

Course Summary Real-Time Systems

2018

Remaining Lectures

- Thursday March 29, 15:15-17:00
(research topics)
- Monday May 14, 13:15-15:00
 - Demo lecture, meet in M:B first, then in lab
- Monday May 14, 15:15-17:00
 - Oral presentations
 - 10 minutes / group
 - Projectors will be available
 - Parallel sessions with multiple groups per session – a schedule will be distributed later

Exams

- Wednesday, April 11
14:00 -19:00, Victoriastadion 1A-1B
- Thursday, May 31
8:00 - 13:00, Sparta D
- Saturday, September 1
8:00 - 13:00, MA 9A

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

Knowledge from the projects

- The use of Java in real-time programming
- The program structure from Lab 1
- Common problems and solutions
- Priorities, synchronization,

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

Open Book Exam

- You may use the two text books during the exam
- You may NOT use the exercise book
- You may NOT use the slide copies
- No extra notes in the text books
- Problems where the solution can be directly taken from the text books will not be given