Introduction to Embedded Systems & Sensor Networks

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CSE 592
Lecture 1

What is an Embedded System?

What is an Embedded System?

- **An *Embedded System***
  - **employs a combination of hardware & software (a "computational engine") to perform a specific function;**
  - **is part of a larger system that may not be a "computer";**
  - **works in a reactive and time-constrained environment.**
- **Software is used for providing features and flexibility**
- **Hardware = {Processors, ASICs, Memory,...} is used for performance (& sometimes security)**

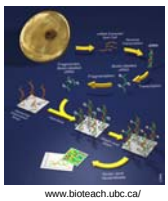
More Examples...

- Signal processing systems
  - radar, sonar, real-time video, set-top boxes, DVD players, medical equipment, residential gateways
- Mission critical systems
  - avionics, space-craft control, nuclear plant control
- Distributed control
  - network routers & switches, mass transit systems, elevators in large buildings
- "Small" systems
  - cellular phones, pagers, home appliances, toys, smart cards, MP3 players, PDAs, digital cameras and camcorders, sensors, smart badges

A Variety of Application Domains

- Hybrid and embedded systems
  - Aerospace, automobiles, robotics, process control, sensor networks, smart spaces
- Multimedia
  - Virtual reality, immersive environment
- Consumer electronics
  - Mobile phones, office electronics, digital appliances
- Network components
  - Bridges, routers, switches, hubs
- Medical devices and instruments
  - Patient monitoring, MRI, infusion pumps, artificial organs
- E-business
  - ATM, vending machines
- Distributed and grid computing
  - Critical infrastructure defense system, air traffic control, intelligent highway systems, emergence response system

Pending Embedded Systems



www.bioteach.ubc.ca/

Pervasive Computing Group, ICU
cds.icu.ac.kr/druid/druid.htm

www.neptunecanada.ca/

- Design Requirements
  - Harsh environment
  - Distributed
  - Networked
- Emerging challenges
  - Wireless ad-hoc
  - Deep sub-micron
  - Sensing
  - Security and Privacy

Embedded Systems Diversity

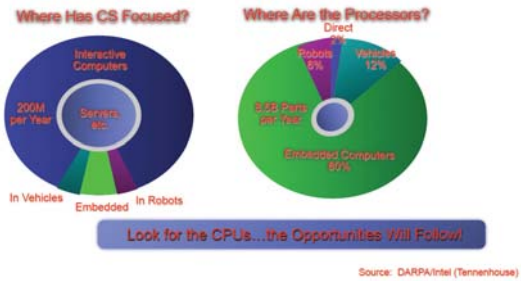
- **Remote control RF transmitter**
  - **100 KIPS, crush-proof, long battery life**
  - **Software optimized for size**
- **Industrial equipment controller**
  - **1 MIPS, safety-critical, 1 MB memory**
  - **Software control loops**
- **Military signal processing**
  - **1 GFLOPS, 1 GB/sec IO, 32 MB**
  - **Software for high performance.**

Why do we care? Some Market Tidbits...in $$$$

	Compound Annual Growth Rate
General Purpose Computing	
PC Chipsets ($6.9B) expected to grow to $10.3B in 2009	10.5%
Embedded Systems	
Wi-Fi ($140M) expected to grow 3x by 2009 (mobile PCs, residential networks, cell phones)	31.6%
Media Devices (digital TVs, MP3 players, video games consoles)	57.0%
ASIC ($209.8M) expected to grow to $2.53B in 2009 (ASSP)	86.3%
RFID ($1.3B) expected to grow 25x by 2010	90.4%

Source: www.instat.com

Where do all the CPUs go?



Embedded Systems Take Over

- 2001: ~50-120 Billion μP used in ES
- Average ES has 4 μP
- Of all μP sold, 90% go into “non-computers”, 10% in “computers”
- ARM sells 3x more CPUs then Intel sells Pentiums
- 2007: ~10B processors sold, almost all embedded (Economist 4/07)

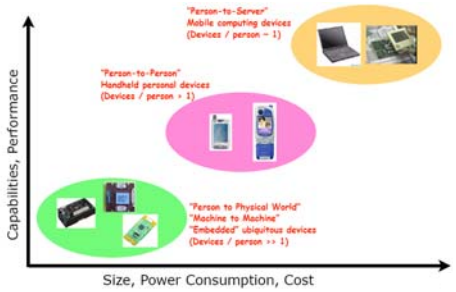
Driving Forces

- Proliferating to non-computing domains
  - portable units with significant data & control ops.
  - medical instrumentation & imaging, information appliances...
- Increasing computation demands
  - e.g. multimedia processing in set-top boxes, HDTV
- Increasingly networked
  - to eliminate host, and remotely monitor/debug
  - embedded Web servers
  - embedded Java virtual machines
  - cameras, disks etc. that sit directly on networks

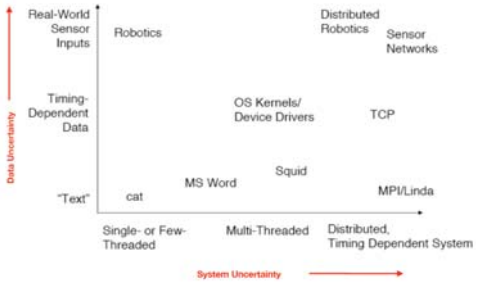
Driving Forces

- Increasing need for flexibility & product personalization
  - Application domains and user differentiation
  - Device programmability
- Competitive pressures of “commodity markets”
  - Time to market (TTM), Time to money (TT$),
    - Product lines
    - Product differentiation

Trends in Computers & Communications



What does this mean for Us?



Characteristics of Embedded Systems: General Perspective

- Tightly coupled to the physical world; i.e., interacts with (or reacts to) its environment
- Correct operation is subject to
  - Physical constraints imposed by the environment
  - Resource constraints of the device
- Heterogeneity, networked at larger scale
- Sociological and ethical requirements
  - Users are not system experts
  - Security and privacy

Characteristics of Embedded Systems: General Perspective

- Single-functioned
  - Executes a single program, repeatedly
- Tightly-constrained
  - Low cost, low power, small, fast, etc.
- Reactive and real-time
  - Continually reacts to changes in the system's environment
  - Must compute certain results in real-time without delay

Source: Vahid/Givargis

Characteristics of Embedded Systems: CSE Perspective

- HW & SW do application-specific function – not G.P.
  - application is known a priori
  - but definition and development concurrent
- Some degree of re-programmability is essential
  - flexibility in upgrading, bug fixing, product differentiation, product customization
- Never terminate (ideally)
- Operation is time constrained: latency, throughput
- Passage of time is important
  - Correctness of results depends on time at which it is produced
- Other limits: power, size, weight, heat, reliability etc.
- Inherently concurrent
- Increasingly high-performance (DSP) & networked
- Security, safety, reliability, maintainability…

Challenges

- Three aspects of embedded system development
  - Embedding for smart control
  - Creating new computing gadgets
  - Connecting the physical world to the computing infrastructure
- The goal is to make them invisible cost-effectively!
  - Trustworthy: should not fail (or gracefully degrade), and safe to use. The existence of embedded software becomes apparent only when an embedded system fails.
  - Context Aware: should be able to sense people, environment, and threats and to plan/notify/actuate responses to provide real-time interaction with the dynamically changing physical environment with limited resources.
  - Seamless Integration: should be invisible at multiple levels of a hierarchy: home systems, metropolitan systems, regional systems, and national systems.

Homework #1- Embedded & Sensor Network Critique

(Due Mon 2/2 at start of class)

- Read
  1. M. Weiser, "The computer for the 21st century," Scientific American, February 1991.
  2. D. Culler, D. Estrin, M.Srivastava. "Overview of Sensor Networks", IEEE Computer, Aug. 2004
  3. D. E. Culler and H. Mulder, "Smart Sensors to Network the World", Scientific American, June 2004
  4. David Tennenhouse, "Proactive computing," Communications of the ACM, vol. 43, no. 5, ACM, May 2000. p.43-50.
- Write a short critique of papers 3&4 (1-2 pages)
  - summarize the main contributions of each paper
  - identify the key points made by the authors
  - point out weaknesses, if any
  - compare/contrast the visions of the papers with each other