Course Summary
Real-Time Systems

2020

Real-Time Systems

The most important parts!

or *with some luck*

What you need to know to pass the exam

Lecture 1: Introduction

- Basic definitions (hard, soft, …)
- Timing parameters in continuous controllers (sampling latency, sampling interval, input-output latency)
- Different event types (periodic, aperiodic, sporadic)

Lecture 2: Concurrent programming

- Process vs threads
- Process' internal states and state transitions
- The ReadyQueue
- Context switches
  - Save, restore
  - The role of the stackpointer
- Process representation
- The Schedule procedure in Stork
- Java threads:
  - Extend Thread versus implement Runnable
  - Thread priorities

Lecture 3: Process communication 1

- Non-reentrant code
- Race conditions
- Mutual exclusion
- Semaphores:
  - Use for mutual exclusion and synchronization
  - Logical semantics
  - Different types of semaphores (counting, binary)
  - Basic version vs alternative version
  - Stork implementation
  - Condition synchronization using semaphores
  - Java Class Semaphore

- Monitors:
  - Basic definitions
  - Condition variables
  - Monitors in Stork
    - Implementation
- Synchronization in Java
  - Synchronized methods
  - Synchronized blocks
  - Instance locks vs class locks
  - Condition synchronization in Java
  - Class ConditionVariable
- Producer-Consumer example
  - Using semaphores
  - Using synchronization
- Passing objects between threads

Lecture 4: Process communication 2

- Deadlock
  - Necessary conditions
  - Deadlock handling (prevention, avoidance, detection & recovery)
  - Hierarchical resource allocation
- Priority inversion
  - When does it occur?
  - Basic priority inheritance
  - Priority Ceiling
  - Immediate inheritance
- Message passing
  - Alternative schemes (asynchronous/synchronous, direct/indirect)

Lecture 5: Interrupts and time

- Interrupts and interrupt handling
- Clock interrupts
  - The actions performed in the clock interrupt handler
  - TimeQueue
- Tick-based vs event-based clock interrupts
- Foreground-background schedulers
- Time primitives (relative vs absolute)
- Implementation of periodic controller tasks:
  - Different alternatives and their problems
- Minimizing the input-output latency
  - CalculateOutput and UpdateState
  - Cascaded controllers
- Jitter

Lecture 6: Sampling of linear systems

- Sample and Hold
- Effects of sampling
- Aliasing
- ZOH sampling
- ZOH sampling of systems with input delays
- Calculating Φ and Γ
- Solution of system equations
- Stability regions
- Convolution
- From difference equations to state-space

Lecture 7: Input-output models

- Shift operators and z-transform
- Pulse transfer operator and Pulse transfer function
- Poles and zeros
- Input-output models
- Frequency response
- Transformation of poles
- Calculation of H(z)

Lecture 8: Approximations of analog controllers, PID control

- Different approximation methods
- Prewarping
- PID control
  - Textbook algorithm (P, I, and D part)
  - Absolute versus incremental form
  - Algorithm modifications
    - Setpoint weighting
    - Limitation of derivative gain
    - Derivative weighting
  - Windup and anti-windup
    - Tracking
  - Bumpless mode and parameter changes
  - Discretization
  - Code

Lecture 9: State feedback and observers

- State feedback
- Deadbeat
- Observers
  - Prediction form
  - Filter form (with direct term)
- Disturbance estimation & integral action

Lecture 10: Feedforward design

- Feedforward to reduce disturbances
- Feedforward to handle reference changes
  - Transfer function approach
  - State-space approach
  - Nonlinear reference generation

Lecture 11: Implementation aspects

- Sampling & Aliasing
- Choice of sampling interval
- Computational delay
- A-D and D-A quantization
- Pulse width modulation
- Fixed-point arithmetic
  - Q format
  - Two's complement representation
  - Fixed point operations (+, -, *, /) including C code
  - Overflow
  - Sensitivity towards coefficient roundoff

Lecture 12: Scheduling theory

- Execution time analysis
  - Measurements vs analysis
  - Basic problems
- CPU utilization
- Critical instant
- Static cyclic scheduling
  - Basic ideas
- Earliest Deadline First Scheduling
  - Draw diagrams
  - Sufficient schedulability condition
  - Overrun behaviour

- Fixed Priority Scheduling:
  - Priority assignment (rate monotonic, deadline monotonic)
  - Rate monotonic analysis
    - Approximate analysis (two formulas !!)
    - 69% rule of thumb
    - Exact analysis
      - Response-time calculations
  - Draw schedules
  - Overrun behaviour
- NOT:
  - Scheduling of aperiodic tasks
  - Alternative scheduling models

Lecture 13: Real-time networks and networked control systems

- The OSI protocol (stack) model
- Shortcomings of the OSI/IP stack for real-time communication
- CAN protocol
  - Basic notions and arbitration mechanism
- TTP
  - Basic notions

Lecture 14: Discrete-event control

- State machines
- Statecharts
- Grafcet
  - Firing rules
  - Action types
  - Be able to use Grafcet in problems and examples
- Petri Nets
  - Firing rules
  - Generalized PNs
  - Dijkstra's problems
- Coding state machines in Java

Lecture 15: Project specifications

~~Lecture 16: Hot research topics~~

- NOT on the exam

Typical Exam Problems

- PID implementation
- Discretization of continuous designs
- Synchronization (semaphores, monitors, deadlock)
- Scheduling theory
- Grafcet / Petri nets
- ZOH sampling
- Input-output models
- State feedback / observers / reference signals
- Fixed point arithmetic

Projects

- Around 50% of you have chosen to instead follow the 7.5 hp course FRTN60 Real-Time Systems
  - We are working on getting this through the administration
- 3-4 have decided to wait with the project until the fall
- The rest have selected among the three options
  - FreeRTOS
  - Simulated Furuta Pendulum
  - Ball & Beam in TrueTime

Exam April 24th, 8:00 – 13:00

Before the exam:

Home exam in Zoom
Link will be sent out a couple of days before
Connect to the Zoom exam already at 07:30 to make sure that it works and that we have time to check your ID (using the camera)
The exam will be emailed to you 07:55 (or made available in Canvas)
You have until 13:30 to hand in the exam
You need to have
A laptop with camera (connected via a charger)
A phone with a camera (or a scanner)
Pen and paper to write on (some problems you may answer by writing text in an editor)

Exam April 24th, 8:00 – 13:00

During the exam:

- Open Book exam

  - Any material and equipment is allowed (including slides, exercise manual, Matlab, ...) but no collaboration or help from anybody else
  - Some problems will probably be possible to solve using Matlab. However, we require that you present the complete derivation of the solution on paper (only the Matlab commands is not OK)
  - We might replace numbers with symbols in some problems to make it more difficult to solve them with Matlab

- Inform the exam responsible if you need to go to the bath room using a private chat message
- You ask questions by sending a private chat message to the exam responsible

Exam April 24th, 8:00 – 13:00

After the exam:

- When you are ready (or at 13:00)
  - Take photos of all you papers using a scanning app such as CamScanner or Genius Scan or something equivalent
  - Make sure that the photos generate a single PDF file (test this before the exam)
- Give the PDF file a name that includes your StiL identity
- Before 13:30 upload the PDF file
  - Most likely you will do the upload through canvas (instructions will follow)
    - Those that have registered for the exam will be added to the Canvas course "Tentamen i Realtidssystem"
  - If that does not work then you can simply send the PDF as a mail attachment to karlerik@control.lth.se

Exam April 24th, 8:00 – 13:00

General things:

- You must register for the exam before the deadline Monday 6th April 23:59

- Anonymous examination is not possible

- Retaking the exam to improve your grade is not allowed this time ("plussa")

- We trust you to not cheat

  - We might send out slightly different exams, e.g., randomize numbers, order of the problems, ...

  - If the exam statistics are drastically better than normal then we might adjust the grade thresholds

  - We may check for plagiarism

  - We may ask for a complementary oral exam

Additional Exams

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May 30, 8-13
- Normal exam in Sparta B, or
- Home exam

August 27, 8-13
- Hopefully a normal exam in MA 10F