/area has changed
  ◦ Run light weight algorithms first
  ◦ Favor algorithms/models with content adaptive capabilities
  ◦ Stop when there is enough information:
    many application only needs to know the presence of 1 object vs. all objects

• Simplify
  ◦ Often easier to run models at different scales than resizing images
  ◦ Optimize brightness to favor detection

• Optimize the entire system end-to-end
  ◦ Use low power sensor
  ◦ Optimize IO
  ◦ Move algorithms to HW when possible
  ◦ Keep memory close to compute engine
Product: Qualcomm®QCC112
Available commercial product

• Product is commercialized

• Supports many uses at ~1mW, including chip, sensor, and power management

• Features:
  ◦ Ultra-low-power MCU
  ◦ Streaming Array Processor (SuP)
    • Programmable
    • Can be power collapsed
    • Data bursted with DMA into TCM
  ◦ Embedded PMU
  ◦ Vision Accelerator
  ◦ Custom memory
    • 2X lower dynamic power and 3X lower retention power vs. standard memory cell
Programmability and SuP

• Support for high level programming language
  ◦ Capable of putting 3rd party neural networks

• Wide-issue 32-bit dataflow architecture
  ◦ Execute up to 16 instruction per cycle

• Supports 8b/16b/32b instructions (compute and I/O)
  ◦ Stream Index Generator
    • Address generator for quad nested loops
    • Loop break, synchronization, double buffering
  ◦ Multi-banked TCM with synchronization support
  ◦ Specialized streaming I/O interface
Roadmap

• Sensor Hub
• Audio
• Lower power
• More resolution, greater distance, smaller objects
• More object classes
Resources

- [https://www.qualcomm.com/invention/artificial-intelligence](https://www.qualcomm.com/invention/artificial-intelligence)

- Contact us at [CVM@qti.qualcomm.com](mailto:CVM@qti.qualcomm.com) for developing new use cases and hardware evaluation for your products