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

Note 1:
The collected material is prepared for the use only in connection with this lecture.
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Note 2:
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Chair of Dynamics and Control

Course System Dynamics
D. Söffker
LU-1: Regularities, definitions, terms

Veranstaltung	System Dynamics (1V, 1Ü, 1P)
Zielgruppe	**ISE (Bachelor) PO15**
URL of the course	http://www.uni-due.de/srs/v-sd_en.shtml
Dozent/innen	Dr.-Ing. Fateme Bakhshande/Univ.-Prof. Dr.-Ing. Söffker
Assistant	Sebastian Wirtz, M.Sc.
Place	MB 143
Day	Friday
Time	01.00 pm – 04.00 pm
First course	April, 12th
Last course	June, 21st
Consulting hours	Thursday, 10.00 – 11.30 am, MB 326
Literature	Lunze, J.: Regelungstechnik 1, Springer, 3. Auflage, 2001 (available in the library) **> L** Ogata, K.: Modern Control Engineering, 4th Edition, 2002. (available in the library) **> O**
Additional Reading	Franklin, G.F.; Powell, J.D.; Emami-Naeini, A.: Feedback Control of Dynamic Systems, Prentice Hall 2002 (available in the library) Dorf, R.C.; Bishop, R.H.: Modern Control Systems, Pearson, 2005.
Content	1 Terms, Definition, Idea of Feed Back, Technical Control (L 1 – 2.10, O1 + Material) 2 Dynamic Systems, Description of dynamical systems (L 3.1-3.2,4.1; O2.3(**), O3.4(*), O3.5(*), O11.4(*) [Eq. 11-25f,11-39f]) 3 Description of linear systems (L 4.1-4.3.3; O2.3(**),O3.4(*),O3.5(*),O11.4(*)[Eq. 11-25f,11-39f]) 4 Behavior of linear systems (L 5.1.1, L 5.1.2-5.2 + Material) 5 Time behavior of elements and loops (L 5.6 + Material)

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Lecture	The website http://www.uni-due.de/srs/v-sd_en.shtml 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.**
Practical Exercise	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.
Exam	Written exam, 90 min, closed-book, mandatory registration at the examination office

Veranstaltungsablauf SoSe 2019
Time table Summer Term 2019

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

Lehrstuhl Steuerung, Regelung und Systemdynamik
Chair of Dynamics and Control

Veranstaltung Course	**Kalenderwoche** Calender Week	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**Prüfung** Exam
Regelungstechnik	v-rt															**Schriftlich**
System Dynamics	v-sde															**Written**
Sensorik u. Aktorik: Teil Aktorik	v-sua															**Schriftlich**
Antriebstechnik	v-ant															**Schriftlich**
Regelungstheorie	v-rth															**Schriftlich**
Kognitive Techn. Systeme	v-kts															**Schriftlich**
Qualitative Methoden der Regelungstechnik 1	v-qmr1															**Schriftlich**
Praktikum RT/SD, CE/SDe*	p-rt															**Antestat**
Praktikum CTh/RTh*	p-cth/rth															**Antestat**
Praktikum SuA (Aktorik)	p-sua															**Antestat**
Mechatroniklabor/ MachineLab/ Teamprojekt/ Praxisprojekt	l-me/ma/te/pr															**Präsentation/ Presentation**

Legende:

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

***: Bitte beachten Sie den gesonderten Ablauf für die Praktika Regelungstechnik, Systemdynamik und Regelungstheorie.**
Please consider the separate timetable for the practical exercises Control Engineering, System Dynamics, and for Control Theory.

Course	**Practical Exercise** **System Dynamics und Control Engineering (1P)** consisting of three experiments (Scripts in german language): • Modellbildung und Simulation (ms) (**SoSe**) • Druckregelung (dr) (**SoSe**) • Elektrohydraulisches Servosystem (hs) (**WiSe**)
Attendance mandatory:	Students Mechanical Engineering (ISE) Bachelor
URL of the course	http://www.uni-due.de/srs/v-ce-an1-Praktikum.shtml
Lecturer	Ph.D. students
Coordination	Sandra Rothe, praktikum-srs@uni-due.de
Attestation date	**Resits:** April, 12th, 5.45pm, Room MC122/MD162 **Regular:** June, 7th, 4.00pm, Room MC122/MD162
Lab dates	Resits: 16th-17th calendar week Regular: 25th-28th calendar week
Place (Labs)	MB 323 (ms), MB 325 (dr), MB 028 (hs)
Day	Daily
Time	Appointments between 8.00am-05.00pm
Consulting hours	Thursday, 10.00 am - 11.30 am, MB 326
Skripts	Scripts for each experiment are located on the SRS homepage. Those have to be worked through until the attestation date as they are the basis for the attestation.
Attestation	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:

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

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

Praktikum Regelungstechnik/Systemdynamik
Practical Exercises Control Engineering/System Dynamics

(Leitung/Head: Univ.-Prof. Dr.-Ing. Dirk Söffker) (V0, März 2019)

Lehrstuhl Steuerung, Regelung und Systemdynamik
Chair of Dynamics and Control

Ablaufplanung/Schedule:

Sommersemester 2019 / Summer term 2019 (Kalenderwochen / Calendar weeks)													
15	**16**	**17**	**18**	**19***	**20***	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
Vorlesung Regelungstechnik (RT) / Lecture System Dynamics (SDe)													
Wiederholer/innen (ms, dr) / Resits (hs)								Antestat RT, SDe	Praktikum RT (Versuch hs) Practical Exercises SDe (labs ms, dr)				

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)														
Wiederholer/innen (hs) / Resits (ms, dr)							Antestat SD, CE	Praktikum Systemdynamik (Versuche ms, dr) Practical Exercise CE (lab hs)						

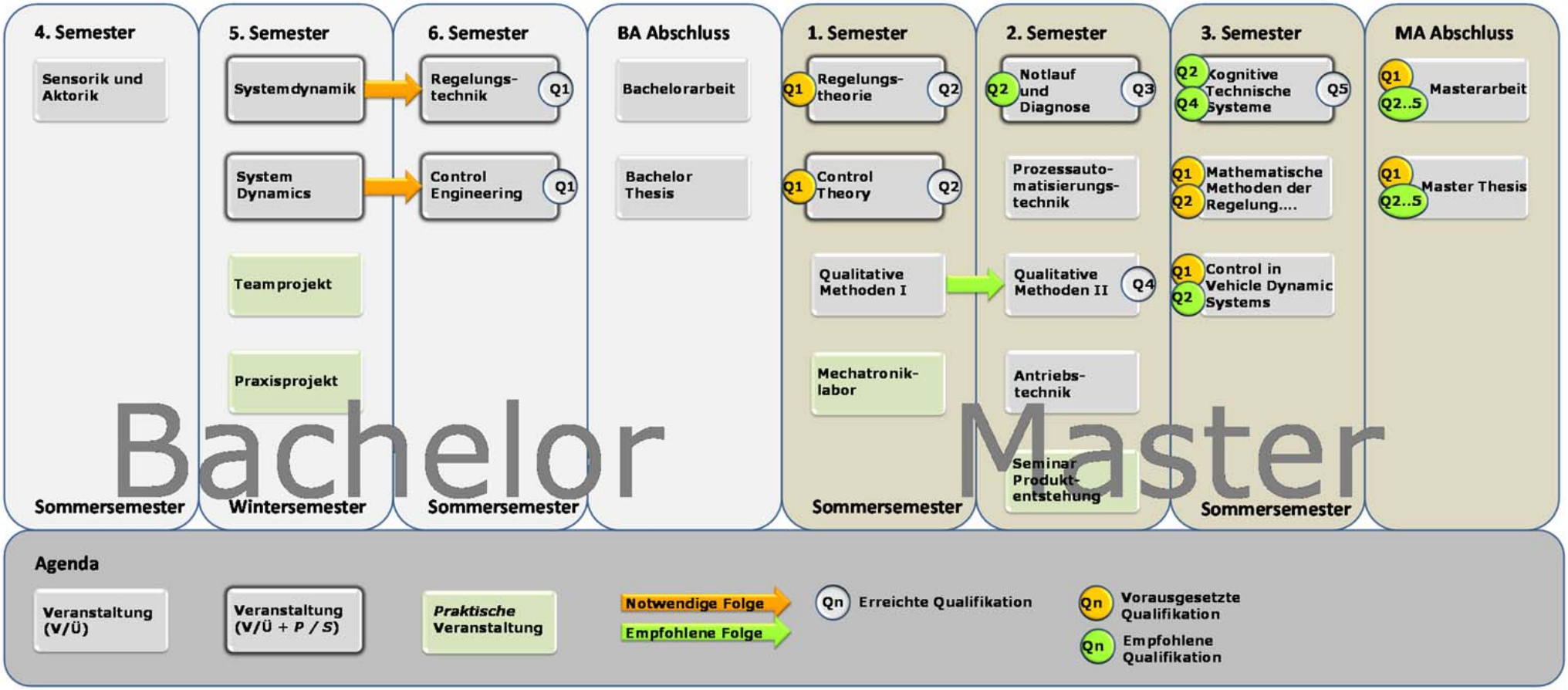
***Wichtig!** In der 5. und 6. Semesterwoche muss die Anmeldung im Prüfungsamt zu a) Praktikum und b) Prüfung erfolgen. Eine Abmeldung vom Praktikumstermin ist bis spätestens 2 Wochen vor dem jeweiligen Termin per Mail an praktikum-srs@uni-due.de möglich.

Das Praktikum Systemdynamik und Regelungstechnik wird benotet. Bei einer 5,0 müssen alle drei Versuche wiederholt werden. Die Versuche müssen innerhalb eines Kalenderjahres (in der Sequenz Systemdynamik+Regelungstechnik) vollständig bestanden sein. Versuche aus älteren Semestern verfallen.

***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.

Lehrangebot Lehrstuhl SRS (empfohlene Veranstaltungsfolge, Stand 03.11)



NEW: Beginning Winter term 2019/20:
ISE **Master program Automation and Safety** with two profiles
Profil 1: Automation Control Enginering (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, Classifikation, Fusion (signals, information, ...)

> Robustness
> Modeling
> Reliability, Safety

Methods/ Mechatronics/ System Dynamics

- Modeling using automata
- Adaptive and reliable classification, able to learn
- Observers
- Nonlinear dynamics
- Power management of hybrid powertrains/ wind energy systems

Structural Health Monitoring

- Acoustic Emission
  > Sensors
  > Filters
  > Fault diagnosis
  > Prognosis
- Fault detection and fault diagnosis methods
- Wear and aging
  > Data-driven modeling
- Safe- und lifetime-oriented operation

Cognitive Technical Systems

- Knowledge-based and individualized assistence of HMS (example: driver assistance)
- Situation recognition of complex situations
- Situated automata, able to learn
- Safe actions and interactions

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).

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

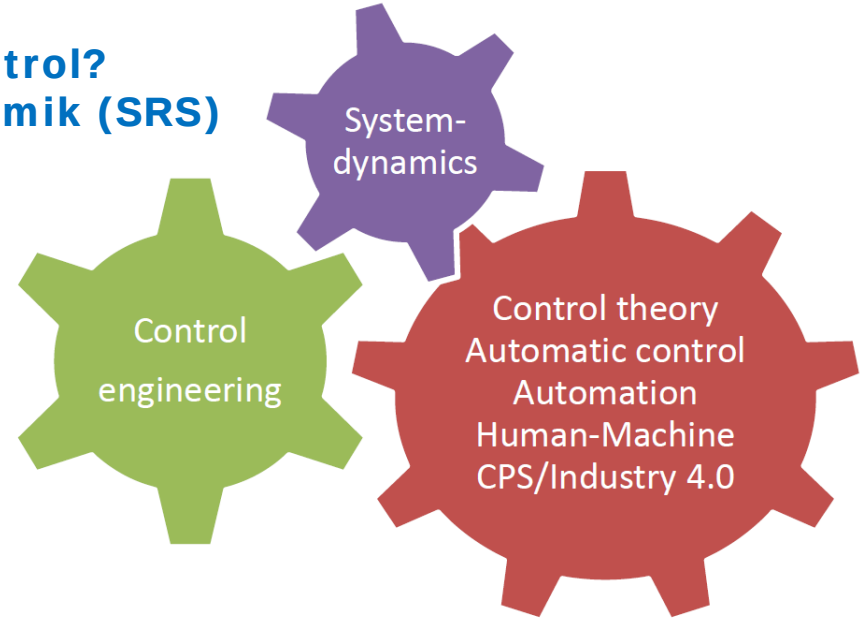
Form

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

Wahl 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).**

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 fre
- Weekly consulting hours up to oral examination

Formal aspects

- Moodle-free course
- NEW: Course in every semester
- Access to german -speeking course

... for your success outcome.

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 feed back > 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

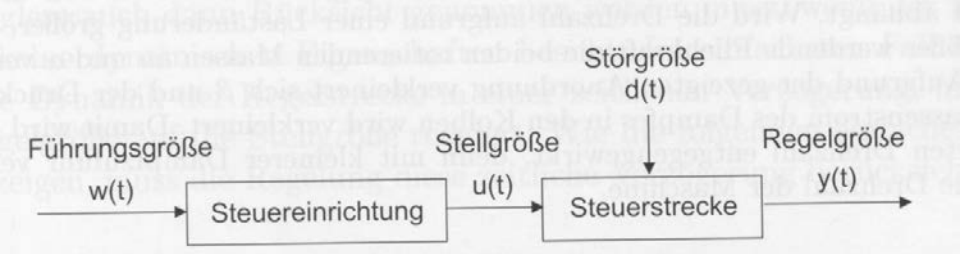


Abb. 1.5: Grundstruktur einer Steuerung

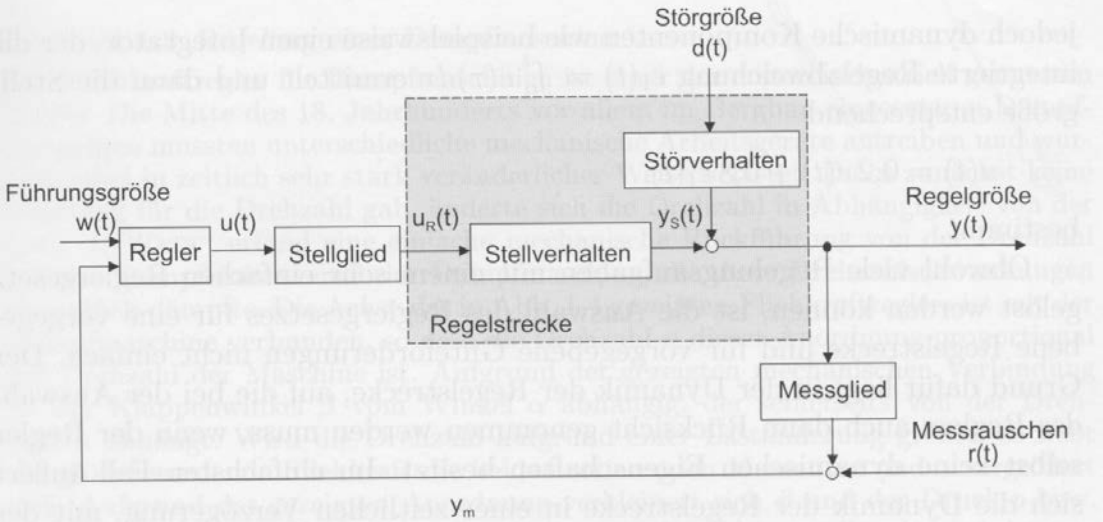


Abb. 1.3: Erweiterte Grundstruktur des Regelkreises

1.3 Definitions (see ‘Definitions’ Chair SRS)

- System

- Physical variable

- Control variable

- Feedforward (‚Def.‘):

- Feedback control (‚Def.‘):

- Disturbance variable

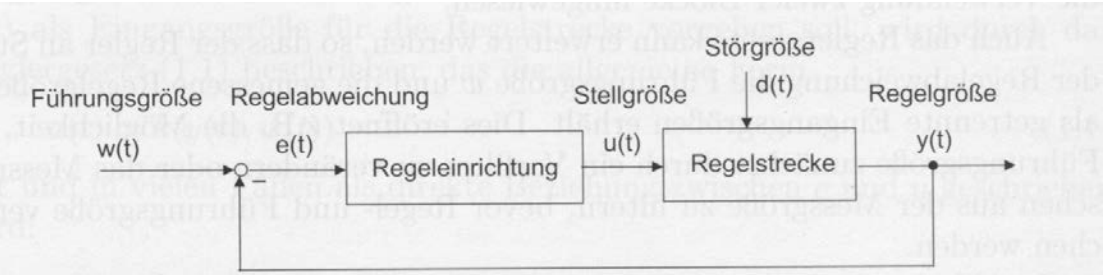


Abb. 1.2: Grundstruktur des Regelkreises

- 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

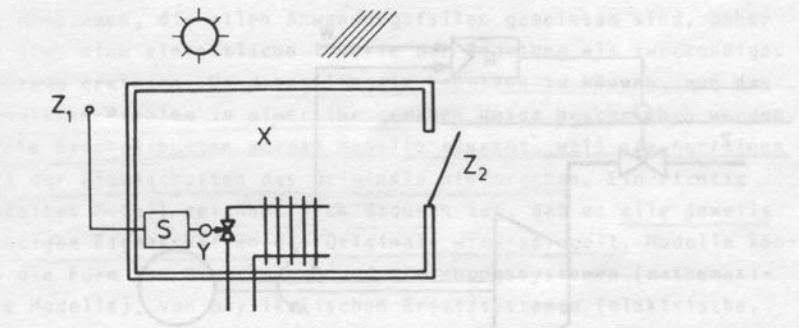


Bild 1-3: Raumtemperatursteuerung

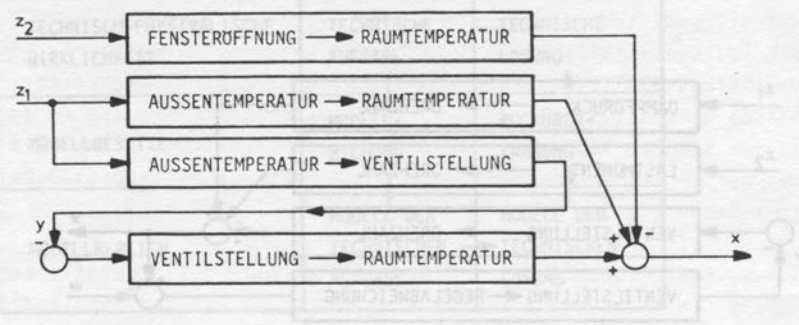


Bild 1-4: Schematische Darstellung der Raumtemperatursteuerung

from: Rake, Regelungstechnik A (Skript), RWTH Aachen, 1984

1.4.1 Heating - 2. example

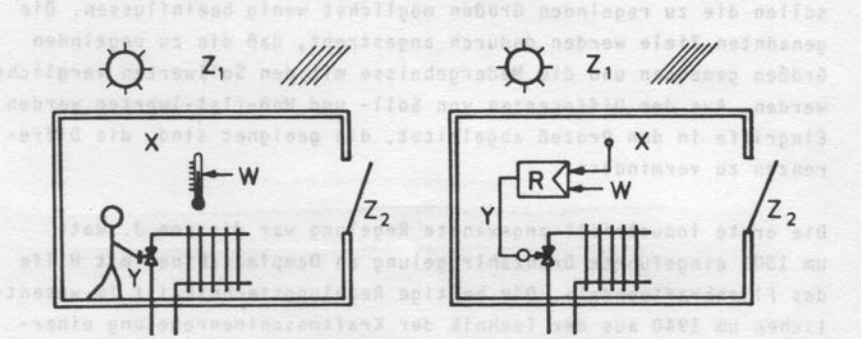


Bild 1-1: Raumtemperaturregelung von Hand und automatisch

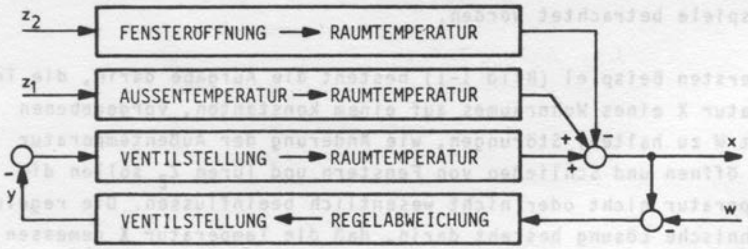


Bild 1-2: Schematische Darstellung der Raumtemperaturregelung

nach: Rake, Regelungstechnik A (Skript), RWTH Aachen, 1984

1.4 Examples
1.4.2 Building automation

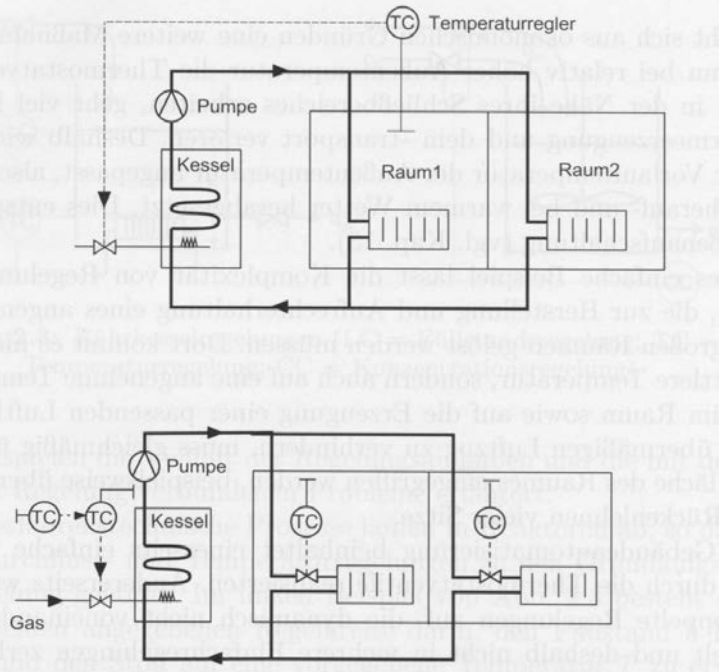


Abb. 2.1: Raumtemperaturregelung: Einzelraumregelung (oben); Regelung mit Thermoventilen und außentemperaturgeführter Vorlauftemperatur (unten)

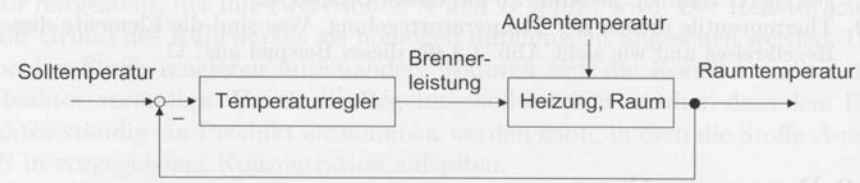
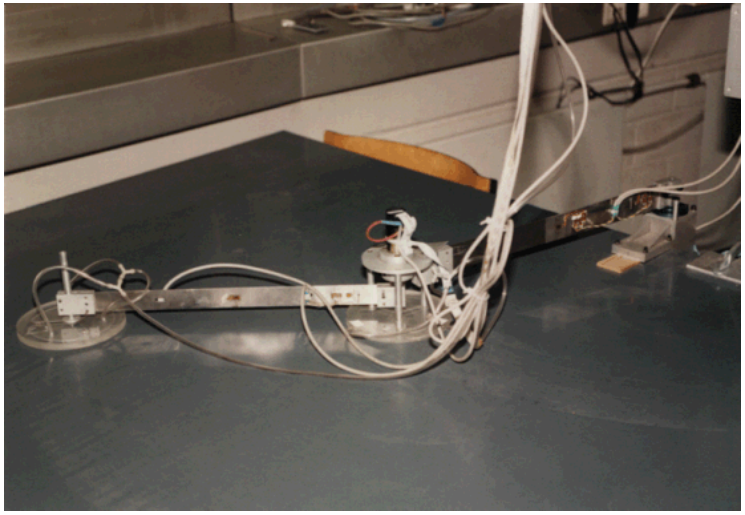
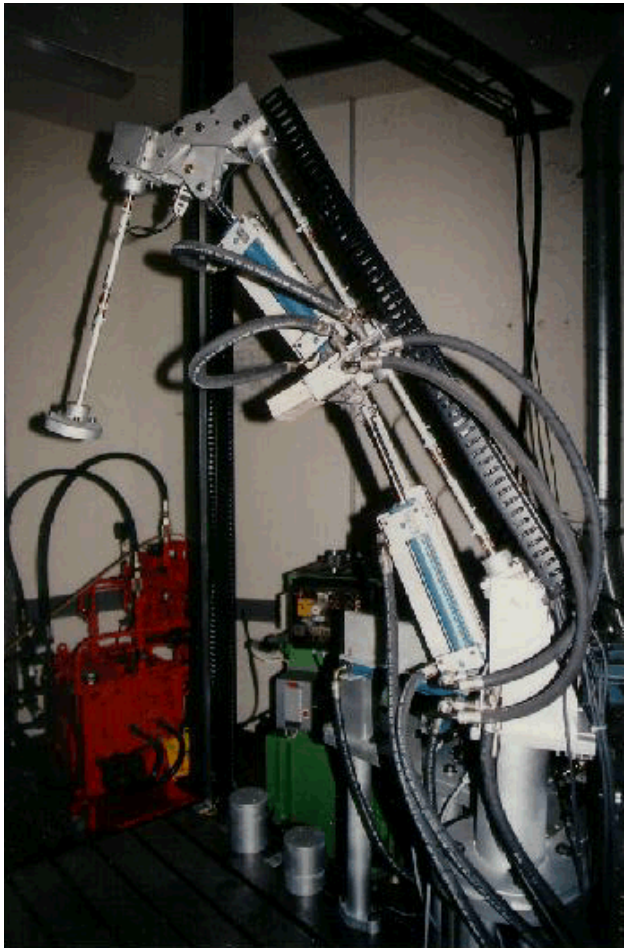


Abb. 2.2: Blockschaltbild der Raumtemperaturregelung

1.4 Examples
1.4.3 Mechatronics / Robotic / Autonomous systems



Elastic robot ELROB,
Chair of Dynamics and Control

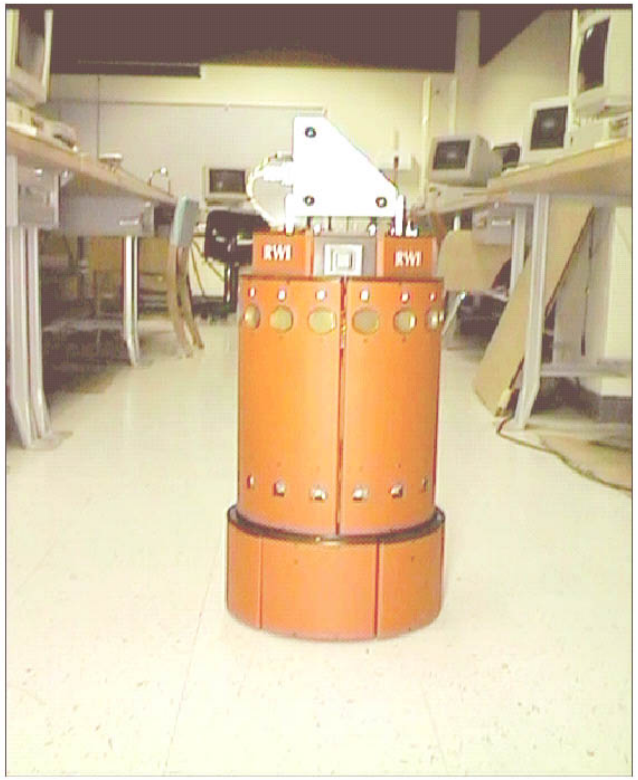


Hydraulic research robot HYROB,
Chair of Dynamics and Control

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
- ...

1.4.4 From process control to supervision

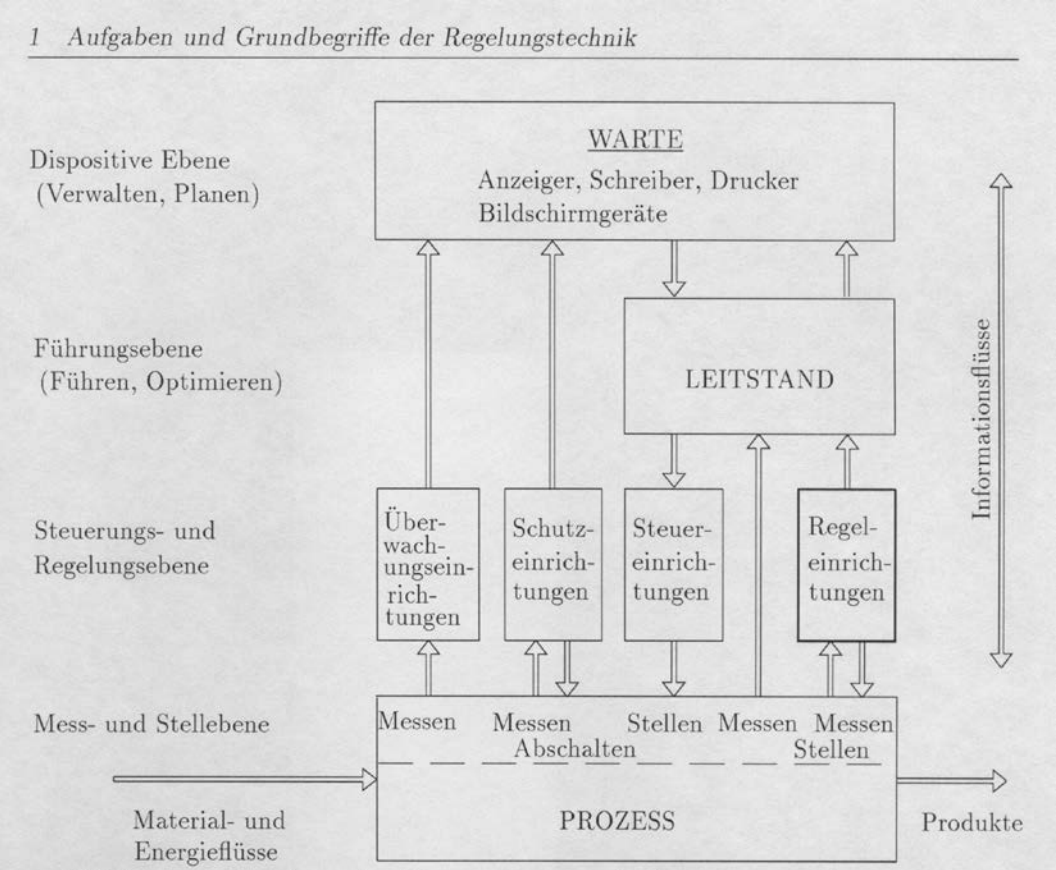
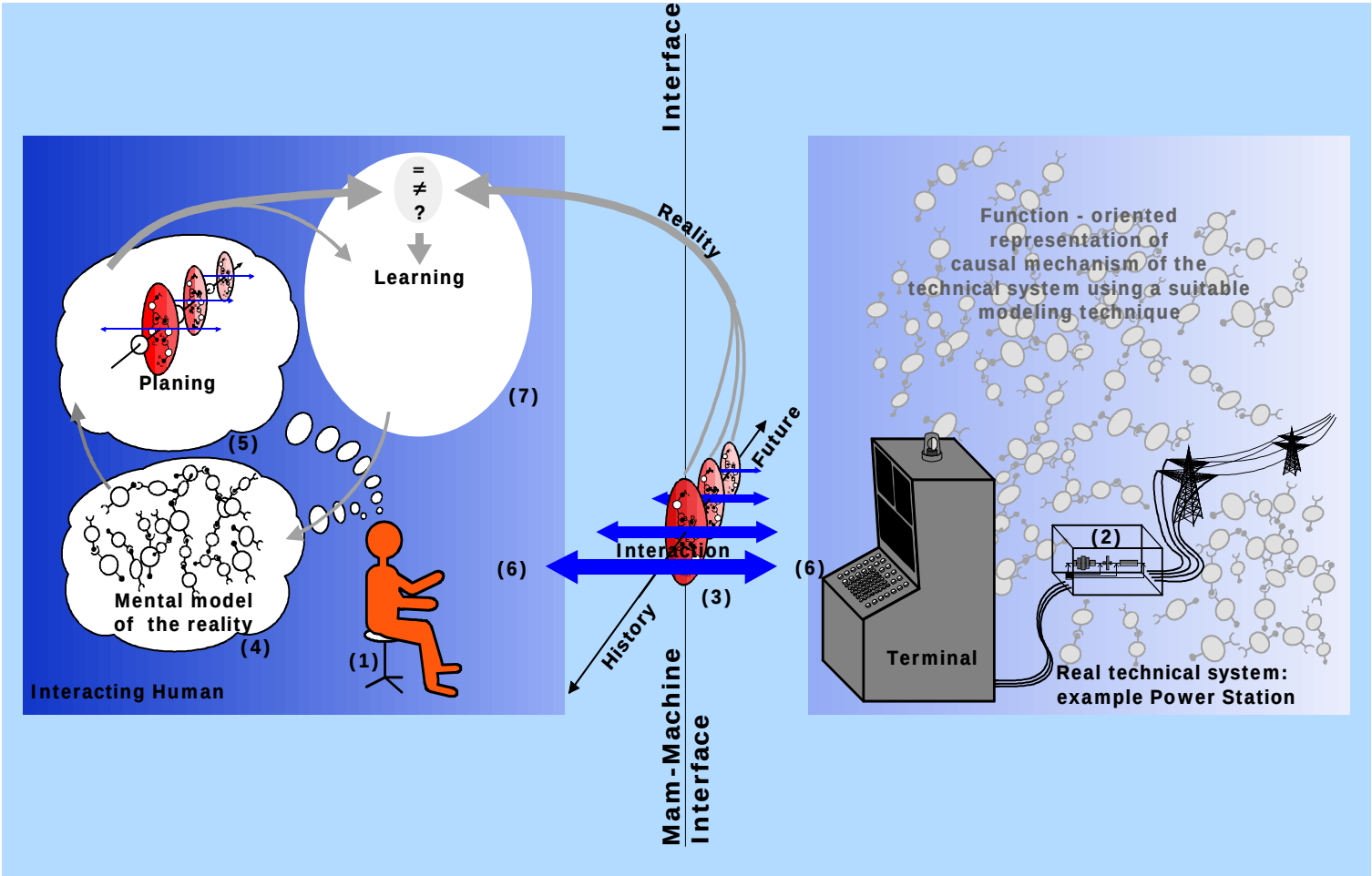


Abbildung 1.4: Informationsflüsse und –ebenen in einem automatisierten Prozeß

1.4 Examples
1.4.4 Process control and supervision / ‚Human in the loop‘



Human-
Maschine-
Interaction I

Example:
Driving
Simulator
(Chair SRS)

Human-
Maschine-
Interaction II

Example:
Driver
(Coop.
with DLR,
Braunschweig)

Human-
Maschine-
Interaction III

Example:
Human operation
at
nuclear power
operating center

Chair of
Dynamics and Control

Course System Dynamics
D. Söffker
LU-1: Regularities, definitions, terms

UNIVERSITÄT
DUISBURG
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University of Duisburg-Essen
Chair of Dynamics and Control
Univ.-Prof. Dr.-Ing. Dirk Söffker

Course System Dynamics / Control Engineering Spring/Summer 2018

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.