Introduction to Embedded Systems (CSE 337/537)

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Partly adopted from EE202A, UCLA Slides by Mani Srivastava

Why?

- How many of you think that learning Embedded Systems necessarily require strong Electronics background?
- Often people with Electronics background think that programming is tough
  - People with programming background shy away from hardware
- Good understanding of both hardware and software often is very beneficial
- What different skills will the course require?
  - Electronics
  - Computer Architecture
  - Operating Systems
  - Of course, good programming skills

Why?

We believe that:

- A good CS/IT engineer should have good understanding of how the hardware, he is using, operates
  - Basic knowledge of hardware instills confidence
- Exposure to embedded systems get you to experience tangible things happening for real - robots moving, LEDs blinking!
  - Learning such activities are fun and will create the right mindset for other IT courses
- Embedded is now everywhere - Metro card, Driving License, Microwave, Automated Car Controls….
  - Basic knowledge of its operation will help in better understanding of how these systems operate

How? - Lectures

- Monday - 2:30 PM - 3:50 PM
- Wednesday - 4 PM - 5:20 PM
  - Lectures will cover basic concepts of hardware components in an embedded system - Power, Memory, External Interfaces …
  - Slides for each lecture will be posted at http://www.iiitd.edu.in/~amarjeet/EmSys.html
  - Each lecture will be audio recorded - Will be made available at the course url
  - Some of the lectures will have corresponding readings
    - You are expected to do the reading before the class for better understanding
    - Exams will include material from these readings
  - Class participation - gets counted in overall evaluation
    - Does not mean you speak just for the sake of participation
    - You can participate by putting up your views related to class discussions on the blog at http://cse537-2011.blogspot.com/

How? - Lab Sessions

- No formal lab sessions
- You will be given three lab assignments with due deadlines (January 23, January 30, February 13)
  - Details on the course webpage - http://www.iiitd.edu.in/~amarjeet/EmSys.html
- Submission to be made online on the Google code repository - https://code.google.com/p/cse537-2011/
  - In each specific directory (Assignment1, ..) create a sub-directory with your name and submit it online
  - Requires using SVN repositories
  - Submissions later than deadline will not count towards evaluation
  - Need all submissions to pass the course
  - Need to be done individually - If you take help from some source online or some student, acknowledge it on top of your code
  - All code available to everyone - Your integrity in your hands!

How? - Lab Sessions

- Hardware platform
  - AVR based microcontroller board
  - Together with other components - ~ Rs 1300
  - Will also be used for course projects
  - Flexibility to program anytime
  - Will be a useful toy for creating something of your own

- Initial document to get you started on AVR programming (C language)
- Several online tutorials to learn other details
- Contact Abhishek (abhishekbhardwaj@nsitonline.in) for doubts related to AVR programming
- For how many the cost burden seems too much?

How? - Lab Sessions

- Expected to learn some hardware stuff besides microcontroller programming - soldering station, other hardware components at your disposal in PhD room
- Policy for using these components
  - Keep the desk clean before you leave
  - Put the components back in their appropriate place
  - If you want to take something outside the room, take permission and record it in the sheet
  - If you want to order some hardware components, record it in the sheet along with your name and date - We will try to order small stuff together as per your requirements

How? - Group Project

- To be performed in a group of 2
  - You can also work in groups of 3 but not more - I will expect proportionately more effort from larger groups
- The project should be based on theme of energy monitoring/healthcare. It should have the following components:
  - Interfacing a sensor relevant to the theme of the project and collecting the sensor data.
  - Basic on-board processing of the data
  - Communicating the processed data over some wired/wireless interface to a front end (computer/mobile phone)
  - Front end UI to control/display the sensor data collected from the microcontroller board.

How? - Group Project

- Guidelines:
  - Look for what others have done but do not copy anyone
    - Ensure that you cite your motivation appropriately
    - Clearly illustrate what is your new contribution
  - If there is some other domain you are also interested in, look for ideas that overlap use of embedded systems with that domain (in certain cases, I am willing to let you chose a domain of your choice outside those specified by me)
  - It is your responsibility to deal with inter-personal issues in the group
  - Final deliverable should clearly specify the contribution of each member in the group

How? - Group Project

- Deadlines:
  - Project proposal giving the exact details of each of the specified components by March 23
    - Divide your proposed work into smaller modules and give timelines by when you propose to finish those modules
    - Maintain a wiki page on your project and provide weekly updates
  - Milestone-1 (Initial demo): Due by April 9
  - Final demo – Post final exams
- Overall evaluation will be divided as - Initial Proposal (15%); Wiki updates (15%); Initial demo (25%); Final demo (45%)

How? - Individual Innovative Hardware Project

- Propose some interesting project on your own and work towards it
- Should involve the microcontroller board
- Discuss with faculty/TA and get a go-ahead before getting into the details of your assignment
- Deliverable
  - One page report
  - 5 min demo in the class
- Deadline for project selection - February 20, 2011
- Deadline for report submission - March 26, 2011
- Does not mean you wait until the deadline
- Finish early to get over with one more thing! :)
- A lot of references online on AVR based projects

How? - Survey

- In groups of 2
- Select a topic related to a relevant emerging embedded technology and do a thorough survey on the topic
- Research the topic in depth - both web resources as well as technical papers
- Deliverable
  - Maintain a wiki page on the topic
  - Short presentation in the class (10-15 minutes)
- I will host a wiki and you can then create a page on that wiki for your article
- Give all citations as appropriate - the article should be your original contribution and should not contain mostly copied stuff

How? - Survey

- A list of topics to be given by me
  - You can chose any other topic outside the list and get it approved by me
  - Topic assignment on first come first serve basis
- Deadlines
  - Selecting a topic - March 12, 2011
  - Class presentations - Towards the end of the course; Schedule to be decided by me later
- Final evaluation will have 40% weight for the presentation 60% weight for the article

Logistics - Evaluation

- Quantifying the evaluation*
  - Class participation (attendance, blogs) - 5%
  - Hardware Assignments (3) - 10%
  - Innovative individual project - 10%
  - Survey - 10%
  - Group Project - 25%
  - Mid term exam - 15%
  - Final exam - 25%

*** Subject to minor changes at a later stage**

Logistics - Miscellaneous

- Teaching Assistant - your first point of contact
  - Abhishek Bhardwaj, UG, NSIT (abhishekbhardwaj@nsitonline.in)
- Office hours
  - Monday, Thursday - 12-1 pm
  - By appointment (Email me a day in advance)
  - Any email communication - Prefix subject with ES2011 (for faster response)
- Feedback
  - First course with embedded hardware and software exposure
  - Feel free to give feedback at regular intervals on how the course can be improved
- Class Information Communication
  - Most of the communication over email (**cse537@iiitd.ac.in list**) - Make sure to subscribe to the list and check your email at least once a day

Logistics - Miscellaneous

- Reference books:
  - Computers as Components: Principles of Embedded Computing System Design by Wayne Wolf
  - Designing Embedded Hardware by John Catsoulis (O'Reilly)
  - Although lecture slides will suffice for most purposes
- **NO** gadget in the class - computer, phone, tablet …
- Food/drinks allowed
- Arrive on time (<2 min) - What if you don't?
- No cross-talk in the class
  - After first warning you will be asked to leave the class

Logistics - Impact of Leaves

- Some leaves due to personal/official reasons
- Will substitute for alternate person to take the lecture or do make up lectures
- Current known conflicts
  - Week-1 (January 3-7): Extended (by 30 minutes) lectures in the second week of January and a demo session on AVR board by Abhishek on Saturday (January 15) as make up sessions
  - Week 10-11 (March 8-18): Dr. Vinayak will take 3 of the 4 missed lectures; 4th lecture will be made up later on

Cheating and Plagiarism Policy

- Go through the articles on cheating and plagiarism sent by me
- Person aiding in cheating (benefactor) in equally responsible as the beneficiary
- Minor first infraction - 0 in that assignment and a reduction in grade
- Second minor infraction (or any major infraction) - F in the course
- Bottom line - I will be putting in a lot of efforts to make this course interesting for you. Please do not indulge in such activities to have bad memories for both of us.

Deadlines - Summary

- Lab assignments Deadlines - January 23, January 30, February 13
- Individual Innovative Hardware Project - Selection by February 20, 2011; Report submission by March 26, 2011
- Survey - Topic selection by March 12, 2011
- Group Project - Proposal by March 23; Initial demo by April 9

What? - Lecture Overview

- Week 1,2: Introduction to embedded systems
  - Course logistics
  - Brief introduction to embedded and cyber physical systems
  - Overview of Embedded Systems design challenges
  - Architectural overview of example embedded system architectures - TelosB (TI-MSP430); mBED (ARM7 based NXP-LPC1768); AVR based (Atmel-ATMega328)
- Week 3: Introduction to AVR programming
  - Exposure to architecture of AVR microcontroller and programming these devices
- Week 4,5,6: Microcontroller peripherals and interfaces
  - Exposure to various peripherals - Timers, counters, watchdog, PWM, ADC
  - Motivation and requirement of voltage regulators
  - External memory interfaces
  - Serial/Parallel communication protocols - RS232, I2C, PCI, SPI

What? - Lecture Overview

- Week 7: Collecting and transmitting data
  - ADC interfaces for external sensors
  - Wireless transceivers for transmitting the collected data
- Week 8: Mid term week
- Week 9: Discussion on project ideas
- Week 10,11: TelosB motes and tinyOS
  - Guest lectures by Dr. Vinayak Naik
  - Exposure to TelosB architecture
  - Deployment experiences with TelosB motes
  - Overview of TinyOS programming

What? - Lecture Overview

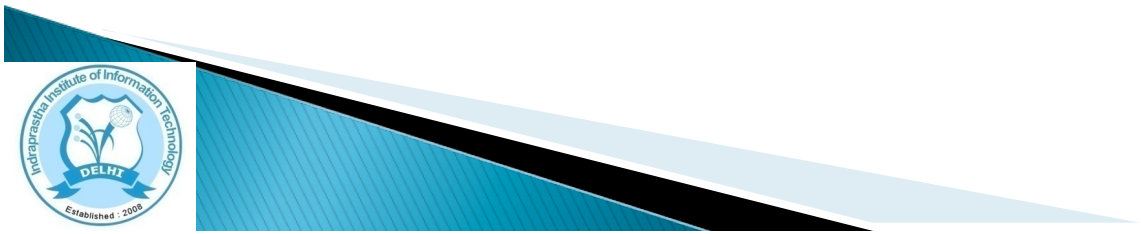
- Week 12,13: Timing and clocking in embedded systems
  - Exposure to timing and clocking issues in embedded systems
  - Exposure to some of the scheduling approaches

- Week 14,15,16: Student presentations
  - Short presentation on individual innovative hardware projects
  - Presentations on surveys undertaken by the students

What? - Hardware Assignments

- Assignment 1: Basic I/O (Due January 23)
  - Getting used to basic I/O of AVR
  - Task - Interface your board with the LCD Screen and display your name on it
- Assignment 2: ADC Interfaces (Due January 30)
  - Task - Interface the temperature/proximity sensor and display the collected data on the LCD
- Assignment 3: External Memory Interface (Due February 13)
  - Task - Interface an external EEPROM with the microcontroller. Collect the sensor data at 10 Hz, store it in the EEPROM and every 3 seconds, compute the average of the historical data and display it on the LCD

QUESTIONS ?


Indraprastha Institute of Information Technology
DELHI
Established : 2008

Readings for this week

- Introduction to Wireless Sensor Networks (David Culler, Deborah Estrin, Mani Srivastava)

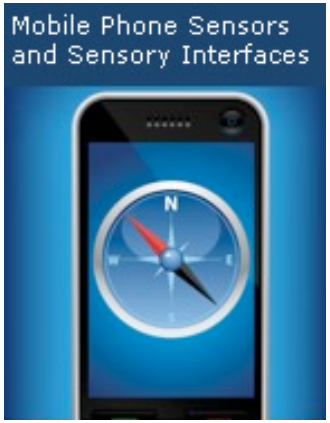
- Wikipedia article on Embedded Systems and Cyber-Physical Systems - http://en.wikipedia.org/wiki/Embedded_system

- Wikipedia article on Embedded Systems and Cyber-Physical Systems http://en.wikipedia.org/wiki/Cyber-physical_system

- Edward Lee, Cyber Physical Systems: Design Challenges, University of California, Berkeley http://www.eecs.berkeley.edu/Pubs/TechRpts/2008/EECS-2008-8.html

Ubiquitous Embedded Systems

- Embedded systems are becoming ever more integral part of our daily lives - to an extent go unnoticed
- Specialized instrumentation - only serve the specific purpose
  - Typically lack interaction thus limiting the system level interaction logging and corresponding decision making
- What systems do you come across in your typical daily routine?

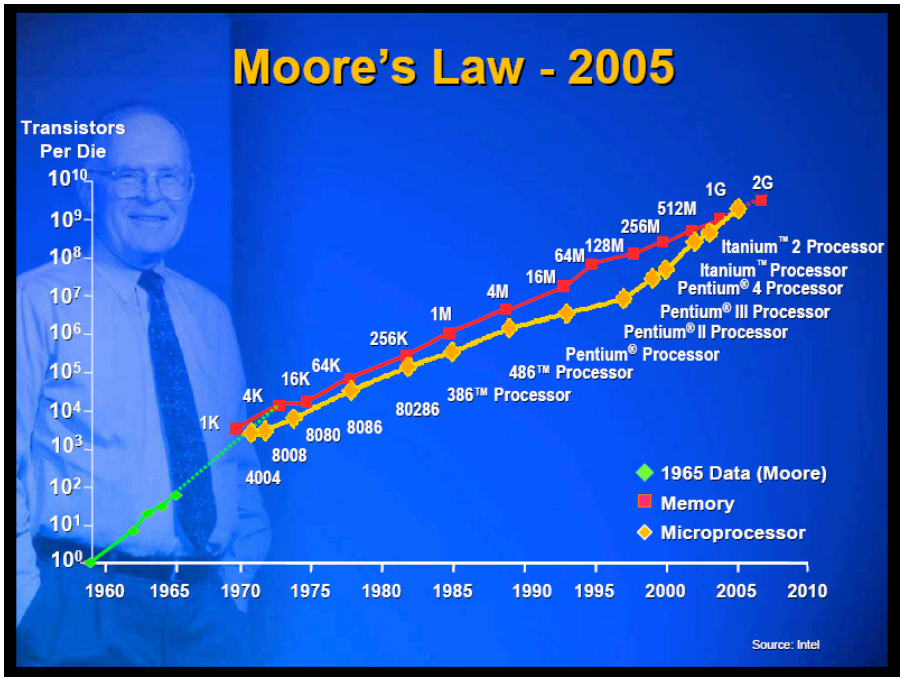


Where else?

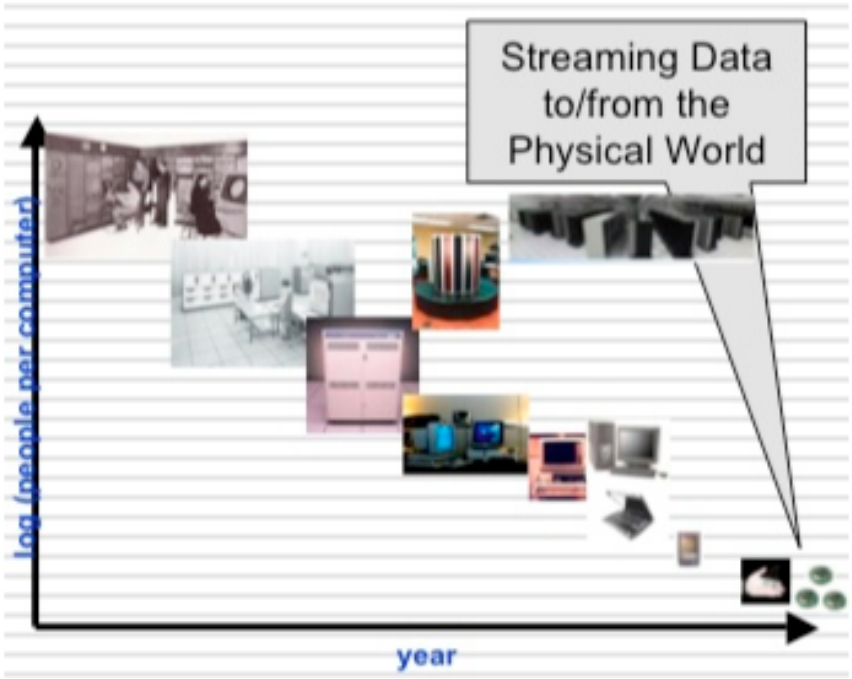
- Home appliances -
- Automotive -
- Personal electronics -
- Entertainment -
- Transportation -
- Manufacturing -
- Healthcare -
- Agriculture -
- Chemical Processes -
- Robotics -

....

Faster, Smaller, Numerous



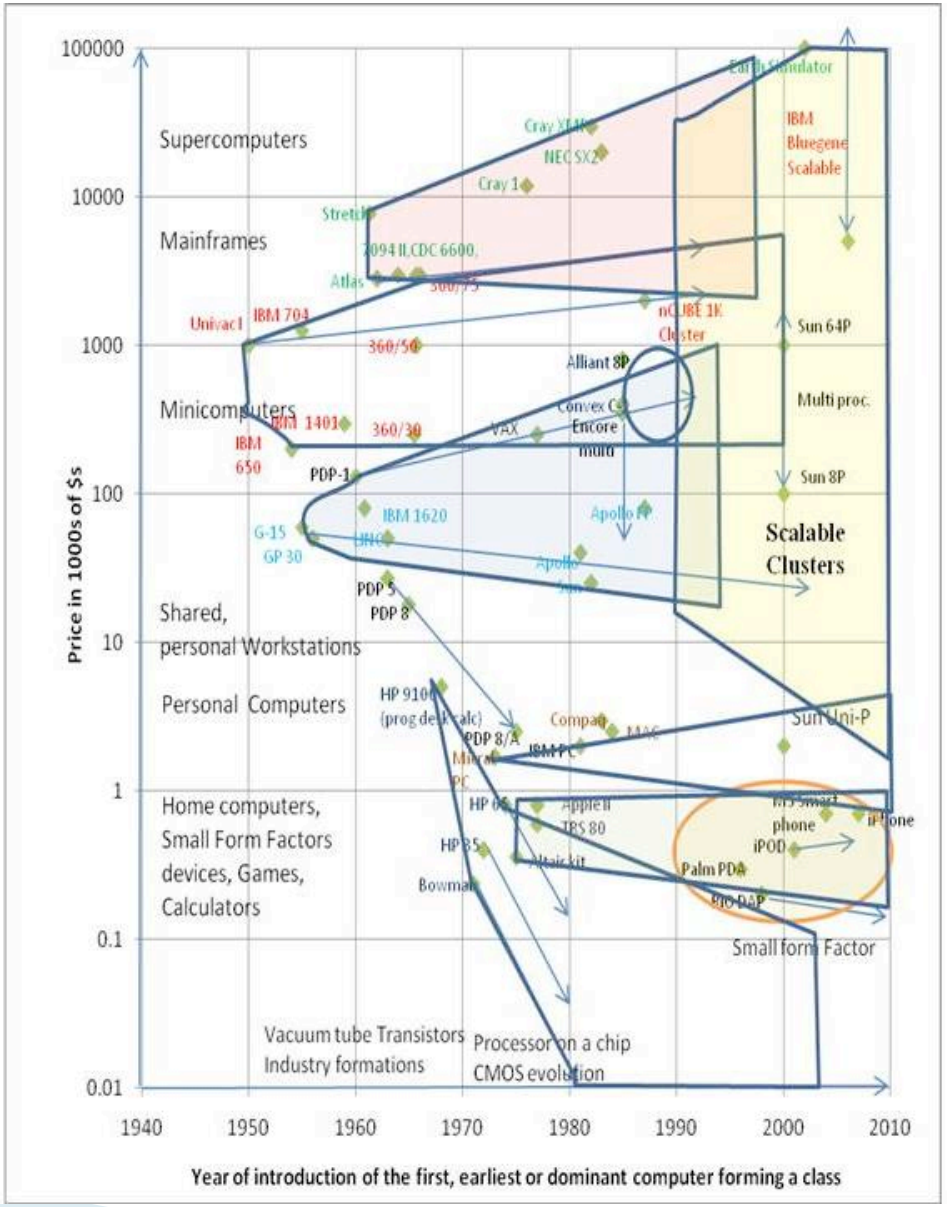
- Moore's Law
  - Computing resources double every 1-2 years



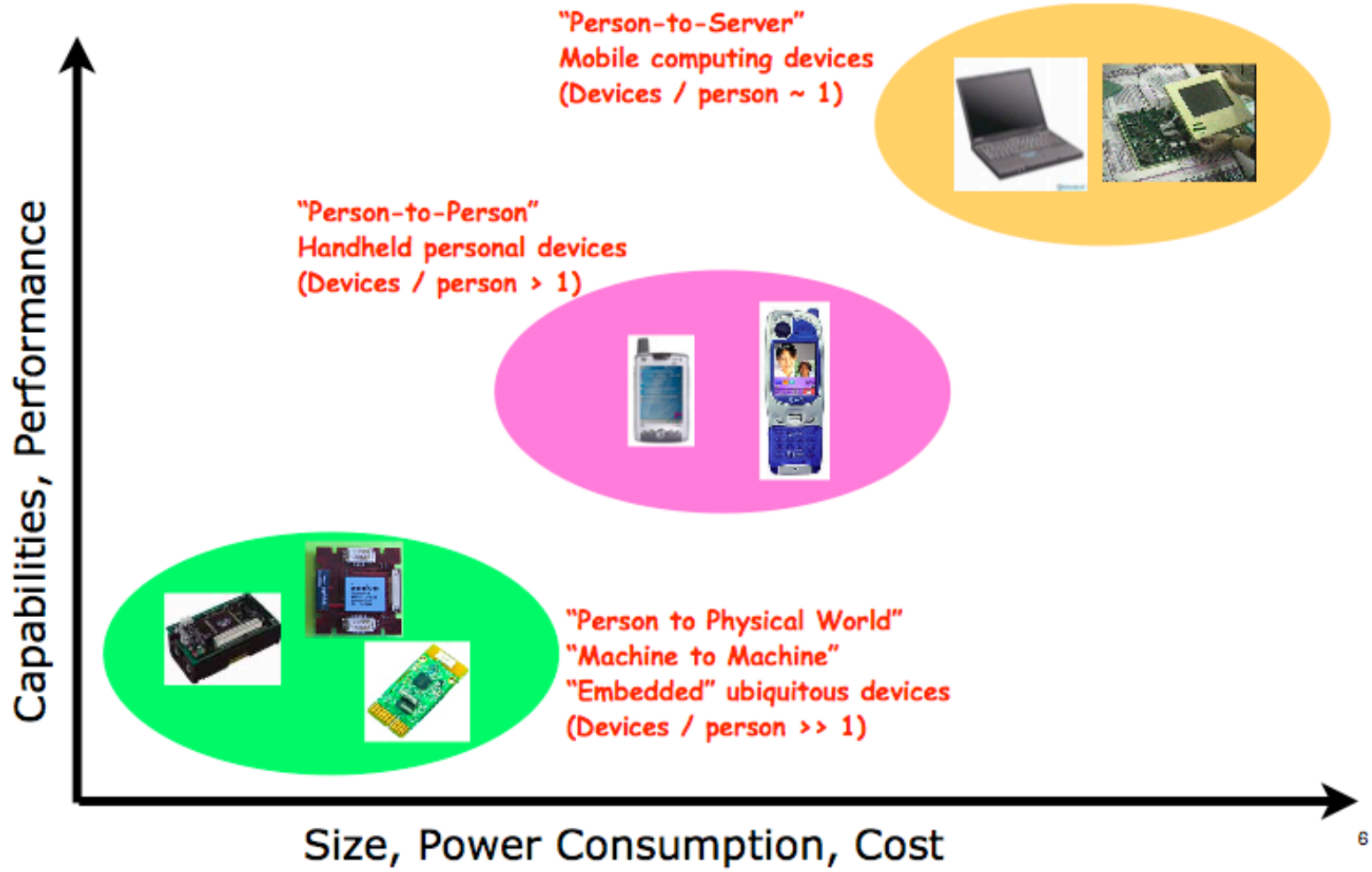
- Bell's Law
  - New computing class every 10 years

Evolution of Computing Classes

- Mainframes - 1960s
- Mini computers - 1970s
- Personal computers and workstations - 1980s
- Web Browser - Client Server Structures enabled by internet - 1990s
- Small form factor devices (cellphones, ipod) - 2000s
- Wireless Sensor Networks - 2010
- Body Networks - vision, hearing, monitoring - 2015
- Embedding of speech and vision functions - 2020
- **What is the trend?**



Changing Face of Computing

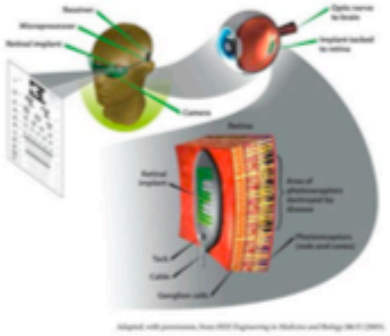


Changing Face of Computing

Sensorial

Actuated

Small, Mobile



Distributed

Embedded Everywhere

- Specialized devices and information appliances are replacing the generalist PC
  - Variety of forms: set-top boxes, smart mobile phones, iPods, iPads, game consoles, robotic appliance etc.
  - Vast majority of internet access devices are appliances and not PCs - In 1997, 96% of internet access devices sold in the US were PCs - Now, unit shipments of just internet-enabled cells phones exceed PCs

- Traditional systems becoming dependent on computation systems
  - Modern cars: up to ~100 processors running complex software - engine & emissions control, stability & traction control, diagnostics, gearless automatic transmission
  - http://www.howstuffworks.com/car-computer.htm

Embedded Everywhere

- An indicator: where are the CPUs being used?
  - More than 90% of all processors get used in "non-computers"
  - Over 10 Billion embedded processors of various types shipped in 2008

- Report by US National Research Council: "Embedded, Everywhere" (2001)
  - http://books.nap.edu/html/embedded_everywhere/

- UN ITU Report in 2005 "The Internet of Things"
  - http://www.itu.int/osg/spu/publications/internetofthings/

- Ubiquitous computing, pervasive computing, physical computing, cyber-physical systems...

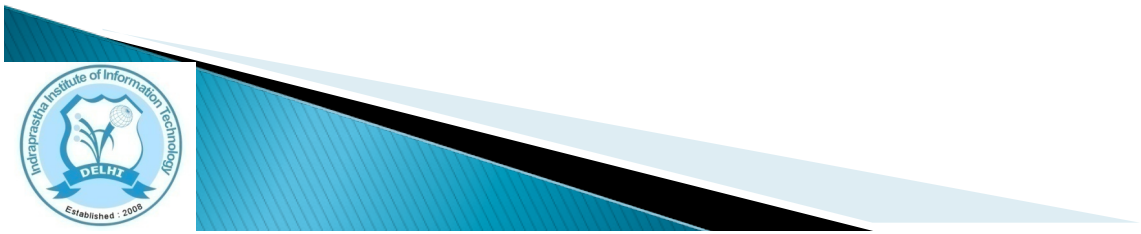
So What Constitute an Embedded System

- Part of a larger system
  - Not a computer with keyboard, display etc..
- Physically coupled
  - Interact (sense, manipulate, communicate) with the external world
- 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
- Operation is time constrained: latency, throughput
- Passage of time is important
  - Correctness of results depends on time at which it is produced
- Increasingly high-performance (DSP) and networked

Embedded Systems - Typical Challenges

- Limited processing speed, storage capacity and communication bandwidth
  - Substantial processing capability in aggregate
- Limited energy
  - But must operate for long periods of time with wireless communication
- Close interaction with environments
  - Indeterminacy in execution - e.g. waiting for events from multiple sources
  - Physical environment is delay intolerant - can't put it on wait with an hour glass icon!
- Multiple concurrent activities - sensing, processing, communication
  - Handling timing constraints are crucial

QUESTIONS?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