Programming Embedded Systems

Lecture 1
Introduction to the course

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Lecture outline

- Organisation
  - Teachers
  - Lectures, exercises, labs, project
- Topics + focus of the course
- Recap of the C language

About myself (course instructor)

- Started at UU 12 days ago
- Diploma/M.Sc. from Karlsruhe University, 2004
- PhD from Chalmers, Gothenburg, 2008
- Main background: formal methods, verification

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About Othmane Rezine (assistant)

- PhD student in verification group
- Will do exercises + labs

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Organisation of the course

Main structure of the course

Part 1
period 3, week 2-11
14 lectures (±), 6 assignments, 2 labs (3hp)

Two main topics:
use of operating systems for embedded systems
programming languages for embedded systems

Part 2
period 4, week 12-22

Embedded systems project (4hp)

Exam (3hp)

Lectures

- **Mondays**: 2 hours
- **Wednesdays**: 1 or 2 hours

Sometimes shared with assignment discussions

- Room + slides available on course page
  http://www.it.uu.se/edu/course/homepage/pins/vt11

Assignments

- 6 assignments, solved by students individually
- Practice material from lectures
- Graded pass/fail
- **≥4 have to be handed in + passed**
- Given out on Wednesdays:
  Jan 19, 26; Feb 2, 9, 16, 23
  handed in Wednesday following week **before the lecture**

Labs

- Done in groups of 2 people
- Small embedded systems projects
- No real embedded hardware → use of simulators
- We will give lab supervision during 1 lab slot per week (probably Fridays)

More infos will be on course page
http://www.it.uu.se/edu/course/homepage/pins/vt11

Labs (2)

- **Lab 1:**
  use of embedded operating systems
  Start: end of week 3 (this week)
  Deadline: Feb 11, week 6
- **Lab 2:**
  embedded programming languages
  Start: week 6
  Deadline: Mar 4, week 9

More infos will be on course page
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Project (period 4)

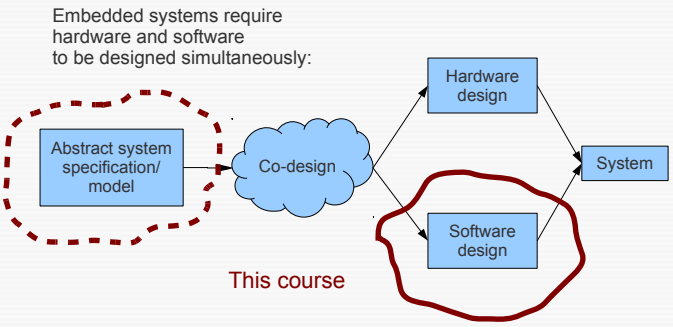
- Larger groups (3-4 people)
- Use of actual “embedded” hardware
- Details made available in due time

Course topics

Recapitulation: embedded systems

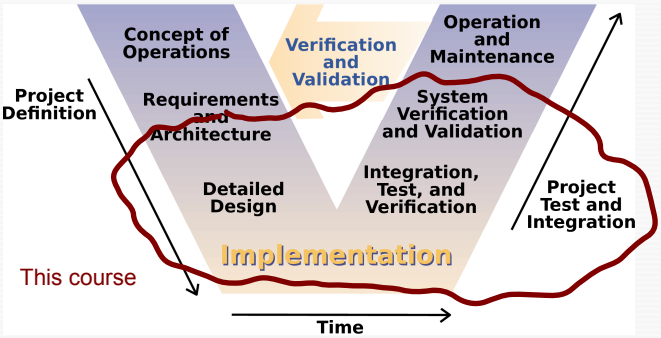
- System fulfilling particular task in a larger context
  - control systems in automotive, avionics, railway, process automation, communication, ...
  - mobile devices, ubiquitous devices
- Often with **real-time constraints**
- System: **hardware + software**

Course location: hardware/software co-design

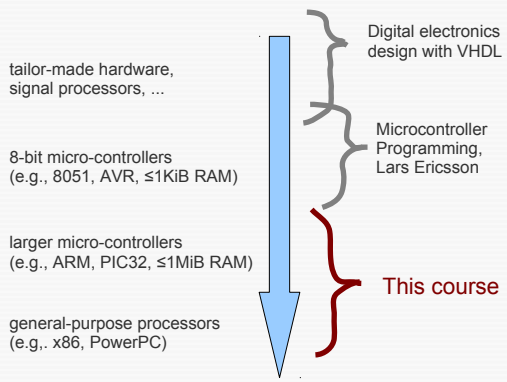


Course covering (more) co-design:
Microcontroller Programming, Lars Ericsson

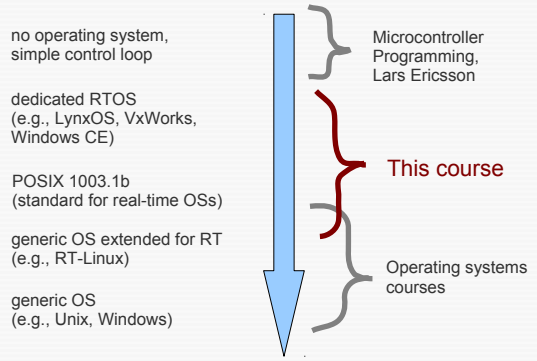
Course location: development process



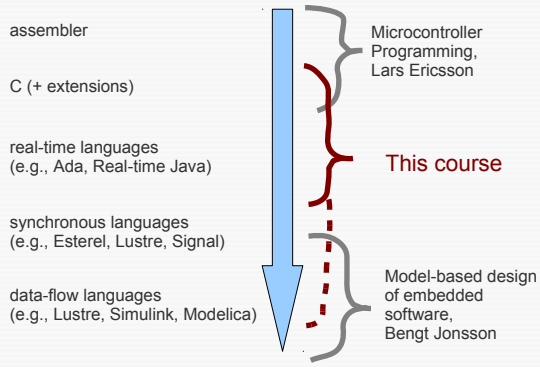
Course location: considered hardware



Course location: software architectures



Course location: programming languages



Course focus 1: embedded operating systems

- OS simplifies development of systems:
  - Multi-tasking, scheduling, task pre-emption, deadlines
  - Synchronisation, shared resources
  - Drivers for communication, periphery
  - Interrupt handling
- Large variety of OSs common for embedded systems
  - e.g, LynxOS, VxWorks, Windows CE, RT-Linux, FreeRTOS, ECOS, OSE, QNX, Integrity, ...

Selection criteria for embedded operating systems

- Hardware requirements:
  Runtime overhead, memory, hardware platforms
- Provided features
  e.g., synchronisation, priority inversion prevention, real-time capabilities
- Guaranteed latencies
  Task switching
  Interrupt handling
- Provided schedulers:
  Static (table driven, priority driven)
  Dynamic (planning based, best effort)
  Fault tolerant scheduling

No single OS can satisfy all needs!

Main OS considered in course: **FreeRTOS**

- Small industrial OS, open-source (GPL)
- C API
- Satisfies hard real-time requirements
- Pre-emptive/cooperative multi-tasking, co-routines
- Fixed-priority scheduler
- Platforms: ARM, x86, Freescale, ...

http://www.freertos.org/

FreeRTOS (2)

- Will be introduced in lectures, used for assignments + labs (via simulators)
- Supporting book:
  Richard Barry, *"Using the FreeRTOS Real Time Kernel - a Practical Guide"*

Related course topics

- Interrupt handling
- Accessing ports, devices like sensors, actuators, buses
- Memory management
- Synchronisation, inter-task communication
- Use of development boards
- Further OSs: RT-Linux, POSIX 1003.1b

Related course topics (2)

- Requirements, safety properties
- Correctness: simulation, testing, debugging, verification
- Fault tolerance, redundancy
- Determinism, predictability

Course focus 2: embedded programming lang.

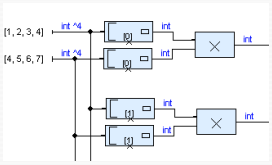
- Language in 1st part of the course: C
- General trend, however: use of increasingly **high-level** languages
- Course will give an overview of different common paradigms

High-level imperative lang.

- Real-time Java, Ada 95
- High-level heap model
- Scoped memory (garbage collectors are difficult in real-time systems)
- Built-in real-time primitives

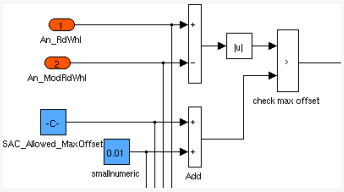
Synchronous languages

- Lustre, Esterel, Signal
- Execution governed by a global clock, static scheduling
- Determinism is guaranteed (even in presence of concurrency)
- Sometimes also used for modelling/prototyping



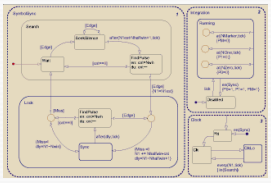
Graphical languages

- Matlab/Simulink, SCADE/Lustre
- **Data-flow**: programs as graphs of data-processing blocks



Graphical languages (2)

- **State charts**: graphical design of program states



- More details in course *"Model-based design of embedded software," Bengt Jonsson*

Prevention of runtime errors

- Techniques to prevent null-pointer dereferences, arithmetic over-/under-flows, etc.
- Static analysis, model checking, theorem proving
- SPARK/Ada: "high-integrity" version of Ada; programs include assertions + specs

What remains

Further information

- Course page: `http://www.it.uu.se/edu/course/homepage/pins/vt11`
- There will be a web forum for questions (as soon as we found out how to set it up on studentportalen ...)
  - **Always check the forum before sending us an email!**

Next lecture

- Wednesday, Jan 19, 13:15, Pol_1245
- Intro to fixed-priority scheduling
- Intro + tutorial to FreeRTOS

Rest of this lecture

- Questionnaire
- Recap of C programming