Course System Dynamics

Spring/Summer 2019

ISE Bachelor in Mechanical Engineering PO15, 4th semester

Dr.-Ing. Fateme Bakhshande / Univ.-Prof. Dr.-Ing. Dirk Söffker

Room: MB 143
Time: Fr 01.00am - 4.00pm

Assistant:
Sebastian Wirtz, M.Sc.

Url: http://www.uni-due.de/srs/v-sd_en.shtml

Manuscript

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Chair of Dynamics and Control

University of Duisburg-Essen
| System Dynamics (1V, 1U, 1P) | Chair of Dynamics and Control
D. Söffker
LU-1: Regularities, definitions, terms |

| ISE (Bachelor) PO15 | http://www.uni-due.de/srs/ys_ssd.html |
| Dr.-Ing. Fatemeh Bakhshehdei/Univ.-Prof. Dr.-Ing. Söffker |
| Sebastian Wirtz, M.Sc. | MB 143 |
| Friday | 01.00 pm – 04.00 pm |
| April, 12th | June, 21st |
| Thursday, 10.00 – 11.30 am, MB 326 |

<table>
<thead>
<tr>
<th>Consulting hours</th>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thursday, 10.00 – 11.30 am, MB 326</td>
<td>Luze, J.: Regelungstechnik 1, Springer, 3. Auflage, 2001 (available in the library)</td>
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<table>
<thead>
<tr>
<th>Additional Reading</th>
<th>Content</th>
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<tr>
<td>1 Terms, Definition, Idea of Feedback, Technical Control (L 1-2, 10, 01 + Material)</td>
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<tr>
<td>2 Dynamic Systems, Description of dynamical systems (L 3.1-2.2, 4.1, 02.3, 03.4, 03.5, 03.9)</td>
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<td>3 Description of linear systems (L 4.1, 4.3, 4.5, 4.6, 4.7, 4.1) (L 11-25f, 11-39f)</td>
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<td>4 Behavior of linear systems (L 5.1, 5.1.2, 5.2 + Material)</td>
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<td>5 Time behavior of elements and loops (L 5.6 + Material)</td>
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<tr>
<td>Lecture</td>
<td>The website <a href="http://www.uni-due.de/srs/v-sd_en.shtml">http://www.uni-due.de/srs/v-sd_en.shtml</a> offers actual information. The course material (as pdf-documents) is encoded with a password. Please note: Starting semester 2012/13 the content of the course System Dynamics is mandatory to know with respect to the course and the exam Control Engineering.</td>
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<tr>
<td>Practical Exercise</td>
<td>3 experiments (ms, dr, hs) The related practical exercise System Dynamics and Control Engineering will be organized separately. It is necessary to pass an attestation to take part. The complete practical exercise is an additional exam and will be graded individually. Check separate notice.</td>
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<tr>
<td>Exam</td>
<td>Written exam, 90 min, closed-book, mandatory registration at the examination office</td>
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# Veranstaltungsablauf SoSe 2019

**Time table Summer Term 2019**

(Leitung/Head: Univ.-Prof. Dr.-Ing. Dirk Söffker) (vfinal, März 2019)

<table>
<thead>
<tr>
<th>Veranstaltung</th>
<th>Kalenderwoche</th>
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<td>p-rt</td>
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<td>Mechatroniklabor/ MachineLab/ Teamprojekt/ Praxisprojekt</td>
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**Prüfung**

- Schriftlich
- Written
- Schriftlich
- Schriftlich
- Schriftlich
- Schriftlich
- Schriftlich
- Schriftlich
- Antestat
- Antestat
- Antestat
- Präsentation/Presentation

**Legende:**

- Vorlesung/Übung / Lecture/Exercise
- Veranstaltung, geblockt / Blocked courses
- Praktika / Practical Exercises
- Labor/Labs
- Prüfung/Exam / Antestat/Attestation

---

### Course System Dynamics

**D. Söffker**

LU-1: Regularities, definitions, terms
<table>
<thead>
<tr>
<th>Course</th>
<th>Attendance mandatory:</th>
<th>URL of the course</th>
<th>Lecturer</th>
<th>Coordination</th>
<th>Attestation date</th>
<th>Lab dates</th>
<th>Place (Labs)</th>
<th>Consulting hours</th>
<th>Skripts</th>
<th>Attestation</th>
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<tbody>
<tr>
<td>Chair of Dynamics and Control</td>
<td>mandatory</td>
<td><a href="http://www.uni-due.de/srs/v-ce-an1-Praktikum.shtml">http://www.uni-due.de/srs/v-ce-an1-Praktikum.shtml</a></td>
<td>Sandra Rothe, <a href="mailto:praktikum-srs@uni-due.de">praktikum-srs@uni-due.de</a></td>
<td></td>
<td>April 12th, 5:45pm, Room MC122/MD162</td>
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<td>Room MC122/MD162</td>
<td>Monday, 10.00 am - 11.30 am, MB 326</td>
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</tbody>
</table>

### Course System Dynamics

D. Söffker

LU-1: Regularities, definitions, terms

You have to succeed one central attestation for the experiments in System Dynamics and one central attestation for the experiment in Control Engineering in order to participate at the labs. The attestations are only offered at the a.m. dates. Participation at the labs without a successfully passed attestation is not possible.
## Registration

The mandatory registration at the examination office has to be realized in the 5th and 6th week of the current summer semester. This registration is valid also for the lab of Control Engineering in the next winter term. A re-registration in the winter term is neither necessary nor possible. ONLY officially registered participants are allowed to take part in the attestation.

A deregistration for individual practical labs is only possible via email to praktikum-srs@uni-due.de latest 2 weeks (full 14 days) before the attestation date. Nonappearance leads to the grading fail for all three experiments. After participation at the attestation a deregistration from the entire practical exercise is not possible.

## Realization of labs

The experiments are held in English language.

The participants are grouped in teams of 5 students and assigned to fixed lab dates. A central date exchange service by the chair will not be provided, but a change-of-dates-forum **is arranged in moodle** (Systemdynamik und Regelungstechnik – Pflichtpraktikum SoSe19). The participants are allowed to switch their dates with another accepted student on their own risk. If the switching party does not participate, the original advised student loses the right to participate. The doctoral candidate conducting the lab has to be informed at the beginning of the experiment about a date's switch. All participants will be checked if their participation is accepted. Not accepted students are not allowed to take part.

As a rough guideline for the division of appointments the following applies: The groups are divided in order of the first letters of the surnames (A, B, C, D ...).

## Grading / fail

Your performance will be graded:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
<th>Grade</th>
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<tbody>
<tr>
<td>0 failed attempt</td>
<td>Both antestations (SDe and CE) are passed on the 1st attempt and positive participation in the labs.</td>
<td>1,0</td>
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<tr>
<td>1 failed attempt</td>
<td>One of the two antestations was once failed, but passed at the rest date and positive participation in the experiments.</td>
<td>3,0</td>
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<tr>
<td>Ab failed attempts</td>
<td>Two failures of the attestation or non-appearance/late arrival at the labs.</td>
<td>5,0 (failed)</td>
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</tbody>
</table>

Grading with 5,0 (failed) all experiments and the attestations have to be repeated. Grades will be reported to the examination office like other examination results.

The experiments have to be completed within one calendar.
## Ablaufplanung / Schedule:

### Sommersemester 2019 / Summer term 2019 (Kalenderwochen / Calendar weeks)

<table>
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<tr>
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<tbody>
<tr>
<td>Vorlesung Regelungstechnik (RT) / Lecture System Dynamics (SDe)</td>
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<td>Antestat RT, SDe</td>
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<td>Praktikum RT (Versuch hs)</td>
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<tr>
<td>Practical Exercises SDe (labs ms, dr)</td>
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</tbody>
</table>

### Wintersemester 2019-20 / Winter term 2019-20 (Kalenderwochen / Calendar weeks)

| 41 | 42 | 43 | 44 | 45* | 46* | 47 | 48 | 49 | 50 | 51 | 1 | 2 | 3 | 4 |
|----|----|----|----|-----|-----|----|----|----|----|----|----|----|----|----|----|
| Vorlesung Systemdynamik (SD) / Lecture Control Engineering (CE) |
| Antestat SD, CE |
| Praktikum Systemdynamik (Versuche ms, dr) |
| Practical Exercise CE (lab hs) |

*Wichtig! In der 5. und 6. Semesterwoche muss die Anmeldung im Prüfungsamt zu a) Praktikum und b) Prüfung erfolgen. Eine Abmeldung vom Praktikumstermin ist bis spätestens 2 Wochen vor dem jeweiligen Termin per Mail an praktikum-srs@uni-due.de möglich.


*Important! In the 5th and 6th week of the term you have to register at the Registrar’s Office for a) the practical exercise and b) the examination. You may unsubscribe from the labs date at least 2 weeks before the contracted date by mail to praktikum-srs@uni-due.de.

The practical exercise System Dynamics and Control Engineering will be graded. Graded with a 5.0 (fail), all three experiments have to be repeated. The experiments must be fully passed within one calendar year (in the sequence System Dynamics + Control Engineering). Tests from earlier semesters expire.
NEW: Beginning Winter term 2019/20:
ISE Master program Automation and Safety with two profiles
Profil 1: Automation Control Engineering (Prof. Ding, EE, strong automation-oriented)
Profil 2: Safe Systems (Prof. Söffker, ME, Diagnosis, Automation, Safety)
Further: new ISE ME-profile Maritime Systems Safety (Profs El-Moctar/Söffker, ME)
# Methods (Control, Diagnosis, Automated Systems)

- Observers, Control, Fault Detection, Fault Diagnosis
- Cognition (Integrated Learning, Planning, Decision Making, …)
- Filtering, Classification, Fusion (signals, information, …)

<table>
<thead>
<tr>
<th>Methods/ Mechatronics/ System Dynamics</th>
<th>Structural Health Monitoring</th>
<th>Cognitive Technical Systems</th>
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<tbody>
<tr>
<td>- Modeling using automata</td>
<td>- Acoustic Emission</td>
<td>- Knowledge-based and individualized assistance of HMS (example: driver assistance)</td>
</tr>
<tr>
<td>- Adaptive and reliable classification, able to learn</td>
<td>&gt; Sensors &gt; Filters &gt; Fault diagnosis &gt; Prognosis</td>
<td>- Situation recognition of complex situations</td>
</tr>
<tr>
<td>- Observers</td>
<td>- Fault detection and fault diagnosis methods</td>
<td>- Situated automata, able to learn</td>
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<tr>
<td>- Nonlinear dynamics</td>
<td>- Wear and aging &gt; Data-driven modeling</td>
<td>- Safe actions and interactions</td>
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<tr>
<td>- Power management of hybrid powertrains/wind energy systems</td>
<td>- Safe- und lifetime-oriented operation</td>
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</table>

> Robustness
> Modeling
> Reliability, Safety
0. Preliminary remarks I

Let's talk about the problems (today: challenges)
- What is so difficult about control technology?
- Why seems the subject particularly difficult for some students?
- Why is it annoying me (Söffker,) if students need more time for their studies due to delayed exams in System Dynamics and Control than necessary?
- Why do some students tell interesting stories and then do not know how simple and schematic lectures, exercises, and practicals are organized, or suffer from perceived disadvantages?

Short answers:
- Who is not being present, can not listen.
  > Personal and mental presence in lecture and practice are strongly recommended
- Control engineering and system dynamics contents are different and seems to be for many students an (affordable) challenge.
- I am sometimes disappointed because we know the problems, give many hints and offers, and these is not perceived by some people, eg. Due to non presence, not reading documents and not preparing in a suitable manner, or even appointments (practicals) are simply ignored etc.

What is the optimal strategy for fast study and good results?
(if necessary: wake up), being present and listening, read the material and recommend books, learn continuously, take all/most of the SRS offers and prepare properly for the exams (attestation for practical plus exam > take time (10-14 days if you are continuously working, if not: 3-4 weeks).
0. Preliminary remarks II

Detailed answers related to challenges with respect to System Dynamics and Control
What is the problem and how to overcome this?

Content
• Strong formal, method-oriented nature of the content
• Strong mathematization
• Constructive teaching content
  > exponentially rising speed of course

Form
• Mathematization leads to a very strong level of abstraction
  > Transferability of the content vs. practical understanding
• Mathematization requires mathematical understanding
  > Mathematical understanding necessary

What to do?
• WATCH OUT! This subject is different.
• Invest time, take advantage of ALL offers of the chair.
• Understand exams and content. We are happy to help.
• Take no semi-knowledge (from anywhere).

Chair of Dynamics and Control
D. Söffker
LU-1: Regularities, definitions, terms
0. Preliminary remarks III

What are the offers of the Chair Dynamics and Control? (in german: Steuerung, Regelung and Systemdynamik (SRS))

Directly to learn
- Exercises
- Tutorials
- Consulting hours (during semester)
- NEW: Repetitorium
- Tutorial material for home
- 'Time management'

Exam relevant
- Master solutions (defined exams)
- Exam collection for free
- Weekly consulting hours up to oral examination

Formal aspects
- Moodle-free course
- NEW: Course in every semester
- Access to German-speaking course

... for your success outcome.

Chair of Dynamics and Control
D. Söffker
LU-1: Regularities, definitions, terms
1.1a  > Standards (Normen)
► DIN 19221f
  > DIN 19226 Regelungs- und Steuerungstechnik
1.1b  > Societies
► VDI/VDE
  > Gesellschaft für Mess- und Automatisierungstechnik
► IEEE – Institute of Electric and Electronics Engineers
  > Control System Society
► IFAC - International Federation of Automatic Control)

1.1c  > Relations to other scientific disciplines
► Measurement techniques
  Dynamics and Control
  Process Informatics
  Automation systems / Automatic control
► Mechatronics (Mechanical Engineering + Electronics)

1.2d  > What makes control so important?
- Fundamental principles
- Enabling technology
1.2 What is control?

- feedback > closed loop // no feedback > open loop, interaction (verbal)

- control (open / closed loop) > interaction

- causal mechanism

- Can the causal mechanism be graphically represented?
  - cause > effect (directed information / signal flow)
  - causal mechanism > 'flow of signals' >> causal representation
Abb. 1.3: Erweiterte Grundstruktur des Regelkreises
1.3 Definitions (see ‘Definitions’ Chair SRS)

- System

- Physical variable

- Control variable

- Feedforward (‘Def.’):

- Feedback control (‘Def.’):

- Disturbance variable

Abb. 1.2: Grundstruktur des Regelkreises
- Input variable

- Control difference / control deviation

- Desired variable

- Plant / system to be controlled

- Controller

- Transfer element / Transfer system
Connections:

► Feedback – Connected systems - Control

► Dynamics – System Dynamics – Control technique - System Theory

Question:
What is the idea of control technique / control?
1.4 Examples

1.4.1 Heating

from: Rake, Regelungstechnik A (Skript), RWTH Aachen, 1984
1.4.1 Heating - 2. example

nach: Rake, Regelungstechnik A (Skript), RWTH Aachen, 1984
1.4 Examples
1.4.2 Building automation
1.4 Examples
1.4.3 Mechatronics / Robotic / Autonomous systems

Elastic robot ELROB, Chair of Dynamics and Control

Hydraulic research robot HYROB, Chair of Dynamics and Control
1.4 Examples
1.4.3 Mechatronics / Robotic / Autonomous systems

Robot arm of a concrete pump machine, Fa. Schwing, Herne

Autonomous robot, Chair of Dynamics and Control

Autonomous robot, UNLV, USA
Example: Stabilization of an inverted, elastic pendulum
Example: Vibration control of elastic, hydraulically driven robot
1.4 Examples
1.4.3 Mechatronics / Robotic / Autonomous systems

examples from automotive engineering:
- ABS
- ESP
- ASR
- ...
1.4 Examples
1.4.4 Process control and supervision / 'Human in the loop'

Learning

Mental model of the reality

Planing

Future

Terminal

Real technical system: example Power Station

Function - oriented representation of causal mechanism of the technical system using a suitable modeling technique

[Image of a diagram showing the interaction between a human and a technical system, with various labeled elements and arrows indicating the flow of information.]
Example: Driving Simulator (Chair SRS)
Example:
Driver
(Coop. with DLR, Braunschweig)
Human-Maschine-Interaction III

Example: Human operation at nuclear power operating center
Terms and Definitions

System:
Purpose-oriented part of the real world. The system is in interaction with the real world, whereby from the real world inputs are acting to the system and outputs are acting from the system to the environment.

Physical variables / physical values:
Interaction qualities (qualities / states) within a system or from the system to the environment, in technical systems usually of physical nature. Physical values are usually defined in connection with the purpose of related systems to be considered. The variables to be considered in control are usually scalars or vectors. The main property of variables considered within system dynamics or control is the time depending behavior.

Control variable / Output (single input – single output system):
Variable of the system to be controlled. The variable should be usually fix or variable. In Single Input - Single Output (SISO) systems the output (here only one exists) is the control variable.

Open loop system:
Open loop systems are working so that the inputs of the systems are affecting the outputs depending on the dynamic properties of the system and not vice versa. The characteristic property of an open loop system is the non closed behavior of the signal flow.

Closed loop system:
Within a closed loop system the control variable is usually online measured and compared with a given desired / reference variable (which also can be zero). The result is given to the input in the way that it is acting so that the control variable tends to the desired value. This realizes the feedback and closes the loop. The characteristic property of a closed loop system is the closed behavior of the signal flow. This changes the dynamic behavior of the overall system and allows the automatic compensation of disturbances acting to the system and affecting the control variable.

Disturbance (variable / value):
From the environment to the system acting variable, which influences the control variable in an unwanted way.

Input (variable / value):
Variable acting direct to the system and changes the output of the system. In open loop system the input variable acts from the environment to the system, in closed loop systems the input is the output of the controller and the input of the system to be controlled.

Desired variable / value / reference variable / value:
Variable from the environment to the controller, which gives the reference for the output as the value to be controlled.

Control deviation / control difference:
Variable denoting the difference between the desired and the control variable. The control deviation is an internal variable inside the controller.
Plant (system to be controlled):
The plant is the system to be controlled (closed loop) or the system to be affected by the input (open loop).

Controller:
The controller is the part of the system, which affects the plant using an actuator. From a practical point of view controller and actuator are distinguished, from a theoretical point the control unit combines the control and the actuator and is called controller. From a practical point of view the technical control unit often also consists of the unit for comparison of desired and control variable.

Transfer element:
Abstract understanding of a general system with dynamic properties, which can be the system to be controlled or the controller or another element of the transfer chain. The important aspect is that the transfer element is a system, whereby the dynamic properties of the transmittance from input to output are of interest. The relevant aspect is the dynamic characterization of the transfer behavior. Plant and controllers are in this way nothing more than transfer elements, the denotation plant or controller results from the function of the transfer element within the loop.

Transfer system:
Abstract understanding of a set of elements building up a new element > system.

Actuator:
Actuator is the physical device in front of the plant used for physical excitation of the plant to affect the plant. In the theoretical / abstract consideration the actuator is part of the transfer element controller.

Measurement device:
The physical device used for measuring of the output / the control variable is called measurement device / unit. In the theoretical / abstract consideration the dynamical properties of usual neglected, so the measurement device is understand is an ideal transfer element without any kind of dynamic properties. For practical considerations the dynamics properties of the measurement unit as well as of the actuator has to be considered.

Reference value:
Parameter of the reference variable

Control value:
Parameter of the control variable

Remark:
The given terms and definitions are used from different authors etc. in a different way.

The important aspect is the verbal/term-based separation from signals and physical variables, from systems and behaviors, from the physical/technical realization and from the mathematical abstract mapping. For example equations are used to described the behavior of systems, the output variables of technical systems show also this behavior. In older text books and practical oriented literature this distinction is often not realized. It is a good idea to understand the clear separation between reality, the mapping-based mathematical representation to be open for future advanced information science oriented control and interaction approaches.