Lecture Note #1
EECS 571
Principles of Real-Time and Embedded Systems

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General Course Information

- Instructor: Kang G. Shin, 4605 CSE, 763-0391; kgshin@umich.edu
- # of credit hours: 4
- Class meeting time and room:
  - Regular classes: MW 10:30am – noon @1012 EECS
  - Makeup/discussion (as needed): F 10:30 – 11:30am @1012 EECS
- Office hours: MW 9:30 – 10:30am, or by appointment but email is the best way to get hold of me.
- Course homepage: http://www.eecs.umich.edu/courses/eecs571

Important Dates and Class Email

- **Important Dates**
  - Start of class: Sep. 8 (Wed)
  - Study break: Oct. 18-19 (Mon-Tue)
  - One-page project proposal due: Oct. 13 (Wed)
  - Thanksgiving break: 5pm Nov. 24 (Wed)–8am Nov. 29 (Mon)
  - Comprehensive exam: Dec. 1, Wed (tentative)
  - Last day of class: Dec. 13 (Mon)
  - Term project presentations: 6pm-midnight 12/13, 3725 CSE
  - Term project report due: electronically by 4pm 12/17 (Fri)
- **Email group:** Subscribe to the mail list by sending email to eecs571-request@eecs with “subscribe” in the Subject field. You may use this email group (eecs571@eecs) only for the class.

Course Materials

- Copies of ``Real-Time Systems," Krishna and Shin, McGraw-Hill, 1997 will be made available at Dollar Bill. Errata is maintained on the course URL http://www.eecs.umich.edu/courses/eecs571/book_correction.pdf and typos and other errors should be reported to me or rtbook@tikva.ecs.umass.edu.
- Reference: ``Designing Embedded Processors," edited by J. Henkel and S. Parameswaran, Springer, 2007.
- Four key sources of reading are:
  - IEEE Real-Time Systems Symposium (RTSS) (1980 –)
  - IEEE Real-Time Technology and Applications Symposium (RTAS) (1995 –)
  - International Journal of Time-Critical Computing (1989 –)
  - ACM Transactions on Embedded Sysems (2002–)
- University Digital Library (http://www.ieeexplore.org and http://www.acm.org)

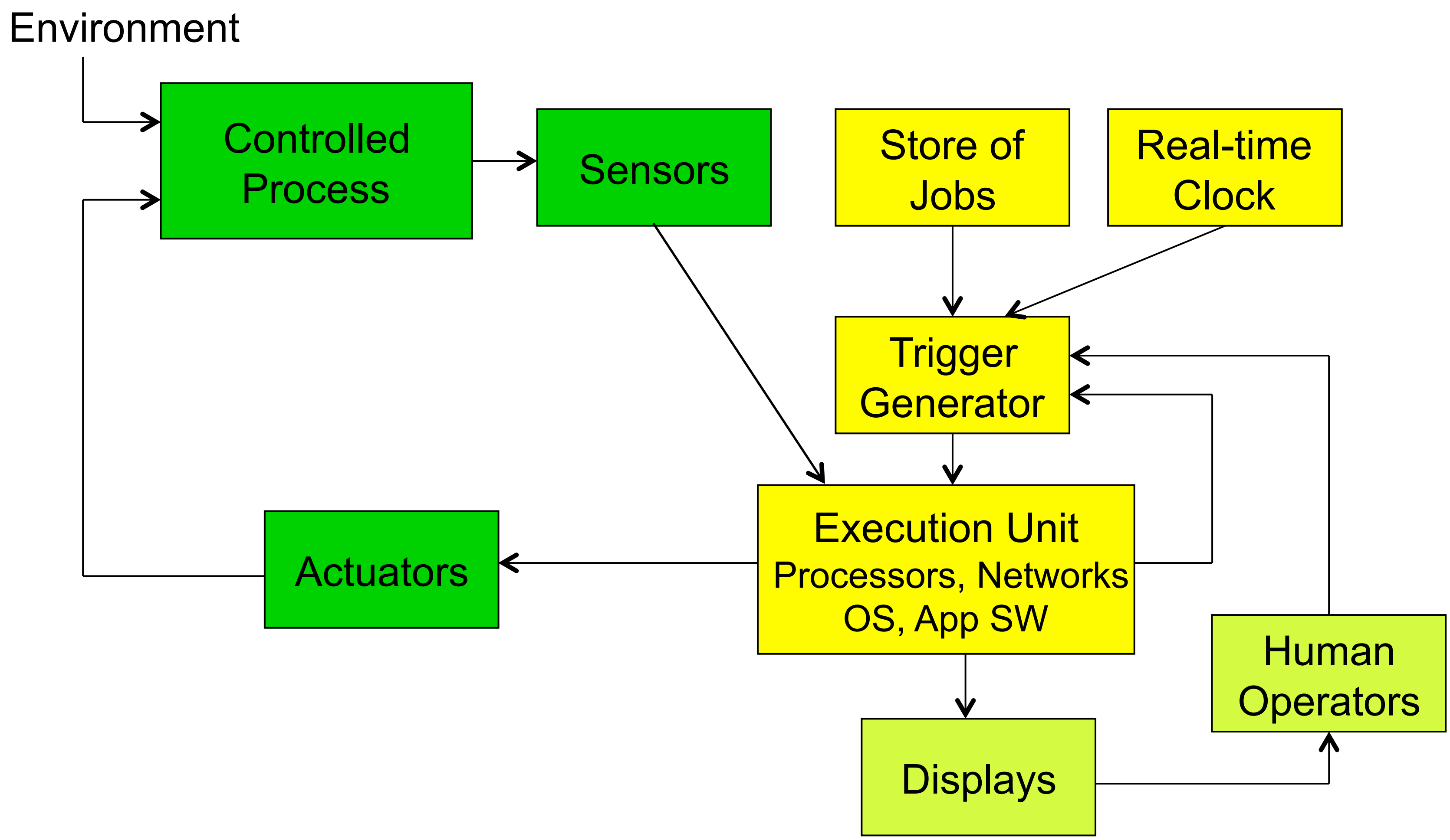
Pre-requisites and Grading Policy

- Pre-requisites: EECS 482 or EECS 470, or basic knowledge in system software and computer architecture is required, or instructor's approval.
- Grading Weights
  - Bi-weekly homeworks: 15%
  - Comprehensive midterm on Dec. 3, 2010: 25%
  - Term project: 55% (presentation 30% and report 25%)
  - Class participation: 5%
- Collaboration and Regrading Policies: see the handout or course homepage.
- Important Information on HWs and Term Projects: see the handout or course homepage.

General Concepts of Real-Time Embedded Systems

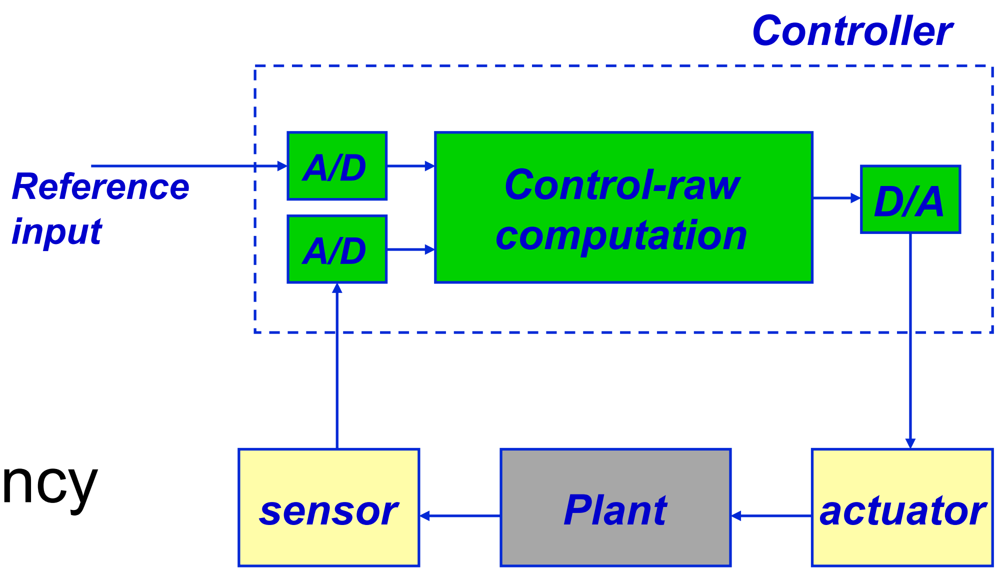
- **What's a real-time system and what's not?**
- **What's an embedded system?**
- **Types of real-time systems**
  - Hard real-time systems: definition and examples
  - Soft real-time systems: definition and examples
- **What's a deadline and where is it coming from?**
  - Law of physics
  - Artifcially imposed.
- **A task/message/packet may be critical or non-critical, depending on its function and system state.**
- **Based on invocation/triggering behavior, a task/message/packet is periodic, aperiodic, or sporadic.**
- **How do we derive message/packet deadlines?**

A Typical Real-Time Embedded System



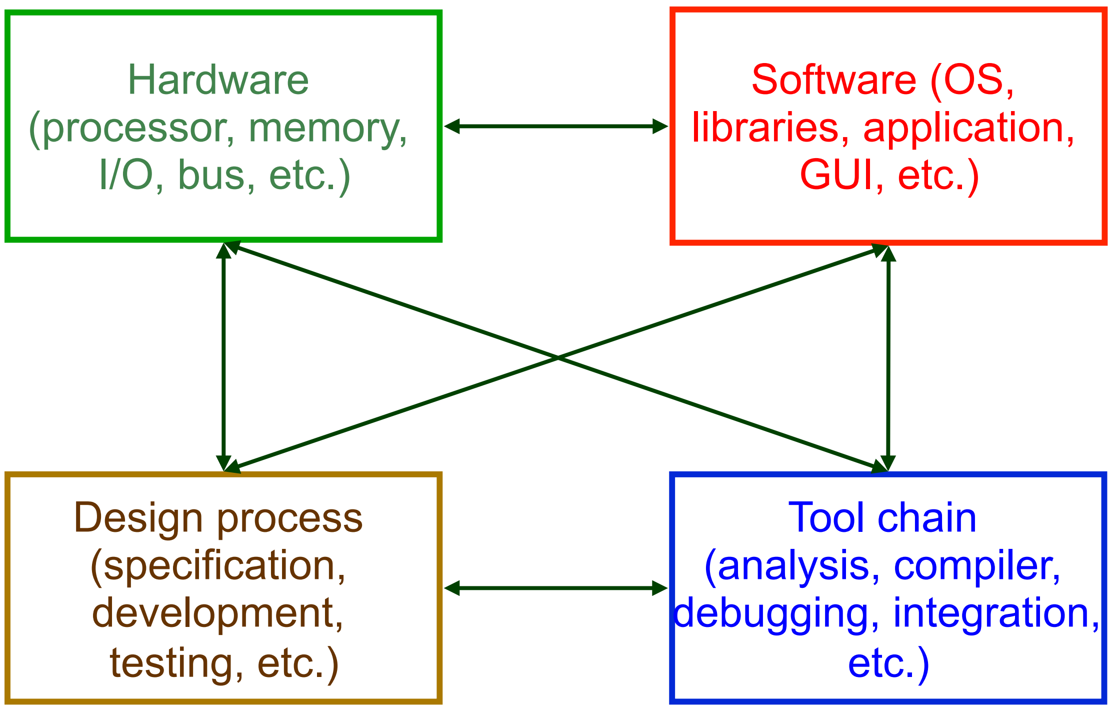
Real-time Embedded Systems

- **Embedded system**
  - The software and hardware component that is an essential part of, and inside another system
- **Real-time system**
  - needs timely computation
  - deadlines, jitters, periodicity
  - temporal dependency



Real-time Embedded Systems

- **Conventional Dedicated Systems**
  - Unique solution (HW/SW/tool) for each application
  - System + domain knowledge



Embedded Systems

- **are everywhere**
- **How many embedded processors in your home?**

  40-50 estimated in 1999.
- **What are they?**

  Hardware (chips) + Software (program)

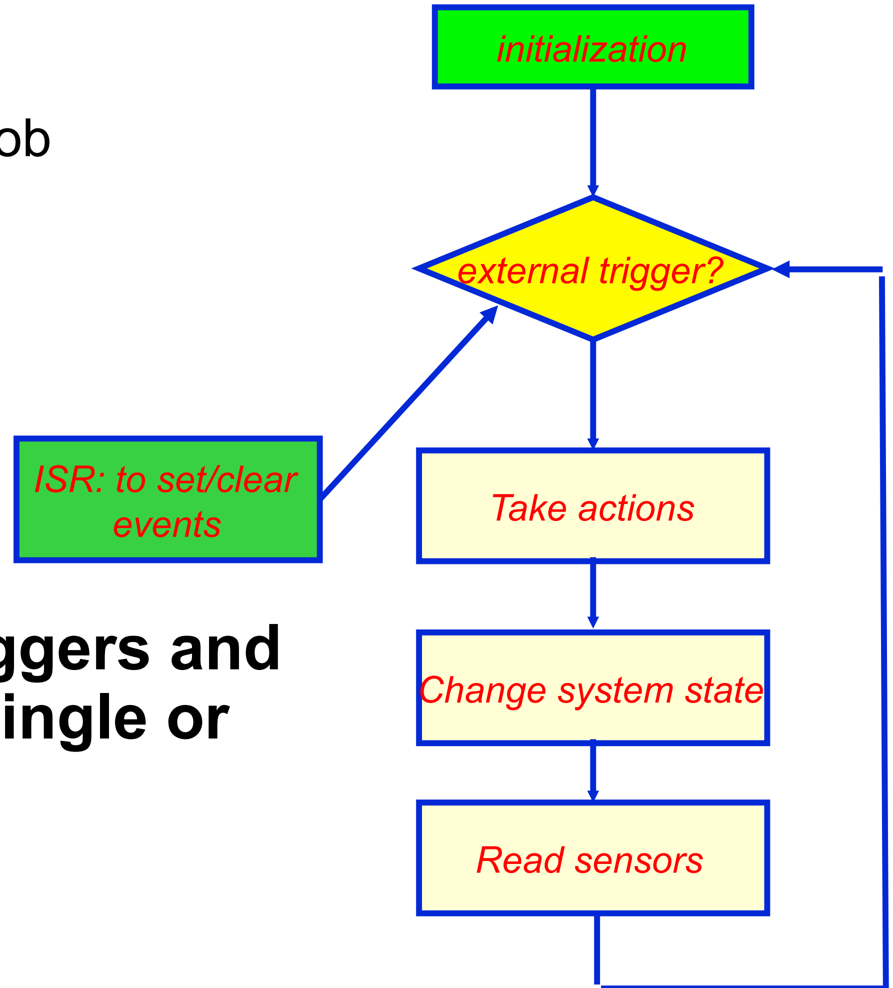
  - CPU processor (ARM, PowerPC, Xscale/SA, 68K)
  - Memory (256MB or more)
  - Input/output interfaces (parallel and serial ports)

Requirements for RTES

- **Environmental – size, power (heat), weight, and radiation-hardened**
- **Performance –responsive, predictable (fast?)**
- **Economics – low cost and time-to-market**
- **Consequence – safety, faulty-tolerance, security**
- **Standards –**http://www.opengroup.org/rtforum/oct2001/minutes.html
  - DO 178b (avionics)
  - FDA 247 (medical devices)
  - ANS 7.4.3.2 (nuclear power plants)
  - Mil-Std 882d (weapon systems)
- **Smaller, cheaper, better, and faster**

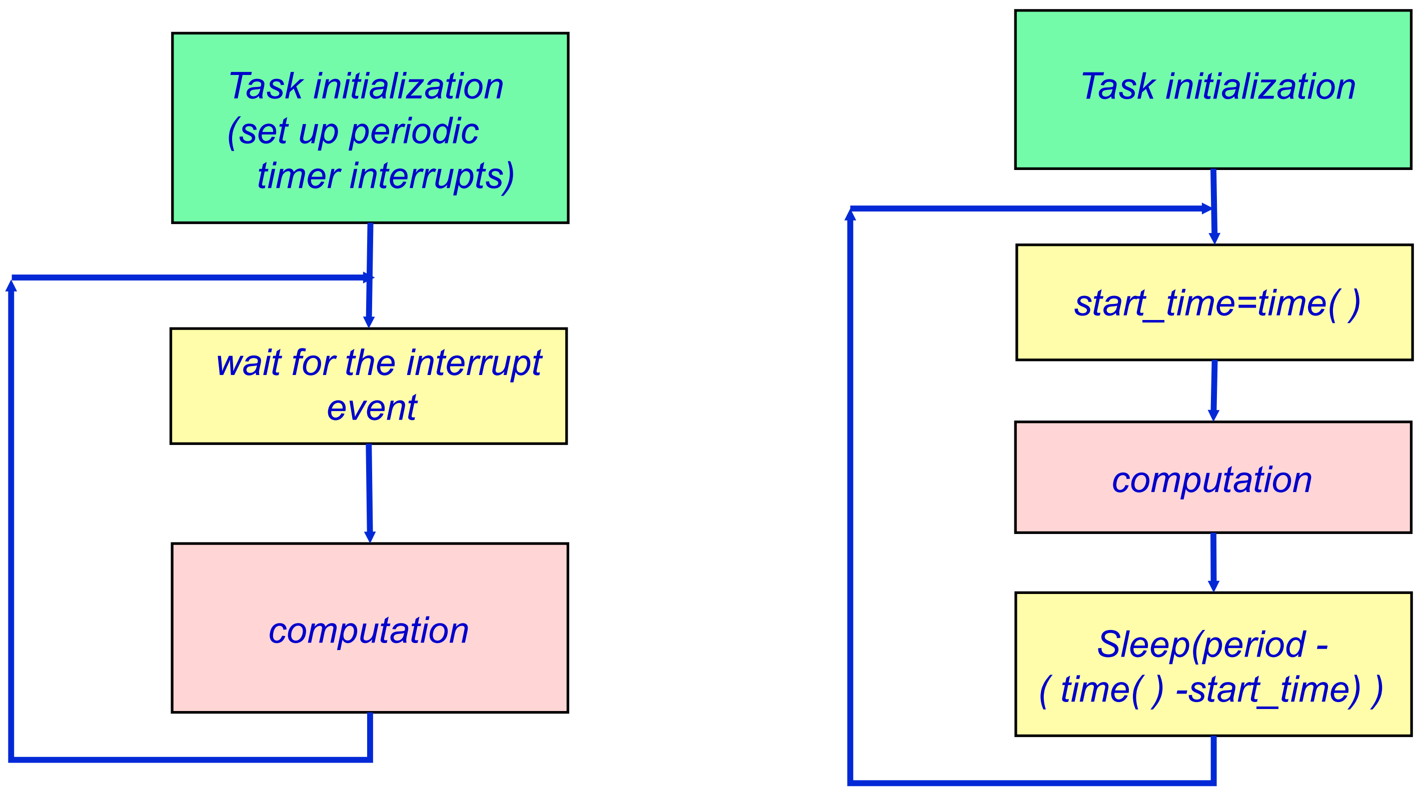
SW Development for RTES

- **To write the control software for a smart washer**
  - initialize
  - read keypad or control knob
  - read sensors
  - take an action
- **Current system state**
  - state transition diagram
  - external triggers via polling or ISR
- **If there are multiple triggers and external conditions – single or multiple control loops**



Periodic Tasks

- **Invoke computation *periodically***
  - Adjust pressure valves at a 20 Hz rate



SW Development for RTES

- **Never-ending in a single control loop**
- **Single execution thread and one address space**
- **Event- and/or time-driven state transitions**
- **Small memory footprint (?)**

- **What are missing in the previous example?**
  - no concurrency (real-world events occur near simultaneously)
  - no explicit timing control (add a timer)
  - difficult to develop and maintain large embedded systems – verifiable, reusable, and maintainable

SW Development for RTES, cont'd

- **Multi-tasking for concurrent events**
- **Machine dependency and portability**
- **Software abstraction, modular design**
  - information hiding, OO, separate compilation, reusable
  - a sorting procedure – function, input, output specification
- **Control timing**
- **Resource constraints and sharing**
  - CPU time, stack, memory, and bandwidth
- **Scheduling**
  - Tasks, messages, and I/O

Timing Constraints and Characteristics

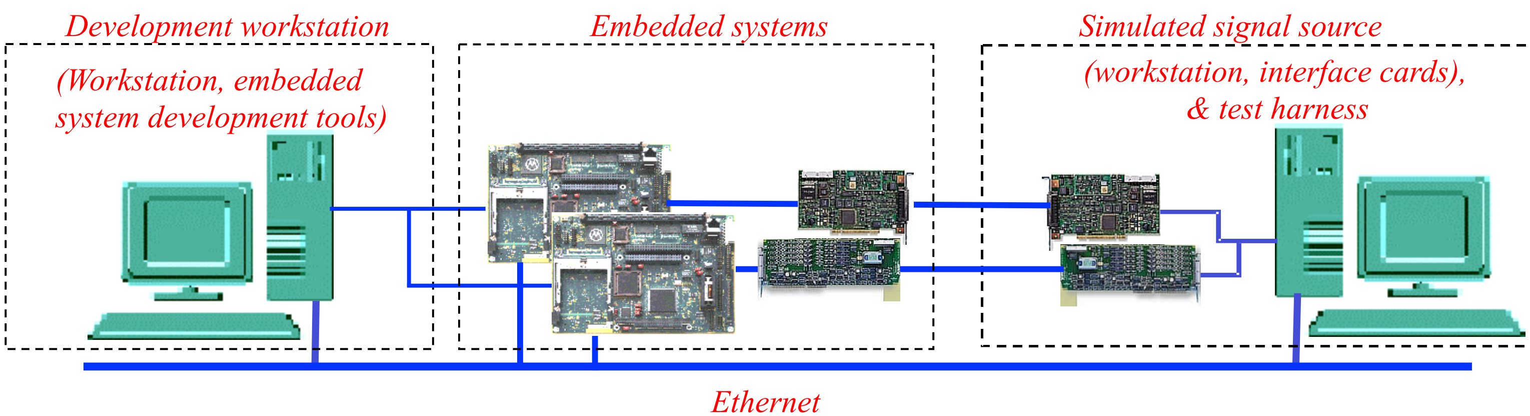
- **Predicting and controlling timing and events**
- **Timing relationship: (can you guarantee it?)**
  - predictable actions in response to external stimuli
  - deadline (absolute or relative), and jitter
- **Instruments play in a band**
  - miss a note or timing
- **Difficult to control timing**
  - all players of an interactive game in Internet see the actions at the same time
  - Sequence, order, and race condition

Timing Constraints and Multi-threading

- **Given input x_1 at time t_1, produce output y_1 at time t_2**
- **Non-deterministic operation, time-dependent behavior, and race condition**
  - difficult to model, analyze, test, and re-produce.
- **Easy to identify the faults and fix them once the failing sequences are reproduced (or observed), but**
  - The failures are rooted in the interaction of multiple concurrent operations/threads and are based on timing dependencies

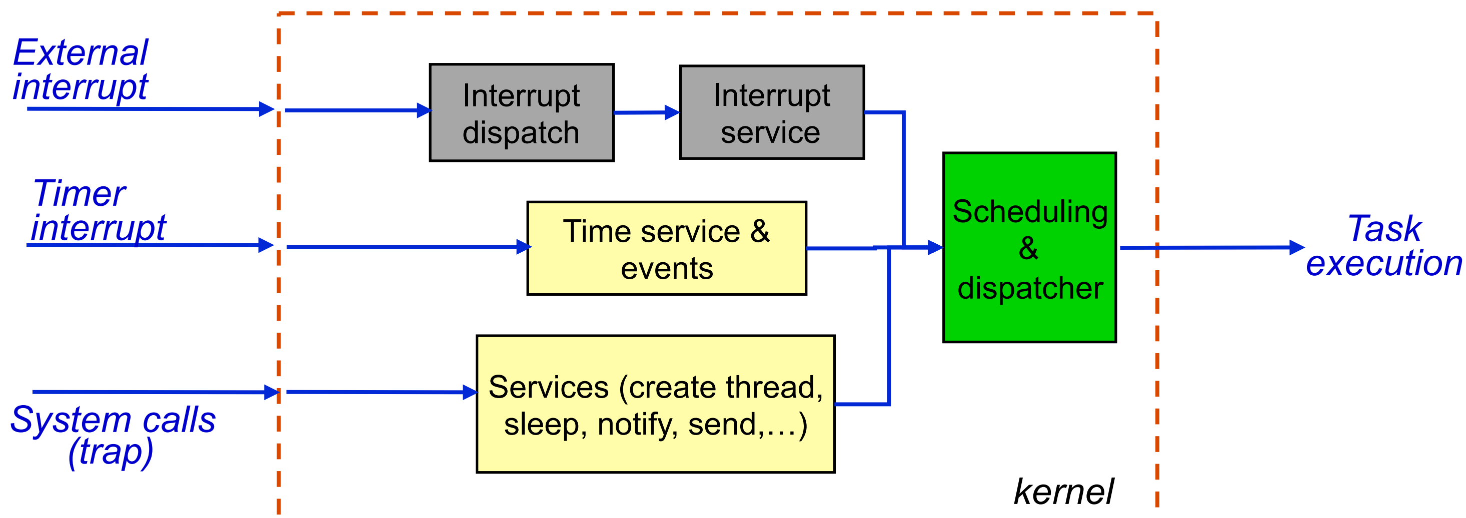
Embedded System Development

- ❑ **Need a real-time (embedded) operating system?**
- ❑ **Need a development and test environment?**
  - ❖ Use the host to edit, compile, and build application programs, and configure the target
  - ❖ At the target embedded system, use tools to load, execute, debug, and monitor (performance and timing)



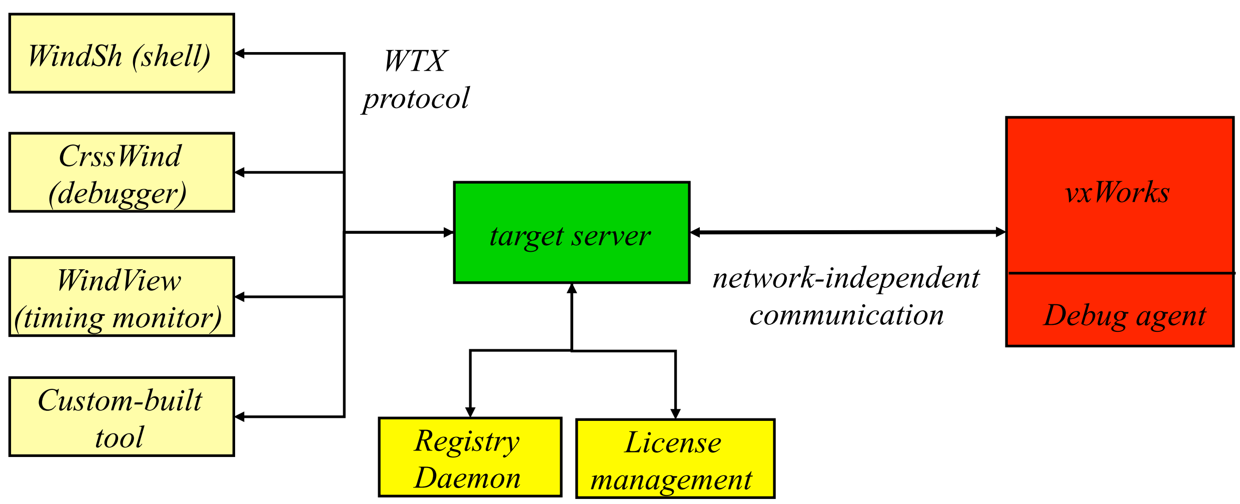
Real-time Operating System (RTOS)

- **Functions:**
  - task management,
    - scheduling, dispatcher
    - communication (pipe, queue)
    - synchronization (semaphore, event)
  - memory management
  - time management
  - device driver
  - interrupt service



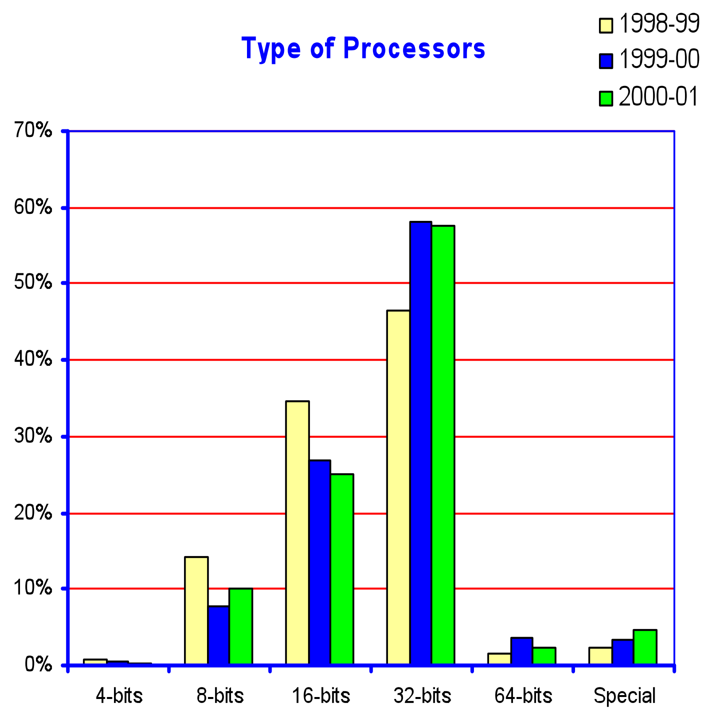
Development Environment

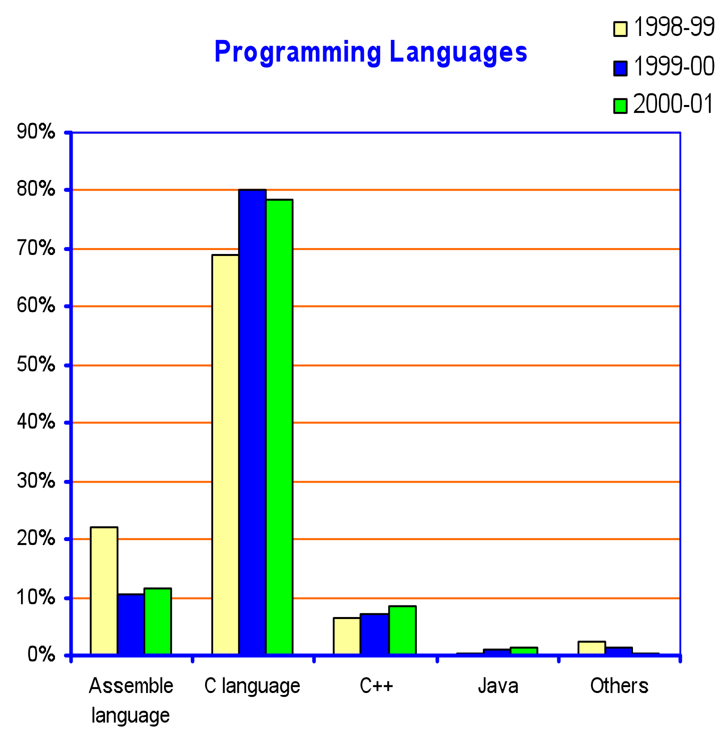
- Use the host to
  - edit, compile, build application programs, and configure the target
- At the target embedded system, use tools to
  - load, execute, debug, and monitor (performance and timing)
- The target server manages the interactions with the target
  - communication channel
  - symbol table for the target



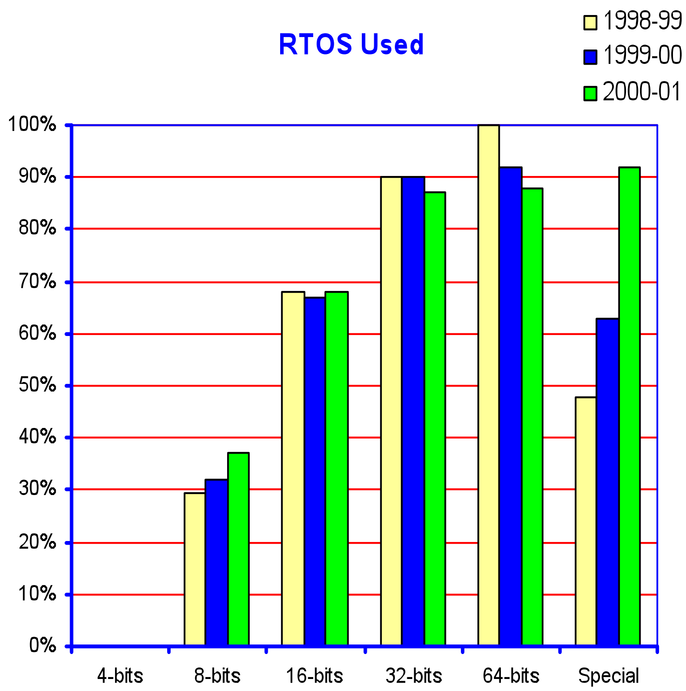
Trends in Embedded Systems

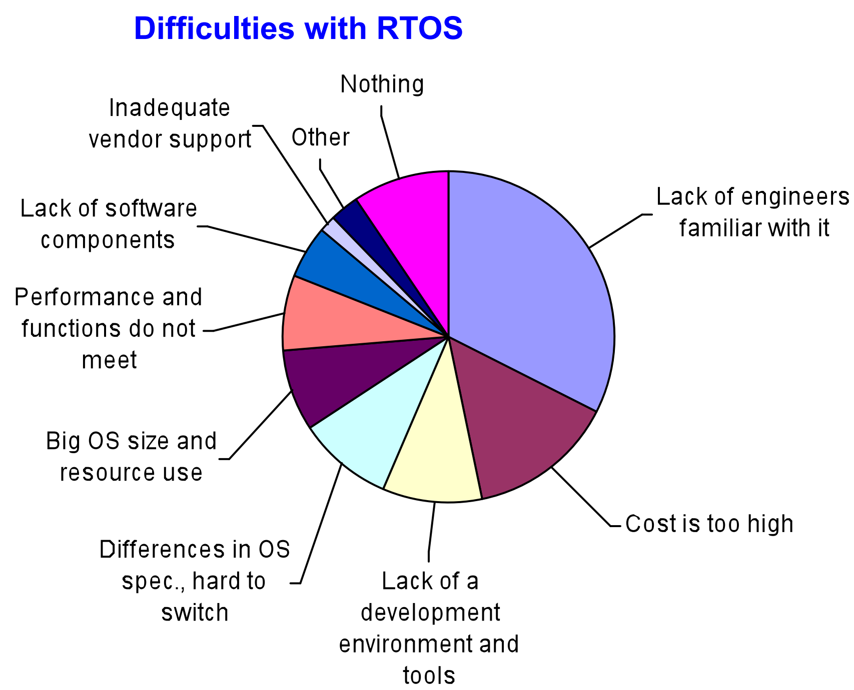
- Data from Japan ITRON survey for new embedded systems





Trends in Embedded Systems





Major Topics of RT ES

- Performance measures & task execution time estimation
- Task assignment & scheduling
- Real-time OS and other system software
- Power management for CPU, memory and disk
- Time-sensitive wired and wireless networking
- Security and privacy of embedded systems and devices
- Model-based integration of embedded real-time software
- Formal methods
- Fault-tolerance of embedded real-time systems
- Clock synchronization
- Applications: multimedia, VoIP/VoWLAN, VoD, info and home appliances, medical devices, sensors & actuators, virtual reality, automotive electronics (powertrain controls and infotainment systems, ITS), automated manufacturing, I large embedded systems (ships, planes),…