STUDY MODULE DESCRIPTION FORM

Name of the module/subject	Code
Sensors Integration	**1010532111010559183**

Field of study	Profile of study (general academic, practical)	Year /Semester
Automatic Control and Robotics	**general academic**	**1 / 1**
Elective path/specialty: **Smart Aerospace and Autonomous Systems**	Subject offered in: **English**	Course (compulsory, elective): **obligatory**

Cycle of study:	Form of study (full-time,part-time)
Second-cycle studies	**full-time**

No. of hours	No. of credits
Lecture: **15** Classes: **-** Laboratory: **15** Project/seminars: **-**	**3**

Status of the course in the study program (Basic, major, other)	(university-wide, from another field)
major	**from field**

Education areas and fields of science and art	ECTS distribution (number and %)

Responsible for subject / lecturer:

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Responsible for subject / lecturer:

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Prerequisites in terms of knowledge, skills and social competencies:

1	**Knowledge**	Student starting this module should have basic knowledge regarding: - basics of control systems theory (state space system, feedback loop, linearization, structure of control scheme) - mathematics (calculus, trigonometry) - probability and statistical data analysis - physics (mechanics, electromagnetism, optics, Coriolis effect, oscillatory movement, dynamics)
2	**Skills**	He/she should - have basic programming skills - be able to acquire information from given sources of information - understand the need to extend his/her competences - be ready to counteract in a group
3	**Social competencies**	In respect to the social skills the student should show attitudes as honesty, responsibility, perseverance, curiosity, creativity, manners, and respect for other people.

Assumptions and objectives of the course:

1. Presentation capabilities of using various techniques and measurement systems for the detection and perception as well as localization in robotics.
2. Consolidation of knowledge regarding techniques of data acquisition and discuss the principle of operation the measuring systems.
3. Provide students knowledge regarding selected methods of signal filtration and estimation. Acquire such skills to practical using with real measurement data.
4. Indentify the main causes of measurements errors and discuss ways to liquidations.

Study outcomes and reference to the educational results for a field of study

Knowledge:

1. understands methods employed to design specialized analog and digital electronic systems - [K_W4]
2. has detailed knowledge in the field of building and employing advanced sensor systems - [K_W6]
3. has theoretical detailed knowledge related to control systems and control and measuring systems - [K_W11]

Skills:

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1. is able to analyze and interpret technical design documentation and make use of literature related to a specific problem - [K_U2]
2. is able to employ advanced methods of processing and analyzing signals, including visual signals, and extract information from analyzed signals - [K_U11]
3. is able to select and integrate elements of a specialized measuring and control system, including a control unit, an execution system, a measuring system as well as peripheral and communication modules - [K_U13]
4. is able to work in accordance with the safety rules related to the profession of automatics and robotics specialist - [K_U17]
5. is able to propose improvements (enhancements) to existing design solutions and models of automatics and robotics elements and systems - [K_U20]
6. is able to evaluate usefulness of methods and tools for solving a robotics and automatics problem; is able to use innovative and non-conventional tools in the field of automatics and robotics and shape the dynamic properties of measurement chains - [K_U22]
Social competencies:
1. is aware of responsibility for their own work, is able to collaborate and cooperate in a team, and take responsibility for the jointly performed tasks; is able to lead a team, set goals and assign priorities to realize a specific task - [K_K3]
2. is aware of the necessity to approach technical aspects professionally, to acquaint themselves in detail with documentation and environmental conditions in which devices and elements will operate - [K_K4]

Assessment methods of study outcomes
Formative assessment:
a) lectures:
- based on answers to question in the written exam,
b) laboratory classes:
- evaluation of doing correctly assigned tasks (following provided lab. instructions),
Total assessment:
a) verification of assumed learning objectives related to lectures:
- evaluation of acquired knowledge on the basis of the written assessment test.
b) verification of assumed learning objectives related to laboratory classes:
- evaluation of student?s knowledge necessary to prepare, and carry out the lab tasks,
- monitoring students? activities during classes,
- evaluation of lab reports (partly started during classes, finished after them)
Additional elements cover:
- discussing more general and related aspects of the class topic,
- showing how to improve the instructions and teaching materials.
Course description
The lecture covers the following topics
1. Basic concepts of Sensor Integration
- robotic perception process (gathering information through sensors, feature extraction, prediction on the basis of previously obtained data, association and matching, model update)
- different types of classification of sensors, depending on the applied criterion
- operation of the basic sensors used in robotics
- main sources and reasons of error in perception process
- basic concepts of probability, Bayes theorem
2. Random variables
- function characteristics
- central tendency and dispersion measures
- examples connected with error detection
3. Multivariate random variables
- function characteristics of bivariate distributions
- central tendency, dispersion and correlation measures
- multivariate Gaussian distribution
4. Random process
- Gaussian process (stationary process, white noise)
- Markov process (Markov sequence, Markov chain)
- examples connected with signals perception
5. Signal estimation
- prediction, on the basis of state transition model

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- correction, using predicted value and the data gathered by sensors
- Bayes filter

6. Optimal Kalman Filter KF

- assumption - Gauss-Markov sequence, Bayes filter
- implementation examples

7. Suboptimal filter - Extended Kalman Filter EKF

- mathematical fundaments of estimators - linearization
- theoretical and practical aspects of implementation

The laboratory classes are held in two-hour exercises. During the first meeting the safety issues and an introduction to laboratory exercises are preformed. Students work in the groups of two. The exercises focus on the following issues:

- practical aspects of detection and perception in robotics
- principle of operation of chosen sensors (i.a. IMU, 2D laser scanner, pulse oximeter, EMG sensor)
- software development for data acquisition
- implementation of chosen filters in Matlab/Simulink environment
- evaluation of filtration quality

Learning methods

- lectures: multimedia presentation, presentation illustrated with examples presented on black board
- labs: solving tasks, practical exercises, discussion, teamwork in groups of two, multimedia showcase, competitions or case studies. The exercises focus on the practical use of the real sensors

Basic bibliography:

1. B. Anderson, J. Moore, Optimal Filtering, Prentice-Hall, 1979

2. Y. Bar-Shalom, X. Rong Li, T. Kirubarajan, Estimation with Applications To Tracking and Navigation, John Wiley & Sons, Canada, 2001

3. H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki, S. Thrun, Principles of Robot Motion: Theory, Algorithms, and Implementations (Intelligent Robotics and Autonomous Agents series), MIT Press, Boston, 2005

4. W. A. Gardner, Introduction to Random Processes, With Applications to Signals and Systems, Macmillan, New York, 1985

Additional bibliography:

1. N. Sunderhauf, Robust Optimization for Simultaneous Localization and Mapping, Technischen Universitat, Chemnitz, 1981

2. S. Sarkka, Bayesian Filtering And Smoothing, Cambridge University Press, Cambridge, 2013

3. P. S. Maybeck, Stochastic models, estimation and control. Volume 1, Department of Electrical and Computer Engineering, Air Force Institute of Technology, Wright-Patterson Air Force Base Ohio, 1979

4. R. Negenborn, Robot Localization and Kalman Filters. On finding your position in a noisy world, Institute of Information and Computing Sciences in partial fulfilment of the requirements for the degree of Master of Science, specialized in Intelligent Systems, 2003

5. G. Welch, G. Bishop, An Introduction to the Kalman Filter, University of North Carolina at Chapel Hill Department of Computer Science Chapel Hill, NC 27599-3175, 2006

Result of average student's workload

Activity	Time (working hours)
1. participating in laboratory classes / tutorials: 15 hours	15
2. preparing to laboratory classes	8
3. finishing reports from laboratory classes (in addition to laboratory classes):	7
4. including consulting issues related to the subject of the course; especially related to laboratory classes and projects,	8
5. writing the program/ programs, testing and verification (in addition to laboratory classes)	5
6. participating in lectures	15
7. studying literature / learning aids	10
8. preparing to and participating in exams: 13 hours + 2	15

Student's workload

Source of workload	hours	ECTS
Total workload	75	3
Contact hours	40	2
Practical activities	35	1

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