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

How New Chips Are Enabling the Proliferation of Machines That See

2011 IMS Intelligent Video Conference

Jeff Bier
BDTI
Oakland, California USA
+1 (510) 451-1800
info@BDTI.com
http://www.BDTI.com

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

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 proliferating now?

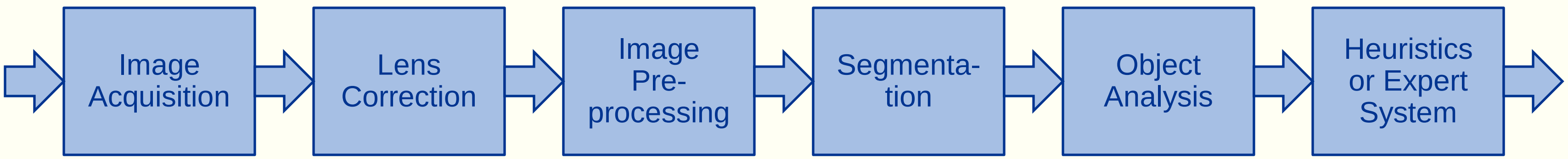
1. It has the potential to create huge value
   - Applications in consumer, medical, automotive, entertainment, retail, industrial, aerospace, …
2. Increasingly, it will be expected
   - As embedded vision becomes common in gaming, consumer electronics, and automotive equipment, consumers will expect it
3. It’s now possible
   - Sufficiently powerful, low-cost, energy-efficient processors are now emerging

But, implementing embedded vision is challenging

- It’s a whole-system problem
- There is limited experience in building practical solutions
- Embedded systems are often highly constrained in cost, size, and power consumption
- 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

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

The Processing Challenge

Embedded vision applications typically require:

- Very high performance
- Programmability
- Low cost
- Energy efficiency

Achieving all of these together is difficult

- Dedicated logic yields high performance at low cost, but with little programmability
- General-purpose CPUs provide programmability, but with weak performance or poor cost-, energy-efficiency

How is Embedded Vision implemented?

Demanding embedded vision applications will most often use a combination of processing elements (similar to wireless baseband chips), e.g.:

- CPU for complex decision-making, network access, user interface, storage management, overall control
- High-performance DSP-oriented processor for real-time, moderate-rate processing with moderately complex algorithms
- Highly parallel engine(s) for pixel-rate processing with simple algorithms

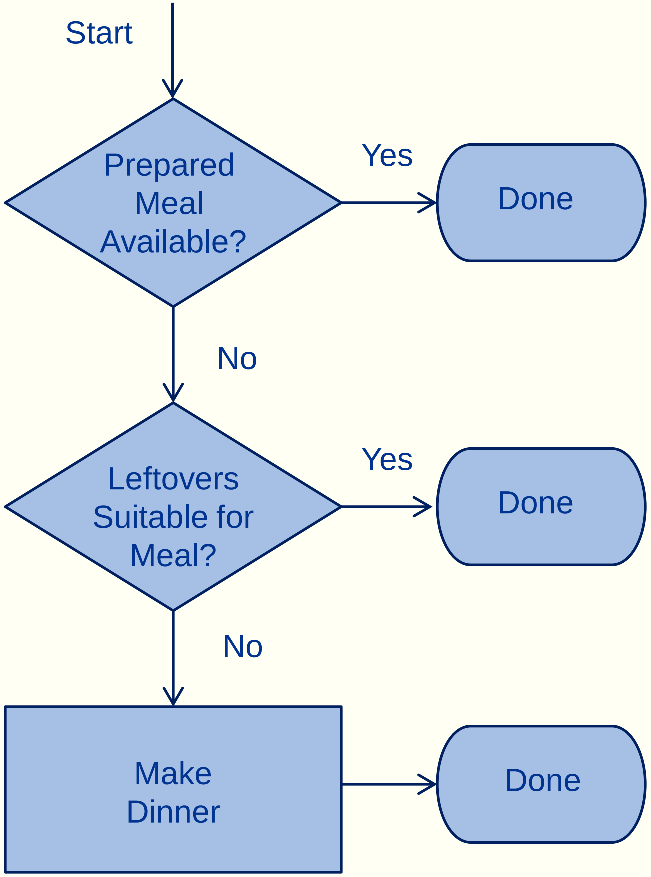
Processor Types for Embedded Vision

While any processor can in theory be used for embedded vision, the most promising types today are:

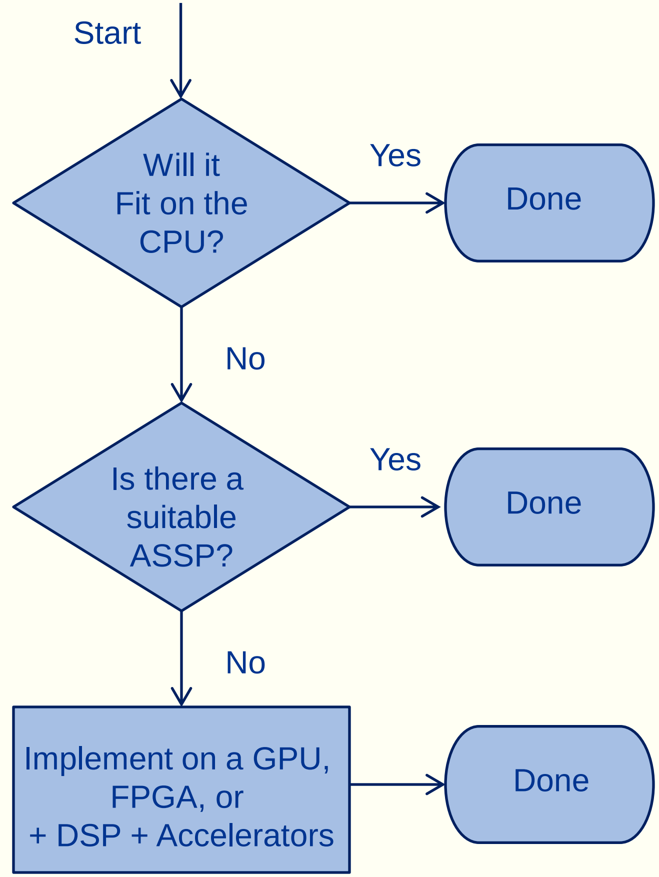
- High-performance embedded CPU
- Application-specific standard product (ASSP) + CPU
- Graphics processing unit (GPU) + CPU
- DSP processor + accelerators + CPU
  - Mobile “application processor”
- Field programmable gate array (FPGA) + CPU

The Path of Least Resistance

Making Dinner on a Weekday



Selecting a Processor for an Embedded Vision Application



High-performance Embedded CPUs

Though challenged with respect to performance and efficiency, unaided high-performance embedded CPUs are attractive for some vision applications

- 👍 Vision algorithms are initially developed on PCs with general-purpose CPUs
- 👍 CPUs are easiest to use: tools, operating systems, middleware, etc.
- 👍 Most systems need a CPU for other tasks

However:

- 👎 Performance and/or efficiency is often inadequate
- 👎 Memory bandwidth is a common bottleneck

Example: Intel Atom E660T

Application-specific Standard Product + CPU

Application-specific standard products (ASSPs) are specialized, highly integrated chips tailored for specific applications or application sets

- ASSPs may incorporate a CPU, or use a separate CPU chip
- 👍 By virtue of specialization, they tend to deliver superior cost- and energy-efficiency
- 👍 They usually include strong application-specific software development infrastructure and/or application software

However:

- 👎 The specialization may not be right for your particular application
- 👎 They may come from small suppliers, which can mean more risk
- 👎 They use unique architectures, which can make programming them, and migration to other solutions, more difficult
- 👎 Some are not user-programmable

Example: PrimeSense PS1080-A2

Graphics Processing Unit (GPU) + CPU

GPUs, mainly used for 3-d graphics, are increasingly capable of being used for other functions

- Referred to as "general-purpose GPU" or "GPGPU"
- 👍 Often used for vision algorithm development
- 👍 Widely available; easy to get started with parallel programming
- 👍 Well-integrated with CPU (sometimes on one chip)
- 👎 Typically cannot be purchased as a chip, only as a board, with limited selection of CPUs
- 👎 Low-cost, low-power GPUs (designed for smart phones, tablets) are not GPGPUs

Example: NVIDIA GT240

DSP Processor + Co-processors + CPU

Digital signal processors ("DSP processors" or "DSPs") are processors specialized for signal processing algorithms

- 👍 This makes them more efficient than CPUs for the kinds of signal processing tasks that are at the heart of vision applications
- 👍 DSPs are relatively mature and easy to use compared to other kinds of parallel processors

However:

- 👎 DSPs often lack sufficient performance, and aren't as easy to use at CPUs
- Hence, DSPs are often augmented with specialized co-processors and a CPU on the same chip

Example: Texas Instruments DM8168

Mobile "Application Processor"

A mobile "application processor" is a highly integrated system-on-chip, typically designed primarily for smart phones but used for other applications

- Typically comprise a high-performance CPU core and a constellation of specialized co-processors: GPU, VPU, 2-d graphics, image acquisition, etc.
- 👍 Energy efficient
- 👍 Often have strong development support, including low-cost development boards, Linux/Android ports, etc.

However:

- 👎 Specialized co-processors usually not user-programmable

Example: Freescale i.MX53

Field Programmable Gate Array + CPU

Field programmable gate arrays (FPGAs) are flexible logic chips that can be reconfigured at the gate and block levels

- Enables custom specialization and enormous parallelism
- Enables selection of I/O interfaces and on-chip peripherals

However:

- FPGA design is hardware design, typically done at a low level (RTL) (register transfer level)
- Ease of use improving due to:
  - “IP” block libraries
  - Reference designs
  - Emerging high-level synthesis tools
- Low-performance CPUs can be implemented in the FPGA; higher-performance integrated CPUs coming

Example: Xilinx Spartan-6 LX150T

Conclusions

To date, embedded computer vision has largely been limited to low-profile applications like surveillance and industrial inspection

Thanks to the emergence of high-performance, low-cost, energy efficient programmable processors, this is changing

Embedded vision technology will rapidly proliferate into many markets, creating opportunities for chip, equipment, algorithm, and services companies

But implementing embedded vision applications is challenging, and there is limited know-how in industry

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

Technology-provider companies can join the Alliance now—contact BDTI for details; public launch May 31

BDTI provides consulting services to companies developing and using vision technology:

- Technology selection
- Product development engineering services
- Competitive analysis