Making always-on vision a reality

Dr. Evgeni Gousev
Sr. Director, Engineering
 Qualcomm Technologies, Inc.
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Outline

1. Problem statement
   • Challenges to develop always-on vision

2. Qualcomm Technologies innovation
   • How we are pioneering the always-on solution

3. Use cases and market opportunity
   • Supports many use cases across numerous verticals
   • Demos
The always-on UI and contextual awareness trend
Delivering significant value across the whole ecosystem (> 1B units/year\(^1\))

- Always-on touch
- Always-on voice
- Always-on motion

1: Source: IDC Mar. ‘17
Human perception is dominated by vision

- 83% of our external world perception is through vision
- Yet, always-on vision technologies have been extremely challenging

Machine vision today

Conventional approaches are very power hungry

Image sensor
10’s mWs

Processor and algorithms
100’s mW
(use case and processor specific)

Object detection
Algorithms running in the processor consume majority of the power

Example: Gesture algorithm partitioning

![Pie chart showing the distribution of power consumption]

Source: Qualcomm Technologies, Inc.
Our always-on vision research and innovation

Solving the key challenges

- Highly integrated & holistically optimized system
- Ultra-low power designs
- Advanced technology nodes

- Always-on vision defined and targeted as < 1 mA, **active** and **end-to-end** (image sensor and digital processor)
Sensor considerations and optimizations

• Low-resolution sensing, inspired by nature

• Data sparsity

• Event-driven architecture

• Ultra-low power designs
High resolution cameras are not required for always-on vision
There's plenty of room for low resolution cameras — A “sweet” spot at < 1M pixels

- Information density is the information per pixel and is more important than just sensor resolution
- The information density required depends on many factors, such as use case, distance, lens, illumination, etc.
- Low-resolution cameras can complement high-resolution cameras
Low-resolution vision: Lessons from nature

**Starfish**
- ~ 120 “pixels” x 5
- Use case: scene detection (e.g. reef)

**Bee**
- ~ 5000 “pixels”
- Use cases: navigation and object recognition
Face detection use case: Resolution and bit depth

Our algorithms work well at low resolution and bit depth

<table>
<thead>
<tr>
<th>Image</th>
<th>120 x 160</th>
<th>101 x 135</th>
<th>85 x 114</th>
<th>72 x 96</th>
<th>61 x 81</th>
<th>51 x 68</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face</td>
<td>39 x 39</td>
<td>31 x 31</td>
<td>27 x 27</td>
<td>22 x 22</td>
<td>Not found</td>
<td>Not found</td>
</tr>
</tbody>
</table>

Number of faces detected (out of 6)

- **Pass**
- **Fail**

- **Face detection use case: Resolution and bit depth**
- **Our algorithms work well at low resolution and bit depth**

<table>
<thead>
<tr>
<th># Bits in input grayscale image</th>
<th>Average face size in pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Image**
- **Face**
- **Not found**
Data sparsity for data compression
Temporal sensing approach as an example

Image data sparsity  Metadata output

Image
Temporal contrast
Metadata: { redDot, 86, 69}
Our prototype always-on computer vision module (CVM)

Key features

• Ultra-low power, < 1 mA (end-to-end, w/ sensor included)
• Small size
• Low cost
• Privacy (output is metadata)
• Configurable for different use cases
• QVGA sensor
• Near-IR compatible
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
Prototype development platforms and SDK

- Qualcomm® Snapdragon™ 820 Development Platform (phone/tablet)
- Snapdragon 410C Development Platform (IoT)
- Connectivity Platform (data “tag”)

Always-on CVM module
The grand “vision”: Ubiquitous vision for sensing

IMAGE SENSOR APPLICATIONS - WHAT’S NEXT?
A roadmap for the next 20 years

- Qualcomm Technologies is helping to drive this industry transformation
- Be part of the growing ecosystem
Resources

- https://www.qualcomm.com/invention/research/projects/computer-vision/always-on
- https://www.qualcomm.com/invention/cognitive-technologies

Contact us at CVM@qti.qualcomm.com for developing new use cases and hardware evaluation for your products
Thank you

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