Study guide - Sensing, Computing, Actuating (5AIB0)

1 Introduction

Almost any modern system contains sensors to observe the environment and actuators to influence this environment. An example of such a system is a modern car which is typically equipped with temperature, pressure, speed, chemical sensors and various mechanical values and engines. This course provides an introduction to sensor and actuator technology. It discusses the basic principles behind the most commonly used types of sensors and actuators. It also deals with the physical principles which underlie the operation of these sensors and actuators. The course provides also a basic introduction into signal processing (FIR filters and their frequency response), control theory and interface electronics such that students can design a complete system which integrates the sensors and actuators introduced in this course.

2 Learning objectives

The course objective is to provide students with an introduction to all components needed in a modern control system. At the end of the course, the students should be able to ...

- describe the basic components (sensor, signal conditioner, controller, actuator) in a control system;
- describe the physical conversion phenomena underlying the operation of transducers (sensors, actuators);
- apply filtering and DSP techniques on the signals from and to the transducers;
- analyse the static and dynamic characteristics of transducers and the complete system;
- analyse the static errors that limit the accuracy of transducers;
- dimension the interface electronics used in a control system that contains sensors and actuators;
- select control algorithms that meet the performance requirements of the system under design.

3 Course schedule

In total there are 15 lectures (including instruction sessions, labs, and an informative test) scheduled. Each lecture has also its own page with all relevant material (slides, videos, exercises, solution, etc.). See `http://www.es.ele.tue.nl/education/SensingActuating/lectures` for the links to all lectures.

You can find the suggested schedule to follow the lectures on the next page.

	23-25 April	30 April – 2 May	7-9 May	14-16 May	21-23 May
Tu 13.30 – 16.15	Introduction to course Sensing displacement	Systems and Control	Stepper motors	Signal amplification	Non-linear sensors
	Arduino lab 1	Thermo-resistive	Strain / Bridges	Arduino lab 2	AD-comverters
Th 8.45 – 12.30	Resistive displacement	Systems and Control	TU/e closed	Signal amplification	No class
	Thermo-resistive	Strain / Bridges		AD Converters Model-based design	Informative test (non graded)

	28-30 May	4-6 June	11-13 June	18-20 June
Tu 13.30 – 16.15	Inductive sensors	Acoustic sensors	Thermocouple	Q&A (old exams)
	Non-linear sensors	Arduino lab 3	LED / Display	Arduino lab 4
Th 8.45 – 12.30	Inductive circuit	Inductive circuit	Thermocouple	No class
	Demodulation	LED / Display	Summary	

lecture / exercises
discuss homework
lab
Informative test (non graded)

In the above table, lectures are indicated in blue. These lectures will be given live on campus (no live stream). Recordings of earlier editions of the lectures are available through the course website (`http://www.es.ele.tue.nl/education/SensingActuating`). Time scheduled to work on exercises and instructions is indicated in green. The questions and complete solutions to all exercises are available as pdf and screen casts through the course website. Lab sessions are indicated in yellow. The lab assignments are available as tutorials at the course website. Each lecture has also its own page with all relevant material (slides, videos, exercises, solution, etc.). See `http://www.es.ele.tue.nl/education/SensingActuating/lectures` for the links to all lectures.

4 Study material

- "Sensors and Actuators: Engineering System Instrumentation, Second Edition" by Clarence W. de Silva, CRC Press, ISBN 9781466506817 (mandatory).
- All slides and exercises that are part of the course. This material is available as a download from the course website. (mandatory).

Slides and exercises are named "<lecture number >-<some informative name>.pdf". For example the slides from the lecture on April 25th are named "02-resistive-temperature.pdf" since this is the second course and it deals with temperature sensing using resistors.

The following material from "Sensors and Actuators: Engineering System Instrumentation, Second Edition" needs to be studied in combination with the various lectures:

Lecture	**Reading**	**Topic**
1. Introduction to course	Ch 1	Control system architecture
1. Sensing displacement	Ch 3.4	Sensor characteristics
1. Sensitivity	Ch 5.3	Transfer function, sensitivity
1. Loading effect	Ch 5.3	Linearity, loading effect, absolute/relative error
2. Sensing temperature	Ch 2.1, 2.2, 5.11	Device model, self-heating, lead-wire error
2. Self-heating	Ch 2.1, 2.2, 5.11	Trade-off linearity, self-heating, sensitivity
3. Control strategies	Ch 1.5	Control strategies
3. Micro-processors	Ch 1.5	Implementing control on a micro-processor
4. Bridges	Ch 2.8	Wheatstone bridge
4. Sensing force	Ch 5.8	Strain gages
4. Compensating errors	Ch 5.8	Error sources (temperature, non-linearity, lead-wire)
5. Stepper motors	Ch 8.1, 8.2, 8.7	Device
5. Stepper motors	Ch 8.8	Control of device
5. Digital transducers	Ch 6	Hall effect, optical encoders, resolution
6. Signal amplification	Ch 2.4	Differential and instrumentation amplifier
7. Digitization	Ch 2.7	Quantization, resolution, sampling frequency
7. AD converters	Ch 2.7	AD circuits, sample and hold circuit
7. Model-based design	Ch 1.3	Matlab Simulink
8. Non-linear sensors	Ch 5.11	Thermistor
8. Linearizing devices	Ch 2.9	Linearizing with hardware and software
9. Informative test	-	-
10. Inductive sensors	Ch 5.4	Magnetic reluctance, LVDT
11. Demodulation	Ch 2.5, 2.6, 2.10	Diode bridges, phase sensitive demodulation
12. Acoustic sensors	Ch 5.7	Piezoelectric sensors
13. LED/Display	-	Not covered in the book
14. Thermoelectric effects	Ch 5.11	Seebeck, Peltier, Thomson effects
14. Thermoelectric sensors	Ch 5.11	Relative sensors, thermocouple sensor circuits
15. Summary/No new material	-	-

5 Assessment

The grade is determined based on one final test which counts for 100% of final grade. The test is scheduled 2 times/year (see `https://mytimetable.tue.nl` for schedule). It covers all material taught in the course. A paper-based exam generated using the ANS-Delft system (see `https://ans-delft.nl/` will be used for this exam. An informative test will be organized on May 30th such that you can familiarize yourself with the exam style questions.

6 More information

More information on this course can be found on the course website `http://www.es.ele.tue.nl/education/SensingActuating`