The most trusted source of advice, analysis, and engineering for embedded processing technology and applications

Computer Vision In Mobile Devices: The Next Killer App?

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What is BDTI?

Since 1991, BDTI has accelerated the commercial adoption of digital signal processing technology via a three-pronged strategy:

1. Educate and Inform:
   - Building awareness of digital signal processing technology, options, benefits, and capabilities
   - Educating system designers on the effective use of digital signal processing technology
2. Unique Partner Services for technology providers
   - Strengthening technology marketing via independent insights and trusted analysis
   - Optimizing "whole product" planning, reducing risk, and accelerating development via specialized services
3. High-quality OEM Services for system developers
   - Enabling system designers to make sound technology-selection decisions quickly, via published analysis and focused consulting services
   - Accelerating product development via leading-edge engineering services

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What is Embedded Vision?

- "Embedded vision" refers to embedded systems that **extract meaning from visual inputs**
  - Embedded vision is distinct from multimedia
- Emerging high-volume embedded vision markets include automotive safety, surveillance, and gaming
  - The Xbox Kinect is the fastest-selling CE device to date: 10 million units in 4 months

$130 including game

$920 installed

$300 + $6/month

Why is Embedded Vision the next mobile killer app?

1. It has the potential to create huge value
2. Increasingly, it will be expected
3. It's now possible

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1. Mobile Embedded Vision creates huge value

- As mobile devices gain increasingly powerful processors and high-speed network access, data input is the bottleneck
  - LTE uplink bandwidth: ~50,000,000 bits/s
  - Expert touch-typist using full-size keyboard: 65 bits/s
  - Typical user on smartphone virtual keyboard: 15 bits/s
  - Normal speech (converted to text): 100 bits/s
  - Typical compressed HD video: 4,000,000 bits/s
- The camera found in virtually every mobile device is the highest-bandwidth input device
  - But need to extract useful information from data

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1. Mobile Embedded Vision creates huge value (cont'd)

Embedded vision enables mobile devices to utilize their highest-bandwidth input sensors—cameras—as information input devices

- Gesture-based user interfaces
  - Screen navigation, presentations, games, …
- Optical character recognition
  - Scan text, then analyze it or search the web
- Visual search
  - Scan an object or person, then search the web
- Augmented reality
  - Bind the physical and virtual worlds
- New dimensions in photography
  - Super-resolution, navigable 3-d models from photos

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1. Mobile Embedded Vision creates huge value (cont'd)

Embedded vision enables mobile devices to become ubiquitous platforms for a wide range of unanticipated applications

- E.g., a smartphone can become a smart surveillance camera
- E.g., a tablet can become an assembly line troubleshooting aid

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2. Increasingly, vision capability will be expected

In the next few years, consumers will become increasingly familiar and comfortable with embedded vision, and will come to expect it

- It will be in their game controllers
- It will be in their cars
- It will be in their home entertainment gear
- It will be in ATMs and point of sale terminals

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3. It's now possible

It is now increasingly practical to implement sophisticated vision capabilities in mobile systems:

- 30+ years of research has produced a solid theoretical foundation
- Sufficient processing power is becoming available in mobile devices
- High-speed, low-latency wireless connections enable cloud-based or cloud-assisted vision applications
- Non-image sensors (e.g., GPS) can help vision
- Sophisticated OSs
- Application development infrastructure is beginning to form

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But, implementing embedded vision is challenging

- It's a whole-system problem
- Mobile systems have poor image sensors and optics, limited processing power, are usually hand-held, etc.
- It's very computationally demanding
  - E.g., a 720p optical flow algorithm, optimized for a modern VLIW DSP architecture, consumed about 200 MHz/frame/second ➔ 5 fps @ 1 GHz
  - Many vision functions will require highly parallel or specialized hardware
  - Algorithms are diverse and dynamic, so fixed-function compute engines are less attractive
- There is limited experience in building practical solutions

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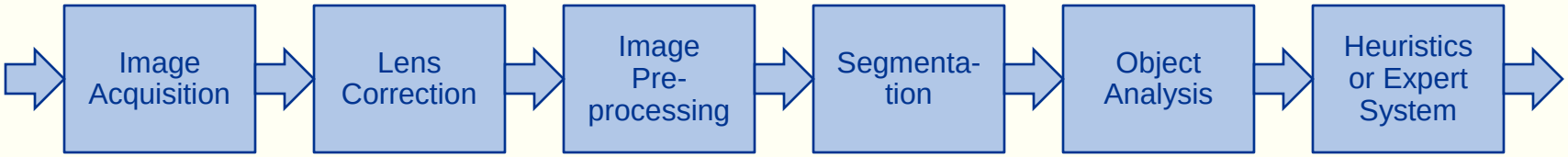
How does Embedded Vision work?

A typical embedded vision pipeline:



Typical total compute load for VGA 30 fps processing: ~3 billion DSP instructions/second

Loads can vary dramatically with pixel rate and algorithm complexity

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How is Embedded Vision implemented? (processor view)

Demanding embedded vision applications will use a hierarchy of processing elements, similar to wireless baseband chips, e.g.:

- CPU for complex decision-making, network access, user interface, overall control
- Digital signal processor for real-time, moderate-rate processing with moderately complex algorithms
- Highly parallel engine(s) for pixel-rate processing with simple algorithms
  - GPU, VPU, or special-purpose engine

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How is Embedded Vision implemented? (software view)

Since vision is a whole-system problem with high compute demands, typical mobile app development techniques fall short

There is little software infrastructure supporting embedded vision application development today

- Application frameworks, reference designs, function libraries, APIs, …

But this is beginning to change; e.g.:

- OpenCV library implementations for TI OMAP, Freescale i.MX processors
- Platforms, such as Layar for augmented reality
- Specialist solution providers, e.g., XTR3D

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Mobile embedded vision opportunities abound

Embedded vision creates big opportunities (and commensurate challenges) throughout the mobile supply chain:

- Cloud computing vendors
- Network operators
- Mobile device manufacturers
- Application processor vendors
- OS and middleware providers
- Application developers

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Embedded Vision is the next mobile killer app

Over the next 10 years, embedded vision will transform the electronics industry—much as wireless connectivity has

Handsets and tablets are particularly fertile ground for the proliferation of embedded vision

- It has the potential to create huge value
- Increasingly, it will be expected
- It's now possible

Big opportunities exist for companies that can create or enable embedded vision solutions

- Meaningful differentiation
- Creation of new markets

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To probe further

The Embedded Vision Alliance is a new industry partnership to facilitate the flow of high-quality information on practical aspects of embedded vision engineering

Watch for related announcements in the coming weeks

Technology-provider companies interested in joining the Alliance may contact BDTI for details

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