Interactive Distributed Embedded Systems

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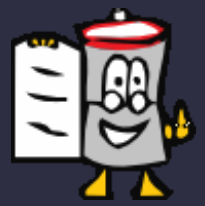
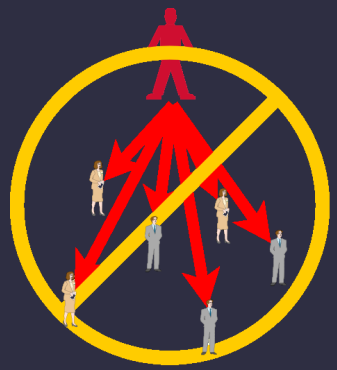




Outline

Section outline

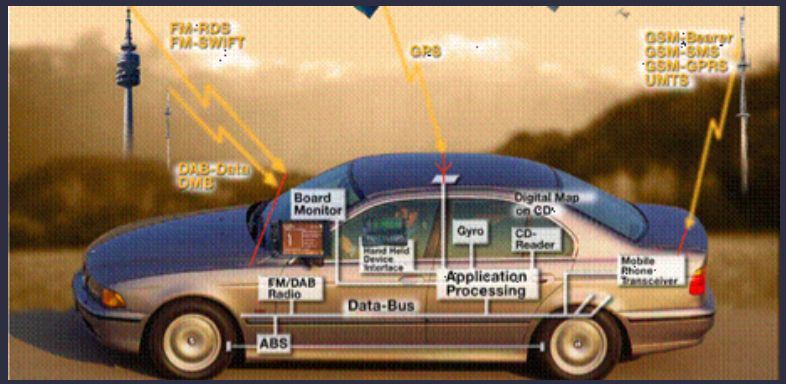
Embedded system definition

Embedded system: A computer within a host device, when the host device itself is not generally considered to be a computer.

Embedded systems examples

Medical devices

Sensor networks



Automobiles

Smartphones

Embedded system market size

- Dominates general-purpose computing market in volume.
- Similar in monetary size to general-purpose computing market.
- Growing at 15% per year, 10% for general-purpose computing.

Embedded system requirements

- Hard real-time
- Wireless
- Reliable
- First time correct
- Rapidly implemented
- Low price
- High-performance
- Low power

More on these later.

Embedded systems research goals

Develop better embedded system design ideas.

Automate embedded system design process.

Course focus

Interactive

Interacting with people or the physical environment to a greater degree than general-purpose computers.

Distributed

Composed of multiple parts that communicate with each other, e.g., systems composed of multiple components that use wireless communication.

Embedded Systems

Special-purpose computers embedded within other systems.

Section outline

Today's goals

1. Know how to get access to course resources.
   - Website.
   - References.
   - Mailing list.
2. Understand work and grading policies.
3. Rough understanding of topics we'll cover in course.

Administration

Lectures and project help sessions

- Lectures: Mondays and Wednesdays 1:40–2:30.
- Project help sessions: Fridays 1:40–3:30
- 1363 GGB.

Office hours

- Mondays 2:30–3:30 and by appointment.
- It will be necessary to schedule a number of meetings to discuss course projects.
- 2417-E EECS.

Course goals I

Have a general understanding of embedded system uses and design process.

Covered in lecture, practical reading material, and study for project.

Have a general understanding of current embedded system research topics.

Covered in lecture, research papers, and study for project.

Have a deep understanding of one particular research problem.

Primarily covered through self-study of research and technical documents while working on project.

Course goals II

Have completed a project that can naturally be developed into substantial (and ideally novel) research.

Be prepared for independent research in embedded system design automation.

Be capable of writing research papers and doing research presentations.

Class prerequisites

Knowledge of **some** of the following topics.

- Computer architecture.
  - Distributed systems.
  - Cache effects.
  - Power consumption impact of architectural decisions.
- Networking.
- Systems programming.
  - Project-oriented course with substantial programming component.
- Algorithm design and analysis.
  - Computational complexity analysis.
  - Efficient algorithm design.

Pick project team members carefully.

Course structure I

Lectures (Mondays and Wednesdays)

- Initially background material, survey papers, classical (old) research papers.
- Then recent research papers.
- Near the end of the course, project presentations will be given.

Project help sessions (Fridays)

- Initially, descriptions of past projects to provide examples.
- Coverage of practical implementation problems.
- Help on specific project problems.
- Near the end of the course, project demos will be given.

Course structure II

Project reports, demos (50% weight), and presentations (25% weight)

- 11 Jan: Topics of interest.
- 14 Jan: Team formation.
- 21 Jan: Written project proposals with clear plan for checkpoint 1 and checkpoint 2.
- 23 Jan and 25 Jan: Project proposal presentations to get feedback from classmates and instructor.
- 25 Feb: Checkpoint 1 report.
- 27 Feb and 1 Mar: Checkpoint 1 presentation and demo.
- 25 Mar: Checkpoint 2 report.
- 27 Mar and 29 Mar: Checkpoint 2 presentation and demo.
- 17 Apr and 19 Apr: Final presentation and demo.
- 23 Apr: Final report.

Brainstorming: possible project topics

- Distributed smartphone-based communication system for facilitating economic exchange in which the behavior of participants directly influences routing decisions.
- Low-power battery-operated wireless distributed sensing system.
- Smart clothing that determines what a user wants from a distributed computing system before the user consciously knows.
- Inexpensive cooperative robotic security system.

Will describe some example projects on Friday.

Project teams

- Multiple people may work on the same topic and collaborate.
  - Individuals or teams of two unless there is a special reason for three.
- Each person's contributions must be made clear in reports and presentations.

Mailing list

- We will use an web archived mailing list for discussion in the course.
- Membership on the list is a course requirement.
- I may post required material or assignments on the list.

Reference books I

- Wayne H. Wolf. *Computers as Components: Principles of Embedded Computing System Design*. Morgan Kaufmann Publishers, CA, 2001.
- Paul Horowitz and Winfield Hill. *The Art of Electronics*. Cambridge University Press, 1989.
- Robert P. Dick. *Multiobjective synthesis of low-power real-time distributed embedded systems*. PhD thesis, Dept. of Electrical Engineering, Princeton University, July 2002.
- Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein. *Introduction to Algorithms*. McGraw-Hill Book Company, NY, second edition, 2002.
- Jack Ganssle. *The Art of Designing Embedded Systems*. Newnes/Elsevier, 1989.

Reference books II

- Frank Vahid and Tony D. Givargis. *Embedded System Design: A Unified Hardware/Software Introduction*. John Wiley & Sons, 2001.
- To be continued.

Web resources

- Deep Chip and e-mail Synopsys user's group. http://www.deepchip.com.
- Electrical Engineering Times. http://www.eetimes.com.
- Embedded.com. http://www.embedded.com.

Journals of note

- ACM Transactions on Embedded Computing Systems.
- IEEE Transactions on Computer-Aided Design.
- IEEE Transactions on VLSI Systems.
- ACM Transactions on Design Automation for Electronic Systems.

Conferences of note

- Embedded Systems Week
  - International Conference on Hardware/Software Codesign and System Synthesis.
  - International Conference on Compilers, Architecture, and Synthesis for Embedded Systems.
  - International Conference on Embedded Systems Software.
- Design Automation Conference.
- International Conference on Information Processing in Sensor Networks.
- Conference on Embedded Networked Sensor Systems.
- International Conference on Mobile Systems, Applications, and Services.
- Design, Automation, and Test in Europe.
- International Conference on Computer-Aided Design.
- Asia South Pacific Design Automation Conference.

Outline

Section outline

2. Embedded system research areas
   - Definitions
   - Topics to cover in class

Review: embedded system definition

An embedded system is a computer within a host device, when the host device, itself, is not generally considered to be a computer.

For example, the computers within automobiles, medical devices, and portable communication devices are embedded systems.

In most applications, well-designed, correctly functioning embedded systems are almost invisible to their users.

Embedded systems research goals

- Develop better embedded system design ideas.
- Automate embedded system design process.

Two major sources of changing problems

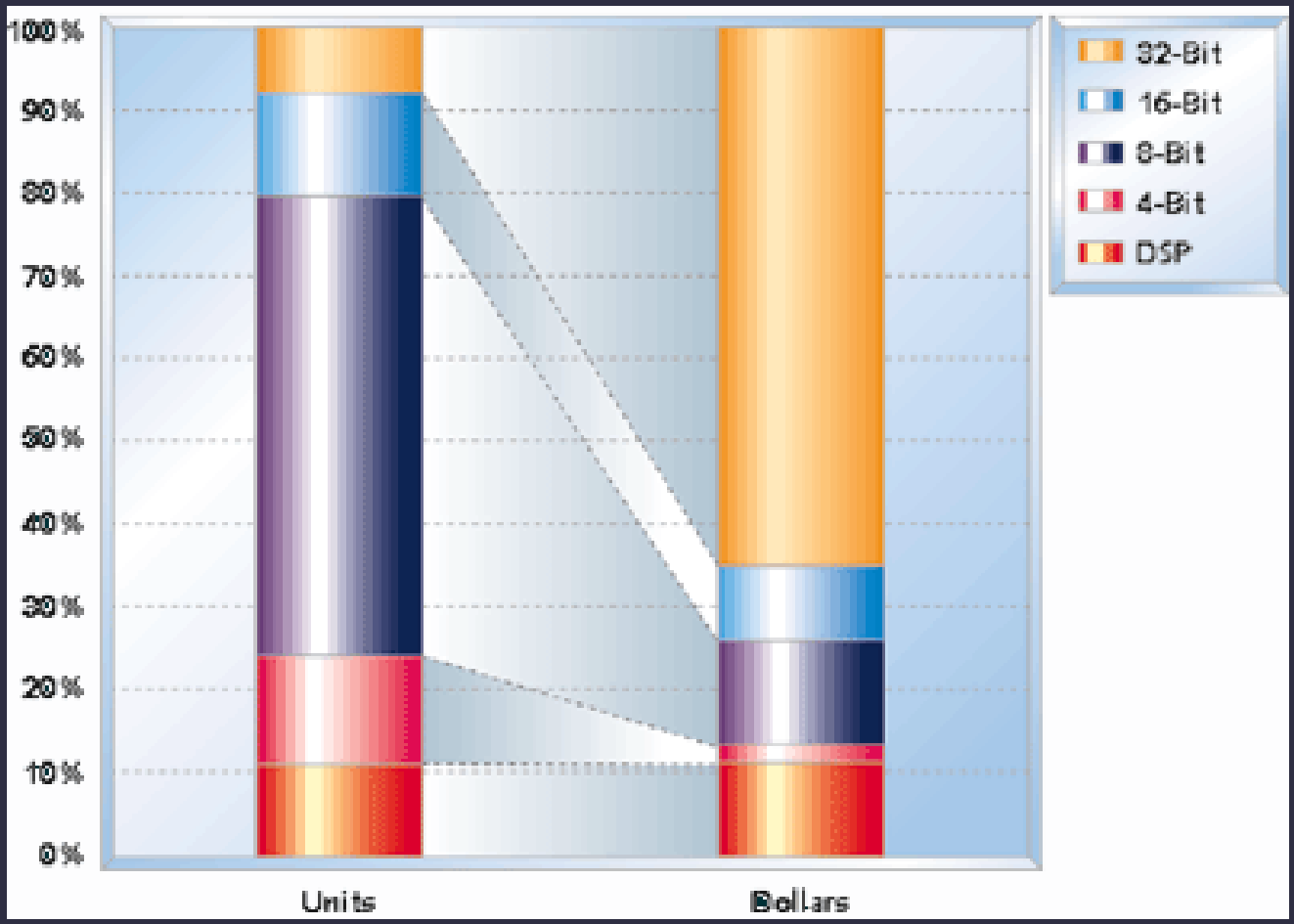
New implementation technologies.

New applications.

Review: embedded system market size

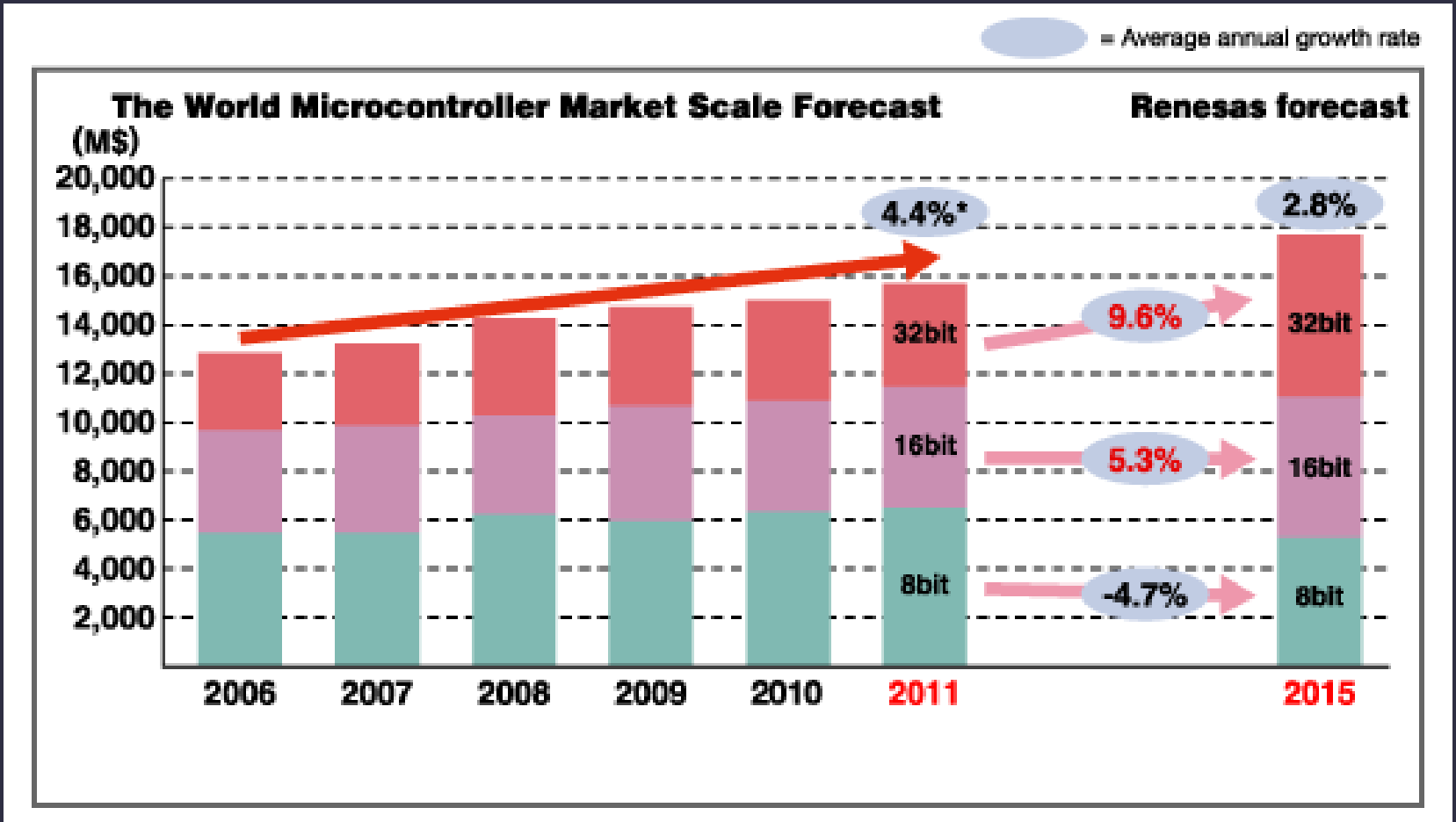
- Dominates general-purpose computing market in volume.
- Similar in monetary size to general-purpose computing market.
- Growing twice as fast.
- Electronics market over \$1,000,000,000/year.

Processor sales by type



From *The Two Percent Solution* by Jim Turley, Embedded Systems Design, 2002.

Worldwide microcontroller market scale forecast



Renesas estimates.

Microcontroller market shares

2007 and 2008 Worldwide Microcontroller Revenue Share by Supplier

Company	2008 Rank	2008 $M	2008 Share	2007 Rank	2007 $M	2007 Share	Y/Y %
Renesas Technology	1	2,770	20.1%	1	2,944	21.2%	-6%
Freescale Semiconductor	2	1,518	11.0%	2	1,743	12.6%	-13%
NEC	3	1,330	9.7%	3	1,296	9.3%	3%
Fujitsu	4	1,065	7.7%	4	1,115	8.0%	-5%
Infineon Technologies	5	983	7.2%	5	1,023	7.4%	-4%
Microchip Technology	6	812	5.9%	6	778	5.6%	4%
STMicroelectronics	7	645	4.7%	7	662	4.8%	-3%
Texas Instruments	8	601	4.4%	8	607	4.4%	-1%
Atmel	9	511	3.7%	9	458	3.3%	12%
NXP Semiconductors	10	286	2.1%	10	303	2.2%	-6%
Other		3,229	23.5%		2,936	21.2%	10%
Total		**13,749**			**13,866**		-1%

databeans estimates, Company Reports

From *Renesas Technology Still Dominates the Microcontroller Market*, Electronics Design, Strategy, News, 2009.

Embedded system requirements

- **Hard real-time:** Deadlines must not be violated.
- **Wireless:** Effects of the communication medium important.
- **Reliable:** Better crash desktops than cars.
- **First time correct:** Field repairs difficult.
- **Rapidly implemented:** IP use, HW–SW co-design.
- **Low price:** Fierce competition between many companies.
- **High-performance:** Massively parallel, using ASICs.
- **Low power:** Battery life and cooling costs.

Low-power motivation

- Embedded systems frequently battery-powered, portable.
- High heat dissipation results in
  - Expensive, bulky packaging,
  - Limited performance, and
  - Short battery life.
- High-level trade-offs between
  - Power,
  - Speed,
  - Price, and
  - Area.

Design automation

2001 CMP Media LLC survey

- 1,100 embedded system developers.
- Majority of projects were running late.
  - Four-month delay normal.
- Majority had lower performance than predicted.
  - 50% expected and planned performance normal.

Possible explanations

- Differences between applications require greater degree of re-design than in general-purpose computing.
- More limited resources per design.
- Design process unpredictability due to manual, ad-hoc design.

Embedded system design automation

- Anything allowing computers to do a portion of embedded system design.
- Broad scope: Try to solve the whole system-level design problem automatically.
  - May need to make limiting assumptions or target narrow problem domains to make scope reasonable.
  - Too large for course project.
  - Can start from existing system, though.
- Narrow scope: Thoroughly solve a sub-problem within embedded system design.

Embedded system design automation

- System-level design automation is embedded system design automation.
- General-purpose system architecture largely already decided.
- Improvements can undergo laborious special-case manual analysis due to high volume.

Embedded system design automation

- Embedded system architectures more flexible.
- Flexibility gives synthesis algorithms freedom to consider numerous solutions.
- Smaller design runs make it difficult to justify assigning many engineers to manual design.

Embedded system design

- Design constraints and resources more varied than in general-purpose computing.
- This requires different design techniques.
- Many highly successful ideas in embedded system design do not work in general-purpose computing.
- Many highly successful ideas in general-purpose computing do not work in embedded systems.
- However, there is also some overlap.

Section outline

2. Embedded system research areas
   - Definitions
   - Topics to cover in class

Overview of topics I

- Isolated embedded system design problem.
- Networked embedded system design problem.
- Models and languages.
- Introduction to complete and stochastic optimization.
- Design automation.
- Reliability.
- Real-time systems and scheduling.
- Memory hierarchies in embedded systems.
- Low-power and power-aware design.
- Embedded operating systems.
- Distributed sensing.
- Wireless communication.

Overview of topics II

- Cyber-physical systems.
- Impact of device technology changes on embedded systems.
- Compilation techniques for embedded systems.
- Implicit interactive computer design.
- Energy supply in embedded systems.

Outline

Get on mailing list

- Due 9 Jan.
- Email dickrp@umich.edu using the address you want to subscribe.

Determine topics of interest

- Due by 11:59 on 11 Jan.
- List three embedded systems topics you are interested in learning more about and working on.
- This is not a commitment to a particular topic.
  - That will come soon, though.

Begin study of topics of interest

- Due before class on 14 Jan.
- Use electronic resources, research papers, and questions posted to the mailing list to answer the following questions for each of the three topics of interest, using 3-5 sentences for each.
  1. Why will work on this topic be useful to its users in the next five years?
  2. Is this topic of special relevance to distributed interactive embedded systems?
  3. Identify a potential research project that is related to this topic and can be completed within the time-frame of this course.
- Your one-page report should back up your claims using research, technical, and business publications. It should contain roughly five references.
- How to get started finding relevant literature?
- Best to get started today or tomorrow.

Upcoming lectures

- Possible project implementation platforms.
- The process of doing a literature survey.