UNIVERSITY OF ZIELONA GÓRA

FACULTY OF COMPUTER, ELECTRICAL AND CONTROL ENGINEERING
UNIVERSITY OF ZIELONA GÓRA

WIEA

GENERAL DESCRIPTION AND ECTS SCORING FOR FIELDS OF STUDY:

CONTROL ENGINEERING AND ROBOTICS

POSTGRADUATE PROGRAMME

OPTIMIZATION METHODS

Course code: 11.9-WE-AIR-MO-PK1_S2S

Type of course: Compulsory

Language of instruction: Polish

Director of studies: Prof. Andrzej Obuchowicz, Ph. D., D.Sc.

Name of lecturer: Prof. Andrzej Obuchowicz, Ph. D., D.Sc.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					6
Lecture	30	2	I	Exam	
Laboratory	30	2		Grade	
Part-time studies					
Lecture	18	2	I	Exam	
Laboratory	18	2		Grade	

COURSE OBJECTIVE:

To provide knowledge on elementary methods of linear and nonlinear programming.

To give skills in formulation and solving the optimization problems in engineering design using dedicated software solvers.

ENTRY REQUIREMENTS:

Mathematical analysis, Algebra, Numerical methods

COURSE CONTENTS:

Linear programming. Standard form. Base solutions review method. Simplex method. Optimal choice of production stock. Mixtures problem. Optimal choice of a technological process. Transport and assignment problems. Linear-fractional programming.

Non-linear programming – optimization conditions. Convex sets and functions. Necessary and sufficient conditions for extremum existence of a problem without constrains. Method of Lagrange multipliers. Equality and inequality constrains. Karush-Kuhn-Tucker conditions. Regularity of constrains. Quadratic programming.

Non-linear programming – computation techniques. One-dimensional searching: gold ratio, Fibonacci, Kiefer, Powell and Davidon methods. Non-gradient methods: Hooke-Jeeves and Nelder-Mead algorithms. Continuous and discrete gradient method. Newton, Gauss-Newton

and Levenberg-Marquardt methods. Basic methods of searching of direction of improvement: Fletcher-Reeves and Davidon-Fletcher-Powell methods. Optimization problems with constrains: penalty functions, complex method, gradient projection and permissible direction methods.

Basic methods of discrete and mixed optimization. Integer programming. Branch and bound method. Net programming. CPM and PERT methods. The shortest path and maximum flow problems. Elements of dynamic programming.

Global optimization. Stochastic optimization. Adaptive random search. Simulated annealing. Monte Carlo methods and Markov chains. Evolutionary algorithms.

Practical problems. Constrains simplification and elimination. Discontinuity elimination. Numerical estimation of gradient. Making use of numerical optimization libraries. Review of the most popular optimization libraries.

TEACHING METHODS:

Lecture, Laboratory exercises.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_W02	*Is able to identify an effective method of optimization for a specific problem.*
K2A_W02	*Can apply numerical environments (Matlab, Maple) in finding optimal solutions of complex problems*
K2A_W02	*Can set optimal solutions for linear and convex programming tasks, and for selected classes of discrete optimization tasks*
K2A_W02	*Can formulate optimization tasks based on technical, technological and logistic problem text description*
K2A_W02	*Can explain operation of iteration-wise optimization algorithms*

ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass is a positive evaluation of written or oral exam in the end of the semester.

Laboratory – the main condition to get a pass is a sufficient number of positive assessments of tests of theoretical preparing to each lab exercise and written reports of these exercises. The set of exercises is defined by the lecturer.

Calculation of the final grade: lecture 50% + laboratory 50%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
60	Class participation	2,0
20	Preparation for classes	0,67
20	Reading of supplementary texts	0,67
30	Preparation of reports	1,0
30	Assignment completion	1,0
0	Personal and on-line consultations	0,0
20	Preparation for exam	0,67
180	**Total**	**6**

Part-time studies		
No. of hours	**Type of workload**	**ECTS**
36	Class participation	1,2
20	Reading of supplementary texts	0,67
20	Preparation of reports	0,67
30	Preparation for classes	1
30	Assignment completion	1
24	Personal and on-line consultations	0,8
20	Preparation for exam	0,67
180	**Total**	**6**

RECOMMENDED READING:

1. Bertsekas D.: *Nonlinear programming*, Athena Scientific, 2004
2. Bertsekas D.: *Convex Analysis and Optimization*, Athena Scientific, 2003
3. Spall J.: *Intoduction to Stochastic Search and Optimization: Estimation, Simulation and Contro*l, Wiley InterScience, 2003.

OPTIONAL READING:

1. Kukuła K.(Ed.): *Operation research in examples and problems*, PWN, Warszawa, 2006 (in Polish)
2. Kusiak J., Danielewska-Tułecka A., Oprocha P.: *Optimization. Chosen methods with sample applications,* PWN, Warszawa, 2009 (in Polish)

REMARKS: -

SYSTEM MODELING AND IDENTIFICATION

Course code: 11.9-WE-AIR-MII-PK2_S2S

Type of course: Compulsory

Language of instruction: Polish

Director of studies: Assoc. Prof. Andrzej Janczak, Ph. D., D.Sc.

Name of lecturer: Assoc. Prof. Andrzej Janczak, Ph. D., D.Sc.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					6
Lecture	30	2	I	Exam	
Laboratory	30	2		Grade	
Part-time studies					
Lecture	18	2	I	Exam	
Laboratory	18	2		Grade	

COURSE OBJECTIVE:

To provide fundamental knowledge in system identification, including: input signal selection, model order selection, non-recursive and recursive identification methods.

To develop skills in building system models based on structure knowledge and input-output measurements, including nonparametric identification methods, parametric identification methods, neural networks and fuzzy models.

ENTRY REQUIREMENTS:

Signals and dynamic systems, Control engineering, Artificial intelligence methods

COURSE CONTENTS:

Introduction. Plants and their models. Model using. System identification and mathematical modelling. Equivalence of models and model equivalence criteria. Parameter estimation. Identifications error definitions. Building system models based on structure knowledge and measurements. Identification algorithm scheme.

Nonparametric identification methods. Transient states analysis. Frequency identification methods. Correlation methods. Power spectrum analysis.

Least squares method. Linear static models. Least squares problem. Normal equations. Analysis of least squares estimator. Best linear unbiased estimator. Confidence intervals of parameter estimates. Model complexity. Finding the least squares solution with orthogonal-triangular decomposition. Recursive least squares algorithm.

Models of dynamic systems. Model classification. General structure of linear model. AR, AR, MA, ARMA, FIR, ARX, ARMAX, OE, and Box-Jenkins models. Multi-input multi-output models. Nonlinear models. Wiener and Hammerstein models. Volterra and Kolmogorov-Gabor models. State-space models. Model structure selection.

Input signals. Deterministic signals. Stochastic signals. Input signals used in system identification. Persistent excitation condition.

Prediction error method. Simulation and prediction. Optimal predictors. Least-squares estimation of ARX model parameters. Parameter consistency problem. Instrumental variables method. Choice of instrumental variables. Prediction error method.

Recursive identification. Properties of recursive identification algorithms. Recursive least squares method. Exponential forgetting. Recursive instrumental variables method. Recursive prediction error method. Parameter adaptation of self-tuning controller.

Closed-loop identification. Identifiability of closed-loop systems. Direct identification methods. Indirect identification methods. Influence of feedback loop on estimation accuracy.

Modeling of static and dynamic nonlinear systems using neural networks and fuzzy models. Neural network models of static and dynamic nonlinear systems. Learning algorithms. Generalization. Neural network model testing and validation. Optima architecture selection. Fuzzy logic. Fuzzy models. Mamdani, Takagi-Sugeno-Kang and Tsukamoto inference methods. Neuro-fuzzy models. Parameter optimization. Rule base optimization. Operator optimization. Examples of neural network and fuzzy modeling.

TEACHING METHODS:

Lecture, laboratory exercises.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_U08	*Can construct models of linear dynamical systems using the prediction error method*
K2A_U08	*Can construct models of dynamical linear systems using the instrumental variables method*
K2A_U08	*Can construct models of linear systems using the least squares method*
K2A_U08	*Can construct models of linear dynamical systems using the transient response analysis*
K2A_W03	*Knows definitions of systems identification, mathematical modeling and general system identification algorithm*
K2A_W03	*Knows linear dynamical systems classification, general model structure, AR, MA, ARMA, FIR, ARX, ARMAX, OE and Box-Jenkins models*
K2A_W03	*Knows principles of linear dynamical system identification with recurrent methods*
K2A_W03	*Knows principles of linear dynamical system identification with predication error method*
K2A_W03	*Knows principles of linear dynamical system identification with least squares method*
K2A_W03	*Knows principles of linear dynamical system identification with instrumental variables method*
K2A_W03	*Knows principles of linear dynamical system identification with neural networks and fuzzy systems*

LEARNING OUTCOMES VERIFICATION AND ASSESMENT CRITERIA:

Lecture – the main condition to get a pass are sufficient marks in written or oral tests conducted at least once per semester.

Laboratory – the passing condition is to obtain positive marks from all laboratory exercises to be planned during the semester.

Calculation of the final grade: lecture 50% + laboratory 50%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
60	Class participation	2,0
20	Preparation for classes	0,67
20	Reading of supplementary texts	0,67
36	Preparation of reports	1,2
4	Assignment completion	0,13
40	Preparation for exam	1,33
180	**Total**	**6**
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
36	Class participation	1,2
32	Preparation for classes	1,07
24	Reading of supplementary texts	0,8
30	Preparation of reports	1,0
10	Assignment completion	0,33
48	Preparation for exam	1,6
150	**Total**	**6**

RECOMMENDED READING:

1. Ljung L.: *System identification. Theory for the User*. Prentice Hall, Upper Saddle River, 1999
2. Nelles O.: *Nonlinear System Identification*. *From Classical Approaches to Neural Networks and Fuzzy models*. Springer, New York, Berlin, Heidelberg, 2001
3. Söderström T., Stoica P.: *System Identification*. Prentice Hall, Upper Saddle River, 1994

OPTIONAL READING:

1. Nørgaard M., Ravn O., Poulsen N.K., Hansen L.K.: *Neural Networks for Modelling and Control of Dynamic Systems*. Springer, London, 2000

REMARKS: -

CONTROL THEORY

Course code: 06.0-WE-AIR-TS-PK3_S2S

Type of course: Compulsory

Language of instruction: Polish

Director of studies: Assoc. Prof. Wojciech Paszke, Ph. D., D.Sc.

Name of lecturer: Assoc. Prof. Wojciech Paszke, Ph. D., D.Sc.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					6
Lecture	30	2	I	Exam	
Laboratory	30	2		Grade	
Part-time studies					
Lecture	18	2	I	Exam	
Laboratory	18	2		Grade	

COURSE OBJECTIVES:

Provide methodology of nonlinear systems analysis. Deliver understanding of various stability criteria. Provide skills in formulation and solving of optimal control problems.

ENTRY REQUIREMENTS:

Mathematical analysis, Linear algebra, Control Engineering, Continuous Process Control

COURSE CONTENTS:

Introduction to nonlinear systems. The most common nonlinear systems. The state space representation. An equilibrium point. Typical behaviour of nonlinear systems. Limit cycles.

Analysis of dynamic properties of nonlinear systems with the phase plane method. The second order nonlinear systems; graphical representation with phase portraits. Singular points. Graphical and numerical methods for generating of a phase portrait. Stability analysis of nonlinear systems by using the phase plane method.

Stability analysis. Different definitions to a nonlinear system stability. Lyapunov's linearization method. Lyapunov's second (direct) method. Global asymptotic stability analysis. La Salle's theorem. Stability of time-varying nonlinear systems. Instability theorems. Absolute stability criterions. A sector nonlinearity. Popov and circle criterion. Controller synthesis based on Lyapunov's method.

The describing function method. Definitions of a limit cycle and characteristics. The existence theorem. Definition of the describing function. Describing function for systems with input saturation, output deadzone and hysteresis respectively. Using the describing function method for limit cycle analysis. Stability analysis of a limit cycle.

Feedback linearization. Mathematical basics of feedback linearization. Lie's algebra. Input-output linearization. Linearization conditions. Controllability conditions. Algorithm for an input-state linearization. Normal forms. Diffeomorphism. Algorithm for an input-output linearization. Internal dynamics. Asymptotic properties of nonlinear minimum phase systems.

Introduction to multivariable control. Transfer functions for MIMO systems. Multivariable frequency response analysis. Condition number and RGA. General control problem formulation. Internal stability of feedback systems. Stabilizing controllers. H2 and H∞ system norms. Control system design.

Limitations on performance in SISO and MIMO systems. Perfect control and plant inversion. Constraints on sensitivity functions .Limitations imposed by RHP zeros and poles. Phase lag and uncertainty.

Introduction to robustness. Representing uncertainty in the frequency domain. Robust stability and performance. Parametric uncertainty and complex unstructured uncertainty. Mu-synthesis and DK-iteration.

TEACHING METHODS:

Lecture, laboratory exercises.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_W04	*Has knowledge on basic methods of analysis of the stability of nonlinear systems*
K2A_U07	*Can analyze the stability and synthesis of a controller based on the method of Lyapunov.*
K2A_U09	*Can solve selected tasks of continuous and discrete optimal control.*
K2A_W04, K2A_U09	*Can bring an optimal control task to a mathematical programming problem.*
K2A_W04, K2A_U07	*Can perform an analysis of a limit cycle by using the describing function*
K2A_W04	*Understands non-linearity impact on static and dynamic characteristics of systems*
K2A_W04, K2A_U04	*Knows non-linear systems linearization methods, in particular applications of coupling methods*

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass are sufficient marks in written or oral tests conducted at least once per semester.

Laboratory – the passing condition is to obtain positive marks from all laboratory exercises to be planned during the semester.

Calculation of the final grade: lecture 50% + laboratory 50%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
60	Class participation	1,5
20	Preparation for classes	0,5
20	Reading of supplementary texts	0,5
20	Preparation of reports	0,5
20	Assignment completion	0,5
20	Personal and on-line consultations	0,5
180	**Total**	**4**

Part-time studies		
No. of hours	**Type of workload**	**ECTS**
36	Class participation	1,2
24	Reading of supplementary texts	0,47
24	Preparation of reports	0,48
24	Preparation for classes	0,47
24	Assignment completion	0,48
24	Personal and on-line consultations	0,48
24	Preparation for exam	0,47
180	**Total**	**4**

RECOMMENDED READING:

1. D. Atherton, An introduction to Nonlinearity in Control systems, Ventus Publishing, 2011.
2. H. K. Khalil, Nonlinear Systems, 3rd edition, Prentice Hall, 2002.
3. S. Skogestad, I. Postlethwaite: Multivariable feedback control. Analysis and design. John Wiley and Sons, 2nd edition, 2005.
4. P. Albertos, A. Sala : Multivariable control systems: An engineering approach, Springer, London, 2004.
5. K.J. Åström, R.M. Murray, *Feedback Systems: An Introduction for Scientists and Engineers*, Princeton University Press, Princeton, 2009

OPTIONAL READING: -

REMARKS: -

AUTOMATIC ACTUATOR SYSTEMS

Course code: 11.9-WE-AIR-UWA-PK4_S2S

Type of course: Compulsory

Language of instruction: Polish

Director of studies: Prof. Igor Korotyeyev, Ph. D., D.Sc.
Jacek Kaniewski, Ph. D.

Name of lecturer: Jacek Kaniewski, Ph. D.
Paweł Szcześniak, Ph. D.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					6
Lecture	30	2	I		
Laboratory	30	2		Grade	
Part-time studies					
Lecture	18	2	I	Exam	
Laboratory	18	2		Grade	

COURSE OBJECTIVES:

Provide knowledge on fundamental types of actuators in automation and robotics.
Introduction to issues related to system automation.

ENTRY REQUIREMENTS:

Basics of Electrical engineering and electronics, Programmable logic controllers

COURSE CONTENT:

Introduction. Engineering realization of actuator device in automatic systems. Energy sources used in actuator device. Examples of actuator device applications in automatics.

Pneumatic actuating devices. Physical behavior of gas's. Compressed air – production and distribution. Pneumatic elements of automatic devices. Construction and basic behavior of pneumatic drive. Interconnections of actuator devices. Computer design of actuator devices. Examples of using of pneumatic actuating devices in automatics.

Hydraulic actuating device. Construction, basis of operation and main behavior of hydraulic actuating devices. Mathematical formulation of behavior of functional systems and hydraulic

devices. Power supply, control and execute parts of hydraulic devices. Graphical symbols of main functional systems of hydraulic devices. Examples of using of hydraulic actuating devices in automatics.

Electrical actuating device. Electrical machines used in automatics as actuating devices. Power supply of actuating motors. Position, speed and torque controls of electric drives. DC and AC motors, brushless and stepper motor drivers in automatics. Actuating devices in electrothermics. Examples of using of electrical and electropneumatic actuating devices in automatics.

Using of actuating devices in automatics. Controllers in automatic devices. Examples of using automatic devices with pneumatic, hydraulic, electrical and electropneumatic actuating devices.

TEACHING METHODS:

Lecture, Laboratory exercises.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_W09	*Has knowledge on pneumatic, hydraulic and electromechanical automation systems*
K2A_U13	*Can use actuating systems of automation*
K2A_U13	*Can work individually and in a team.*
K2A_W09	*Knows theoretical fundamentals relating to executive systems and their application in automatics systems*
K2A_W09	*Knows problems related to basic executive systems in typical automatics systems*

ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass is a sufficient number of positive evaluations of written or oral tests conducted at least once per semester.

Laboratory – the main condition to get a pass is a positive assessments of the all laboratory exercises specified by the laboratory program.Calculation of the final grade: lecture 60% + laboratory 40%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
60	Class participation	2,0
20	Preparation for classes	0,67
30	Reading of supplementary texts	1,0
10	Preparation of reports	0,33
20	Assignment completion	0,67
20	Personal and on-line consultations	0,67
20	Preparation for exam	0,67
180	**Total**	**6**
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
36	Class participation	1,2
39	Reading of supplementary texts	1,3
37	Preparation of reports	1,23
29	Preparation for classes	0,96
29	Assignment completion	0,97
0	Personal and on-line consultations	0
10	Preparation for exam	0,33
180	**Total**	**6**

RECOMMENDED READING:

1. Z. Zajda, L. Żebrowski, Devices and automatic systems, Wrocław Politechnics publishing house, Wrocław, 1993, “in Polish”
2. J. Bednarczyk, Electrical elements of automatics, AGH, Kraków, 1988, “in Polish”
3. J. Honczarenko, Industrial robots. Construction and using. WNT, Warszawa, 2004, “in Polish”
4. A. Pizoń, Analog and digital electrohydraulic automatic devices. WNT, Warszawa, 1995, „in Polish”
5. M. Hering, Bases of electrothermics. *Parts I and II*, Warszawa, WNT, 1992, 1998, „in Polish”

OPTIONAL READING:

1. B. Chorowski, M. Werszko, Mechanical devices of automatics, Warszawa, WNT, „in Polish”
2. P. Osiecka, Hydrostatic machine drive, Warszawa, WNT, 2004, „in Polish”
3. T. Legierski, J. Kasprzyk, J. Wyrwał, J. Hajda, PLC controller programming, Computer d Publishing House of Jacek Skalmierski, Gliwice, 1998, „in Polish”

REMARKS: -

SENSORICS AND INDUSTRIAL MEASUREMENTS

Kod przedmiotu: 06.0-WE-AIR-SIPP-PK5_S2S

Type of course: Compulsory

Language of instruction: Polish

Director of studies: Assoc. Prof. Ryszard Rybski, Ph. D., D.Sc.

Name of lecturer: Assoc. Prof. Ryszard Rybski, Ph. D., D.Sc.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					6
Lecture	**30**	**2**	I	Grade	
Laboratory	**30**	**2**		Grade	
Part-time studies					
Lecture	**18**	**2**	I	Grade	
Laboratory	**18**	**2**		Grade	

COURSE OBJECTIVES:

Provide knowledge on sensor parameters and their static and dynamic properties. Deliver basics of functional blocks for measurement processing channels. Principles of requirements for sensors and measurement tranducers.

ENTRY REQUIREMENTS:

Fundamentals of electrical engineering, Metrology

COURSE CONTENTS:

Introduction. Measurement sensors properties in metrology. Sensors typology. Sensors manufacturing technologies.

Sensors and converters in measurement systems. Analogue, digital-analogue and analogue-digital converters. Sensors output signal transmission. Sensors and measurement converters interfaces. Intelligent sensors. Wireless sensory networks.

Temperature measurements. Resistance based thermometers. Thermoelectric thermometers. Semiconductor based temperature sensors. Pyrometers. Noise thermometers. Fiber optic thermometers.

Pressure measurements. Piezoresistive sensors. Piezoresistive sensor error compensation. Strain gages. Capacitive sensors.

Level measurements. Float, hydrostatic and capacitive level meters. Ultrasounds in level measurements.

Liquid velocity and flow measurements. Liquid velocity measurements with anemometric method. Doppler velocimeters. Orifice plate meters. Rotameters. Turbine flow meters. Coriolis flow meters. Ultrasonic flow meters. Electromagnetic flow meters. Fluid density meters.

Measurements of movement. Inductive and capacitive movement sensors. Proximity sensors. Fiber optic movement sensors. Ultrasonic converters in movement measurements.

Motion parameters measurement. Rotational speed measurements. Vibrations and quakes measurements. Piezoelectric accelerometers. Capacitive accelerometers.

Force and mass measurements. Strain gages. Strain gages measurement systems. Piezoelectric force sensors.

Humidity measurements. Humidity measurements: psychrometric hygrometer, dew point hygrometer, impedance based humidity sensors. Humidity of solids measurements: impedance method, spectrometric methods.

TEACHING METHODS:

Lecture, Laboratory exercises.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_W14	*Is aware of the requirements for the sensors in industrial measurements*
K2A_W14	*Can name basic functional blocks of modern measurement signals processing path*
K2A_U18	*Can plan and carry out characteristics measurements for sensors, measurement converters and elements of measurement signal processing path*
K2A_W14	*Knows parameters and methods applied in description and evaluation of static and dynamic measurement sensors*
K2A_W14	*Can explain operation principles of measurement sensors for basic non-electric values and can indicate using examples most important areas for their applications*

ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass is acquiring a positive evaluation ftom the written test.

Laboratory – the main condition to get a pass is acquiring positive assessments from theoretical background evaluation tests perceding practical exercises, and from exercise reports as selected by the lecturer.

Calculation of the final grade: lecture 50% + laboratory 50%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
60	Class participation	2
24	Preparation for classes	0,8
24	Reading of supplementary texts	0,8
24	Preparation of reports	0,8

24	Assignment completion	0,8
12	Personal and on-line consultations	0,4
12	Preparation for exam	0,4
180	**Total**	**6**
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
36	Class participation	1,20
29	Reading of supplementary texts	0,97
29	Preparation of reports	0,97
29	Preparation for classes	0,97
29	Assignment completion	0,97
12	Personal and on-line consultations	0,40
16	Preparation for exam	0,53
180	**Total**	**6**

RECOMMENDED READING:

1. D.M. Scott, *Industrial process sensors*, CRC Press, 2007
2. J. Vetelino, A. Reghu, *Introduction to sensors*. CRC Press, 2010
3. J. Fraden, *Handbook of modern sensors*. Springer, 2010
4. R. Pallas-Areny, J.G. Webster, *Sensors and signal conditioning*. John Willey& Sons, Inc., Chichester, 2001
5. S. Tumanski, *Principles of electrical measurement*. Taylor & Francis, 2006

OPTIONAL READING: -

REMARKS: -

INTELLIGENT CONTROL METHODS

Course code: 11.9-WE-AIR-ISS-PS6_S2S
Type of course: Compulsory
Language of instruction: English
Director of studies: Prof. Marcin Witczak, Ph. D., D.Sc.
Name of lecturer: Prof. Marcin Witczak, Ph. D., D.Sc.
Assoc. Prof. Krzysztof Patan, Ph. D., D.Sc.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					6
Lecture	30	2	II	Grade	
Laboratory	30	2		Grade	
Part-time studies					
Lecture	18	2	II	Grade	
Laboratory	18	2		Grade	

ENTRY REQUIREMENTS:

Automatic control, Modelling and simulation, Programming with essentials of algorithmics

COURSE CONTENTS:

Introduction to artificial neural networks: Properties of neural networks, basic structures, training methods, application areas in automatic control and robotics.

Multilayer perceptrons: Structure of the artificial neuron. Network topologies and information processing, the BackPropagation (BP) algorithm and its modifications, generalization properties, regulatization. Application of multilayer perceptrons to classification.

Dynamic networks: Multilayer perceptrons with tapped delay lines, recurrent networks (Williams-Zipser) and partially recurrent networks (Elman). Series-parallel and parallel identification models.

Introduction to fuzzy logic: Fuzzy sets, fuzzyfication and defuzzyfication, the fuzzy interference system, the rule base. Mamdani and Takagi-Sugeno models.

Inverse model control: Analysis of control system with inverse model, basic assumptions. Designing of the inverse model using neural networks. Collecting the training data. Synthesis of the control system with the neural inverse model. Implementing the neural based inverse control in the Simulink environment.

Feedforward control: Analysis of PID control system with additional feedforward control. Synthesis of feedforward control using neural inverse model. Implementing the neural based feedforward control in the Simulink environment.

Model predictive control: Analysis of model predictive control systems. Neural network based design of *i*-step ahead predictor. Defining the optimal control sequence selection as the optimization problem. Synthesis of neural based model predictive control. Implementing the neural based predictive control in the Simulink environment.

Fuzzy control: Fuzzy realization of the PID controller. Comparison of the fuzzy controller with the PID controller. Designing the rule base. Synthesis of the fuzzy controller. Implementing the fuzzy logic based control in the Simulink environment.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_W06	*Is aware of the dynamic development of the discipline.*
K2A_U12	*Can design and implement modern control systems with the application of artificial neural networks and fuzzy logic.*
K2A_W06	*Understands functioning of intelligent calculations techniques based on artificial neural networks and fuzzy logic, and also is aware of their usefulness in situations in which classic control techniques are not effective*

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass is a sufficient number of positive evaluations of written or oral tests conducted at least once per semester.

Laboratory exercices – the main condition to get a pass is a positive assessment of the both written tests and project reports assigned by the lecturer.

Calculation of the final grade: lecture 50% + laboratory 50%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
60	Class participation	2,0
30	Preparation for classes	1
15	Reading of supplementary texts	0,5
15	Preparation of reports	0,5
15	Assignment completion	0,5
15	Personal and on-line consultations	0,5
30	Preparation for exam	1
180	**Total**	**6**
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
36	Class participation	1,5
22	Reading of supplementary Texas	0,7
22	Preparation of reports	0,7
22	Preparation for classes	0,7
22	Assignment completion	0,7
22	Personal and on-line consultations	0,7
34	Preparation for exam	1
180	**Total**	**6**

RECOMMENDED READING:

1. S. Haykin, *Neural networks. A comprehensive foundation, 2nd edition,* Prentice-Hall, New Jersey, 1999.
2. O. Nelles, *Nonlinear system identification. From classical approaches to neural networks and fuzzy models*, Springer-Verlag, Berlin, 2001.
3. L. Rutkowski, *New soft computing techniques for system modelling, pattern classification and image processing*, Springer-Verlag, London, 2004.
4. M. Noorgard, O. Ravn, N.M. Poulsen, L.K. Hansen, *Neural networks for Modelling and Control of Dynamic Systems*, Springer-Verlag, London, 2000.

OPTIONAL READING: -

REMARKS: -

ROBOT LOCALIZATION AND NAVIGATION

Course code: 11.9-WE-AIR-LINR-PS8_S2S

Type of course: Compulsory

Language of instruction: Polish

Director of studies: Assoc. Prof. Maciej Patan, Ph. D., D.Sc.

Name of lecturer: Assoc. Prof. Maciej Patan, Ph. D., D.Sc.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					6
Lecture	30	2	II	Exam	
Laboratory	30	2		Grade	
Part-time studies					
Lecture	18	2	II	Exam	
Laboratory	18	2		Grade	

COURSE OBJECTIVE:

To provide fundamental skills within the framework of formulation and implementation of localization and path planning for mobile robots.

To provide knowledge on methods of mobile platforms navigation.

To learn skills of robotic systems integration.

ENTRY REQUIREMENTS:

Fundamentals of robotics, Robot control

COURSE CONTENTS:

Introduction. Typical mobile robot platforms. Legs and wheels as the movement mechanisms. Essential problems. Examples and applications.

Robot perception. Sensor classification. Characterization of sensor performance and uncertainty of measurements. Feature extraction. Perception algorithms. Vision algorithms. Models of workspace (raster, geometric, topological).

Kinematics of mobile robots. Kinematic models and constraints. Controllability of robot. Workspace and motion control. Kinematics of actuators (camera, laser rangefinders, manipulators, etc.).

Localization of mobile robot. Classification of methods. Challenges in localization. Odometry. Localization based on maps. Probabilistic methods. Kalman filtering In localization. Systems based on environmental marks and global positioning systems. Autonomous map building.

Navigation. Trajectory planning. Classification of motion planning methods. Fundamental techniques of motion planning (visibility graphs, workspace decomposition, Bayesian methods, potential methods etc.). Obstacles avoidance. Movement optimization.

Mobile robot networks. Models of robotnic networks. Centralized and multiagent systems. Methods of motion planning for swarms of robots. Coordination of tasks. Problems of connectivity, randez-vous and optimal robot deployment.

TEACHING METHODS:

Lecture, Laboratory exercises.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_W06, K2A_W08	*Has knowledge on basic systems and typical applications of mobile robotics*
K2A_U10	*Can creatively use dedicated software and accessible numerical libraries in implementing navigation tasks*
K2A_U10	*Can apply algorithmic approach to setting motion planning solutions for mobile robots swarms*
K2A_W06, K2A_U10	*Can apply perception methods and algorithms based on a robot sensory systems*
K2A_W06, K2A_W08	*Understands aims and navigation task limitations of mobile robots*
K2A_W06, K2A_U10	*Knows and can apply simple mobile robots models*

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass is a positive assessment of written or/and oral examination test

Laboratory – the main condition to get a pass is a sufficient number of positive evaluations of written or oral tests conducted at least three times per semester and positive evaluations of the laboratory tasks assigned by the lecturer.

Calculation of the final grade: lecture 50% + laboratory 50%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
60	Class participation	2,0
20	Preparation for classes	0,67
20	Reading of supplementary texts	0,67
20	Preparation of reports	0,67
20	Assignment completion	0,67
20	Personal and on-line consultations	0,67
20	Preparation for exam	0,67
180	**Total**	**6**
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
36	Class participation	1,2
24	Reading of supplementary texts	0,8
24	Preparation of reports	0,8
24	Preparation for classes	0,8

24	Assignment completion	0,8
24	Personal and on-line consultations	0,8
24	Preparation for exam	0,8
180	**Total**	**6**

RECOMMENDED READING:

1. Siegwart R., Nourbakhsh I.: *Introduction to autonomous mobile robots*, MIT Press, 2004
2. Murphy R.: *Introduction to AI Robotics*, MIT Press, 2000
3. V.J. Lumelsky.: Sensing, Intelligence, Motion., Wiley, 2006

OPTIONAL READING: -

REMARKS: -

INDUSTRIAL AUTOMATION

Course code: 06.0-WE-AIR-APP-PS11_S2S

Type of course: Compulsory

Language of instruction: Polish

Director of studies: Ass. Prof. Paweł Majdzik, Ph.D.

Name of lecturer: Ass. Prof. Paweł Majdzik, Ph.D.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					3
Lecture	15	1	III	Grade	
Laboratory	30	2		Grade	
Part-time studies					
Lecture	9	1	III	Grade	
Laboratory	18	2		Grade	

COURSE OBJECTIVE:

To provide fundamental knowledge in the methods and techniques to implement real - time systems.

To provide fundamental knowledge in programming Programmable Logic Controllers by using different techniques.

Skills and competencies needed to design and to implementation simple industrial systems especially Flexible Manufacturing System.

ENTRY REQUIREMENTS:

Operating systems, programming languages

COURSE CONTENTS:

Introduction. Basic terms of Industrial Automation, automation of technical products and technical plants components of an industrial automation system. The types of automation devices and structures, automation hierarchies, distributed automation systems, different types and application areas of field busses.
Devices of industrial production systems. Interfaces between the technical process and the automation computer system, sensors and actuators, representation of process data in automation computers, field bus systems. Flexible Manufacturing System, synchronizations methods and concepts, scheduling methods of industrial tasks.
Real-time systems. Real-time programming methods, the types of Real-time programs, the methods of design of Real-time systems, parts of a real-time operating system, organization tasks of a real-time operating system.
Programming languages. Programming languages applied in industrial automation systems and Real - time systems. Synchronization of tasks, communication between tasks, scheduling methods, programming

Programmable Logic Controllers (PLC), universal programming languages for Industrial Automation, Real-time programming language.

TEACHING METHODS:

Lecture, laboratory exercises.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_U05	Can write a program in LAD language
K2A_W05	Can name and characterize methods and devices for signal transmission in distributed production systems
K2A_W01	Can characterize basic integral elements of production system and distinguish and characterize production process automation levels
K2A_U05	Knows PLC drivers structure and can give examples for their applications

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass is a sufficient number of positive evaluations of written or oral tests conducted at least once per semester.

Laboratory – the main condition to get a pass is a positive assessment of the all laboratory exercises.

Calculation of the final grade: lecture 50% + laboratory 50%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
45	Class participation	1,5
18	Preparation for classes	0,6
9	Reading of supplementary texts	0,3
18	Assignment completion	0,6
90	**Total**	**3**
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
27	Class participation	0,9
9	Reading of supplementary texts	0,3
30	Preparation for classes	1.0
24	Assignment completion	0,8
90	**Total**	**3**

RECOMMENDED READING:

1. Mikulczyński, T.: *Automatization of industrial processes.* Wydawnictwa Naukowo-Techniczne WNT, Warszawa, 2009.
2. Burns A, Wellings A. Concurrent and Real-Time Programming in Ada, Cambridge University Press
3. Kowalewski, H.: Automatization of discreet production processes, WNT, Warszawa, 1984.

OPTIONAL READING:

1. Collins K.: *PLC Programming for Industrial Automation.* Exposure Publishing, 2006

REMARKS: -

DECENTRALIZED SYSTEMS OF CONTROL ENGINEERING AND ROBOTICS

Course code: 11.9-WE-AIR-ZUAR-PS12_S2S

Type of course: Compulsory

Language of instruction: Polish

Director of studies: Ass. Prof. Paweł Majdzik, Ph.D.

Name of lecturer: Ass. Prof. Paweł Majdzik, Ph.D.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					6
Lecture	30	2	III	Grade	
Laboratory	30	2		Grade	
Part-time studies					
Lecture	18	2	III	Grade	
Laboratory	9	1		Grade	

COURSE OBJECTIVE:

Skills and competencies regarding various DCS solutions as well as the ability of designing DCS for control and monitoring of industrial processes.

COURSE CONTENTS:

Introduction. Functional computer structures for control engineering. Hardware structures – classification. Features of systems: DCS, hybrid, SCADA.

System structures. Review of DCS structures, network structures, redundancy.

Process stations. Review of process stations: functions, hardware structures, redundancy, software.

Development directions. New functions of DCS, advanced control systems and diagnostics in DCS.

Introduction to Proficy Process Systems. Demonstration of exemplary solutions.

Design of DCS. Review of Architectures of *Proficy Process Systems. Engineer stations. Alarm maintenance. Process data processing. Operator consoles. Acquisition and processing of historical data.*

ENTRY REQUIREMENTS:

Technique of automatic control, Control of continuous processes

ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass is a sufficient number of positive evaluations of written or oral tests conducted at least once per semester.

Laboratory – the main condition to get a pass is a sufficient number of positive evaluations of written or oral tests conducted after each lab.

TEACHING METHODS:

Lecture, laboratory exercises.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_U06	*Can work individually and in a team.*
K2A_U06	*Is able to implement the proposed DCS system and plan and run its tests*
K2A_U17	*Can prepare and carry out the project of DCS system application to control and to supervise industrial processes*
K2A_U06, K2A_U17	*Characterizes and interprets the work of process, operator and engineering stations*
K2A_U06, K2A_U17	*Can name and characterize various solutions for DCS class systems (decentralized control systems) and their structure*

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass are sufficient marks in written or oral tests conducted at least once per semester.

Laboratory – the passing condition is to obtain positive marks from all laboratory exercises to be planned during the semester.

Calculation of the final grade: lecture 50% + laboratory 50%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
60	Class participation	2,0
24	Preparation for classes	0,8
24	Reading of supplementary texts	0,8
24	Preparation of reports	0,8
24	Assignment completion	0,8
24	Personal and on-line consultations	0,8
180	**Total**	**6**
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
36	Class participation	1,2
24	Reading of supplementary texts	0,8
24	Preparation of reports	0,8
24	Preparation for classes	0,8
24	Assignment completion	0,8
24	Personal and on-line consultations	0,8
24	Preparation for exam	0,8
180	**Total**	**6**

RECOMMENDED READING:

1. A. G. Aghdam, J. Lavaei: *Decentralized control of interconnected systems*, VDM Verlag, Berlin, 2008
2. Bailey D. i E. Wright: Practical SCADA for Industry, Elsevier, London, 2003
3. P. Tatjewski: *Zaawansowane sterowanie obiektów przemysłowych, struktury i algorytmy*, EXIT, Warszawa 2002.
4. GE Fanuc: Proficy Process Systems – dokumentacja, www.astor.com.pl
5. Stanisław H. Żak, *Systems and Control*, Oxford University Press, New York, 2003

OPTIONAL READING: -

REMARKS: -

ADVANCED DECISION SYSTEMS

Course code: 11.9-WE-AIR-ZSD-PS13_S2S

Type of course: Compulsory

Language of instruction: Polish

Director of studies: Assoc. Prof. Andrzej Pieczyński, Ph. D., D.Sc.

Name of lecturer: Assoc. Prof. Andrzej Pieczyński, Ph. D., D.Sc.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					3
Lecture	15	1	III	Grade	
Laboratory	15	1		Grade	
Part-time studies					
Lecture	9	1	III	Grade	
Laboratory	9	1		Grade	

COURSE OBJECTIVE:

To provide knowledge about exploration from data bases and advanced decision systems design.

To develop skills in intelligent computation usage in decision making systems.

ENTRY REQUIREMENTS:

Mathematical logic, artificial intelligence methods, expert systems

COURSE CONTENTS:

The incomplete, uncertain and inaccurate information in a decision making task. Parametric and nonparametric decision problems. Application of rough and expanded expert systems. Capabilities theory. Rough and fuzzy sets application in knowledge bases. Decision tree optimization.

Knowledge discovery in data bases, data exploration. Preliminary data preparation. Soft computing in data mining.

Application of neural networks in decision making. Neural networks in data grouping and classification tasks. Knowledge extraction from data bases with application of neural networks.

Fuzzy decision systems. Application of neuro-fuzzy and evolution-fuzzy systems in the knowledge base creation. Fuzzy classifiers. Various types of neuro-fuzzy decision systems.

Application of rough sets as support of decision making. Domination based rough sets. Patterns classification induction resulting in principles formulation for decision making.

Decision supporting systems design. Hybrid decision systems.

TEACHING METHODS:

Lecture, laboratory exercises.

LEARNING OUTCOMES:

Code	Effects of the course
K1A_K01	*Is creative when selecting the environment to construct a complex expert system*
K1A_W16	*Is aware of the role of decision-making systems in support of activities of management in enterprises*
K1A_W16	*Has knowledge on the description methods of uncertain and inaccurate knowledge*
K1A_W16	*Has knowledge on the structure of approximate and developed expert systems*
K1A_W12	*Has knowledge on the operation of a hybrid decision making system*
K1A_U17	*Can develop an optimal representation of uncertain and imprecise knowledge with the application of selected elements of artificial intelligence*
K1A_U17	*Can prepare the description of knowledge by combining selected elements of artificial intelligence and can design the structure of a hybrid expert system*
K1A_U17	*Can prepare documentation of the implemented system and cares about the completeness of the documentation*
K1A_U17	*Can build an expert system implementing artificial neural networks and fuzzy logic followed by ability to evaluate properness of the designed system operation*
K1A_U17	*Can use soft calculations in knowledge extraction from data (data mining)*

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lectures: the main condition to get a pass is acquiring sufficient marks from two written tests (full time studies) or a written exam (part time studies)

Laboratory: the main condition to get a pass is acquiring sufficient marks from all laboratory exercises (a test covering theoretical knowledge related to exercised tasks and exercises documentation).

Calculation of the final grade: lecture 50% + laboratory 50%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
30	Class participation	1,00
10	Preparation for classes	0,33
10	Reading of supplementary texts	0,33
10	Preparation of reports	0,33
10	Assignment completion	0,33
10	Personal and on-line consultations	0,33
10	Preparation for exam	0,34
90	**Total**	**3,00**
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
18	Class participation	0,60
12	Reading of supplementary texts	0,40

12	Preparation of reports	0,40
12	Preparation for classes	0,40
12	Assignment completion	0,40
12	Personal and on-line consultations	0,40
12	Preparation for exam	0,40
90	**Total**	**3,00**

RECOMMENDED READING:

1. Dettmer H.W.: *The Logical Thinking Process*: *A Systems Approach to Complex Problem Solving,* ASQ Quality Press, 2007
2. Matsatsinīs N.F., Siskos Y.: *Intelligent support systems for marketing decisions*, Springer, 2003
3. Marakas G.M.: *Decision support systems in the 21st century*, Prentice Hall, 2003
4. Rakus-Andersson E.; Yager, R.R.; Ichalkaranje, N.: *Recent Advances in Decision Making*, Springer, 2009
5. Turban E., Sharda R., Dursun D.: *Decision support systems and business intelligence systems*, Prentice Hall, 2010

OPTIONAL READING: -

REMARKS: -

MULTI-AGENT SYSTEMS

Course code: 11.9-WE-AIR-SW-PSW_A9_S2S

Type of course: optional

Language of instruction: Polish

Director of studies: Ass. Prof. Mariusz Jacyno, Ph.D.

Name of lecturer: Ass. Prof. Mariusz Jacyno, Ph.D.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					5
Lecture	30	2	II	Grade	
Project	15	1		Grade	
Part-time studies					
Lecture	18	2	II	Grade	
Project	9	1		Grade	

COURSE OBJECTIVE:

To introduce students to novel techniques of building distributed intelligent systems. To develop skills in working in a group and designing software components responsible for multi-robot coordination.

ENTRY REQUIREMENTS:

Programming with essentials of algorithmics, Artificial intelligence methods, Distributed systems

COURSE CONTENTS:

Introduction. Agents and objects. Agents and expert systems. Agents and distributed systems. Typical behaviours of agent systems.

Intelligent agents. Abstract architectures for intelligent agents. Design of intelligent agents. Deductive reasoning agents. Agents as reactive systems. Hybrid agents.

Multiagent systems. Social aspects of agency theory. Coordination techniques. Distributed problem solving. Collaboration: cooperative distributed problem solving (CDPS), partial global planning, consistency and coordination.

Distributed and dencetralised systems engineering. Multi-agent systems as complex systems. Engineering autonomic systems using agent-based techniques. Applying multi-agent systems to model distributed, multi-robot systems in cooperative scenarios. Decentralised control techniques based on bio-inspired coordination algorithms.

TEACHING METHODS:

Lecture, project assignment.

LEARNING OUTCOMES:

Code	Effects of the course
K1A_W12	*Skills and competencies needed to design intelligent autonomous agents.*
K1A_W12	*Knowledge of the main approaches and techniques to implement software agents.*
K1A_U13	*Skills and competencies of designing multi-agent systems together with techniques to enable communication and cooperation in such systems.*

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lecture – the passing condition is positive mark obtained from a written test

Project – the passing condition is a positive mark obtained from a project assignment

Calculation of the final grade: lecture 50% + project 50%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
45	Class participation	1,5
15	Reading of supplementary texts	0,5
15	Preparation of reports	0,5
30	Assignment completion	0,5
15	Personal and on-line consultations	0,5
30	Preparation for tests	0,5
150	**Total**	**5**
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
27	Class participation	0.9
20	Reading of supplementary texts	0,6
23	Preparation of reports	0,7
30	Assignment completion	1
20	Personal and on-line consultations	0.6
30	Preparation for test	1
150	**Total**	**5**

RECOMMENDED READING:

1. M. Wooldridge. *Multi-agent systems (second edition)*, MIT Press, 2013
2. Y. Shoham and K. Leyton-Brown *Multiagent Systems: Algorithmic, Gamer-Theoretic, and Logical Foundations,* Cambridge University Press, Cambridge, 2008

OPTIONAL READING:

1. M. Wooldridge, *An Introduction to MutliAgent Systems*, Wiley, Chichester, 2009

REMARKS: -

MACHINE VISION AT ROBOTICS AND AUTOMATIZATION

Course code: 11.9-WE-AIR-WMWRIA-PSW_A9_S2S
Type of course: Optional
Language of instruction: Polish
Director of studies: Ass. Prof. Bartłomiej Sulikowski, Ph.D.
Name of lecturer: Ass. Prof. Bartłomiej Sulikowski, Ph.D.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					2
Lecture	30	2	II	Grade	
Project	15	1		Grade	
Part-time studies					
Lecture	18	2	II	Grade	
Project	9	1		Grade	

COURSE OBJECTIVE:

- To familiarize students with the applications of vision systems in the robot control and complex robotics systems control
- To familiarize students with the advanced algorithms of image processing, feature extraction and classification of the the vision system
- To develop the tuning skills of the image processing system (use of filters of different kinds, two-dimensional Fourier transform, Hadamard transform)
- To familiarize students with the stereovision
- To familiarize students with the problem of motion recognition (determining the direction, speed, position anticipation etc.)

ENTRY REQUIREMENTS:

Digital signal processing, Vision systems, Decision support systems

COURSE CONTENTS:

Digital Image Acquisition. Optics. Discretization. Shannon Theorem. CCD and CMOS sensors, Images transfer effective methods

Integration of the vision systems with executive devices (robots, automatic control systems) and protection systems.

Global and local transformations. Fourier transformation. Fast Fourier transformation. Hadamard transformation. Linear and nonlinear operators.

Segmentation methods. Thresholding. Gradient methods.

Feature selection and extraction. Statistical methods. Principal Component Analysis (PCA). Entropy minimization method (ME).

Classification. NN methods, Artificial intelligence methods in pattern recognition.

Stereovision.

Image oriented robot control. Orientation. Movement detection.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_W07	*Student can describe a stereovision issue and identify areas of its applications in robotics*
K2A_W07	*Student can characterize the process control of a manipulator based on a vision system*
K2A_W07	*Student can characterize all stages of image processing*
K2A_W07, K2A_U11	*Student can suggest integral elements selection for meeting given requirements*
K2A_U11	*Student can integrate a visual system with operating automatics and robotics systems*
K2A_W07	*Student knows operation of industrial visual systems*
K2A_W07	*Student can describe a stereovision issue and identify areas of its applications in robotics*
K2A_W07	*Student can characterize the process control of a manipulator based on a vision system*

ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass is a sufficient number of positive evaluations of written or oral tests conducted at least once per semester.

Project – the main condition to get a pass is a positive assessment of the project task assigned by the lecturer.

Calculation of the final grade: lecture 65% + project 35%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
45	Class participation	1,5
5	Preparation for classes	0,17
7	Reading of supplementary texts	0,23
3	Preparation of reports	0,1
60	**Total**	**2**
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
27	Class participation	0,9
7	Reading of supplementary texts	0,24
6	Preparation of reports	0,2
10	Preparation for classes	0,33
10	Assignment completion	0,33
60	**Total**	**2**

RECOMMENDED READING:

1. Horn B. K. P., *Robot Vision*, MIT Press, McGraw--Hill, 1986
2. Nieniewski M., *Digital Images segmentation. Watershed segmentation method,* EXIT, Warsaw, 2005 (in Polish)
3. Davies E.R., *Machine Vision. Theory, algorithms, practicalities,* Elsevier, 2005
4. Hornberg A. (ed)., *Handbook of machine vision*, Willey-VCH Verlag, 2006

OPTIONAL READING:

1. Skarbek W., *Digital images representation methods*, PLJ, Warsaw, 1993, (in Polish).
2. Pavlidis T., *Graphics and image processing*, WNT, Warsaw, 1987, (in Polish).
3. Tadeusiewicz R., Korohoda P., *Computer-based analisys and processing of images*, FPT, Cracow, 1997, (in Polish).
4. Ballard D. H., Brown C. M., *Computer Vision*, Prentice--Hall, New York, 1982.

REMARKS: -

METHODS OF PROGRAMMING OF LOGIC CONTROLLERS

Course code: 11.9-WE-AIR-MPSL-PSW_B10_S2S

Type of course: Optional

Language of instruction: Polish

Director of studies: Ass. Prof. Grzegorz Andrzejewski, Ph.D.
Ass. Prof. Małgorzata Kołopieńczyk, Ph.D.

Name of lecturer: Employees WIEA

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					2
Lecture	30	2	II	Grade	
Laboratory	15	1		Grade	
Part-time studies					
Lecture	18	2	II	Grade	
Laboratory	9	1		Grade	

COURSE OBJECTIVE:

To provide knowledge on design and programming of contemporary industrial control systems of PLC class.
To develop skills in configuration and programming of SIMATIC S7-1200 controllers.
To develop skills in visualization of simple industrial processes.

ENTRY REQUIREMENTS:

Control theory.

COURSE CONTENTS:

Introduction to formal specification and verification of programs for logical control.
Design of program in Ladder Diagram language with use of decision tables.
New generation PLC controllers: S7 series. Network configuration, system structure. Programming with new engineering tools.
PLC programming according to IEC standard. Process visualisation. Human Machine Interface in control system.
Implementation of control algorithms. Program concurrency. Diagnostics of control algorithm.
Algorithm specification in Function Block Diagram and Ladder Diagram. Modular and linear program structure.
Program testing and verification.

TEACHING METHODS:

Lecture, laboratory exercises.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_W12	*Possesses skills to visualize simple production processes*
K2A_U16	*Can solve tasks related to realization of control system based on PLC controllers*
K2A_W12	*Can characterize digital control systems specification methods*
K2A_U16	*Knows and can practically apply PLC drivers programming languages*

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lecture – the passing condition is to obtain a positive mark from the test.

Laboratory – the passing condition is to obtain positive marks from laboratory exercises to be planned during the semester.

Calculation of the final grade: lecture 50% + laboratory 50%.

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
45	Class participation	1,5
3	Preparation for classes	0,1
3	Reading of supplementary texts	0,1
3	Preparation of reports	0,1
6	Assignment completion	0,2
60	**Total**	**2**
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
27	Class participation	0,9
7	Preparation for classes	0,23
7	Reading of supplementary texts	0,23
7	Preparation of reports	0,24
12	Assignment completion	0,4
60	**Total**	**2**

RECOMMENDED READING:

1. F. Bonifatti, P. Monari, U. Samperi, IEC 1131-1 Programming Methodology. Software engineering methods for industrial automated systems, CJ International, 1997.
2. L. A. Bryan, E. A. Bryan: Programmable controllers. Theory and Implementation, Amber Technical Pub, 2003.
3. K. Collins: PLC Programming for Industrial Automation, Exposure Publishing, 2006.

OPTIONAL READING: -

REMARKS: -

AUTOMATION OF SYSTEMS USING RENEWABLE ENERGY SOURCES

Course code: 06.0-WE-AIR-ASZOZE-PSW_C14_S2S

Type of course: Optional

Language of instruction: Polish

Director of studies: Prof. Grzegorz Benysek, Ph. D., D.Sc.

Name of lecturer: Ass. Prof. Marcin Jarnut, Ph. D.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					2
Lecture	15	1	III	Grade	
Laboratory	15	1		Grade	
Part-time studies					
Lecture	9	1	III	Grade	
Laboratory	9	1		Grade	

COURSE OBJECTIVE:

To provide fundamental knowledge in subject of analysis and control for modern systems with renewable energy sources (RES).

To develop skills in proper RES selection and evaluation for industrial applications.

ENTRY REQUIREMENTS:

Control theory, Sensorics and industrial measurements

COURSE CONTENTS:

Introduction. Energy resources and energy needs.

Renewable energy sources. Wind energy. Wind transformation systems. Solar energy. Types and construction of solar collectors. Examples of industrial installations using photo-voltaic cells. Geothermic energy. Basic functioning and construction of heat pumps. Biogas, biomass and waste heat. Fermentation as a means of obtaining biogas. Exploitation of straw, brush wood. Exploitation of electrolysis and hydrogen.

Renewable energy source control systems. Control in systems using photo-voltaic cells. Automation of wind generators. Automatic control of heat pumps. Control systems for solar collectors. Controlling systems using biomass and biogas.

Energy systems using renewable energy sources. Automation of systems using combined renewable electrical energy sources. Systems using photo-voltaic cells and solar collectors. Heating systems using heat pumps, solar collectors and boilers fueled by biomass or biogas.

Renewable energy sources in intelligent buildings. Intelligent buildings. Control systems in intelligent buildings. Exploitation of renewable energy sources in intelligent buildings. Management of electrical energy. Heating systems. Automation of different systems in intelligent buildings. Application of PLC controllers in intelligent buildings using renewable energy sources.

TEACHING METHODS:

Lecture, laboratory exercises.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_W10	Has knowledge on renewable energy sources
K2A_W10	Knows theoretical fundamentals of controlling systems and applications of renewable energy sources in intelligent buildings
K2A_W10	Knows problems related to operation automation of renewable energy sources systems
K2A_U13	Can use the methods and devices enabling the analysis of the properties of systems with renewable energy sources

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass are sufficient marks in written or oral tests conducted at least once per semester.

Laboratory – the passing condition is to obtain positive marks from all laboratory exercises to be planned during the semester.

Calculation of the final grade: lecture 50% + laboratory 50%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
30	Class participation	1,0
6	Preparation for classes	0,2
6	Reading of supplementary texts	0,2
6	Preparation of reports	0,2
6	Assignment completion	0,2
6	Personal and on-line consultations	0,2
0	Preparation for exam	0
60	**Total**	**2**
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
18	Class participation	0,6
6	Reading of supplementary texts	0,2
6	Preparation of reports	0,2
9	Preparation for classes	0,3
9	Assignment completion	0,3
12	Personal and on-line consultations	0,4
0	Preparation for exam	0
60	**Total**	**2**

RECOMMENDED READING:

1. Heier S., Waddington R.: Grid integration of wind energy conversion systems, John Wiley & Sons, 2006.
2. Luque A.: Handbook of photovoltaic science and engineering, John Wiley & Sons, 2003.
3. R. O'Hayre, *Fuel Cell Fundamentals,* John Wiley & Sons, 2006

OPTIONAL READING:

1. E. Klugmann, E. Klugmann-Radziemska, *Alternatywne źródła energii. Energetyka fotowoltaiczna*, Wydawnictwo Ekonomia i Środowisko, Białystok, 1999
2. W. Lewandowski, Proekologiczne źródła energii odnawialnej, WNT, Warszawa, 2001
3. J. Marecki, *Podstawy przemian energii*, WNT, Warszawa, 1995
4. T. Legierski, J. Kasprzyk, J. Wyrwał, J. Hajda, *Programowanie sterowników PLC*, Wydawnictwo Pracowni Komputerowej Jacka Skalmierskiego, Gliwice 1998

REMARKS: -

INDUSTRIAL DRIVES AND ELECTRIC VEHICLES

Course code: 06.0-WE-AIR-NUPIPM-PSW_C14_S2S

Type of course: Optional

Language of instruction: Polish

Director of studies: Assoc. Prof. Adam Kempski, Ph. D., D.Sc.

Name of lecturer: Assoc. Prof. Robert Smoleński, Ph. D., D.Sc.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					2
Lecture	15	1	III	Grade	
Laboratory	15	1		Grade	
Part-time studies					
Lecture	9	1	III	Grade	
Laboratory	9	1		Grade	

COURSE OBJECTIVES:

Provide knowledge on modern drives in typical industrial applications and mechanical vehicles. Deliver understanding of various stability criteria. Provide skills in proper selection of drives for industrial devices and vehicles.

ENTRY REQUIREMENTS:

Control engineering, Actuators, Precision drives and industrial robots

COURSE CONTENTS:

Structures and control algorithms of the drives applied in industrial devices and electrical vehicles. DC drives: commutator with electromagnetic excitation, commutator with permanent magnet excitation, brushless DC. Three-phase AC drives: asynchronous induction squirrel-cage, permanent magnet synchronous motor, synchronous reluctance.

Pneumatic and hydraulic drives. Structure and principles of operation of basic pneumatic elements. Examples of the typical pneumatic drives. Introduction to hydraulic drives. Hydraulic servo drives.

Specificity of industrial devices drives. Mechanical characteristics of the load and drives selection for: machine tool, crane, winder, cam, etc. Monitoring-control systems for drives.

Electromechanical systems of vehicles. Electric drives for vehicles. Hybrid drive systems. Structure of torque transfer arrangement. Electrical steering system. Electrohydraulic and electromechanical brakes. Fuel cells. Properties of accumulator types (mechanical, electrochemical, hydro accumulators, ultra capacitors). Conceptions of electrical cars charging.

TEACHING METHODS:

Lecture, Laboratory exercises.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_W14	*is aware of the importance of electric drives for technology development*
K2A_W14	*Can choose the proper parameters of converter drives in order to enlarge their power efficiency*
K2A_U18	*Can classify electric drives and choose the appropriate drive system to the specific requirements of industrial devices and mechanical vehicles*
K2A_W14	*Can apply basic characteristics of electric machines and mechanical characteristics of workstations in drives selection of industrial devices and mechanical vehicles*

ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass is a sufficient number of positive evaluations of written or oral tests conducted at least once per semester.

Laboratory – in order to get a credit it is necessary to earn positive grades for all laboratory works defined by tutor

Calculation of the final grade: lecture 60% + laboratory 40%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
30	Class participation	1
6	Preparation for classes	0,2
6	Reading of supplementary texts	0,2
6	Preparation of reports	0,2
6	Assignment completion	0,2
6	Personal and on-line consultations	0,2
180	**Total**	**2**
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
18	Class participation	0,6
9	Reading of supplementary texts	0,3
9	Preparation of reports	0,3
9	Preparation for classes	0,3
9	Assignment completion	0,3
8	Personal and on-line consultations	0,26
8	Preparation for exam	0,26
180	**Total**	**2**

RECOMMENDED READING:

1. I. Boldea, S.A. Nasar, Electric Drives, CRC Press, 1999
2. T. Orłowska-Kowalska, Bezczujnikowe układy napędowe z silnikami indukcyjnymi, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław, 2003
3. M. P. Kaźmierkowski, F. Blaabjerg, R. Krishnan, Control in Power Electronics, Selected Problems, Elsevier, 2002
4. T. R. Crompton, Battery Reference Book, Newnes, Oxford, 2003

OPTIONAL READING:

1. H. Tunia, M. P. Kaźmierkowski, Automatyka napędu przekształtnikowego, PWN, 1987, (in Polish)
2. Z. Grunwald, Napęd elektryczny, WNT, 1987 (in Polish)
3. W. Szejnach, Napęd i sterowanie pneumatyczne, WNT, 2005 (in Polish)

REMARKS: -

CONTROL IN THE STRUCTURE OF WIDE-AREA NETWORKS

Course code:	06.5-WE-AIR-SWSSR-PSW_D15_S2S
Type of course:	Optional
Language of instruction:	Polish
Director of studies:	Assoc. Prof. Wiesław Miczulski, Ph. D., D.Sc.
Name of lecturer:	Ass. Prof. Robert Szulim, Ph.D.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					2
Lecture	15	1	III	Grade	
Laboratory	15	1		Grade	
Part-time studies					
Lecture	9	1	III	Grade	
Laboratory	9	1		Grade	

COURSE OBJECTIVE:

To familiarize with selected elements of information technology used in the structure of systems using wide area network.

To develop basic skills in the design and commissioning of systems using network interfaces, components of concurrent programming and databases.

ENTRY REQUIREMENTS:

Programming with essentials of algorithmic, Computer networks

COURSE CONTENTS:

Introduction. Selected elements of the network technologies used in the structure of the wide area network. Protocols: TCPIP, HTTP, FTP and SMTP.

Overview of the capabilities of modern operating systems used in embedded devices and servers to communicate with external devices using TCPIP protocol. Dedicated software solutions for the data exchange in heterogeneous network environments. TCP and UDP streams of the network data exchange.

Selected elements of building concurrent applications. Use them to build applications that use Internet technologies and automation equipment. Processes, threads, sharing resources and deadlock avoiding

The Web Servers. The construction of servers, administration and implementation in the wide area network structure. Launching the web server on Windows and Linux operating systems. Designing

Web portals to cooperate with control devices. The use of Java and. NET control in the structure of a wide area network.

The use of selected elements of the technology to transmit data over the network environments and present them in the form of applets on Web pages.

Integration of database systems with the automation devices. Selected elements of building applications for embedded systems to collect data in databases and make them available for further processing

TEACHING METHODS:

Lecture, laboratory exercises, team work, project.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_W15, T2A_W02	Is aware of the importance of data exchange between devices and systems in the area of automatics and robotics
K2A_U19, T2A_U09, T2A_U10, T2A_U16	Can build a simple IT system employing communication interface and elements of concurrent programming
K2A_U19, T2A_U09, T2A_U10, T2A_U16	Can build a simple IT system with a database implementation in order to store system operation information
K2A_U19, T2A_U09, T2A_U10, T2A_U16	Can start simple, dynamic web portals
K2A_W15, T2A_W02	Has a basic knowledge on information technologies used in the structure of WAN

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass are sufficient marks in written or oral tests conducted at least once per semester.

Laboratory – the passing condition is to obtain positive marks from all laboratory exercises to be planned during the semester.

Calculation of the final grade: lecture 40% + laboratory 60%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
30	Class participation	1,0
8	Preparation for classes	0,26
6	Reading of supplementary texts	0,20
4	Preparation of reports	0,14
8	Assignment completion	0,26
4	Personal and on-line consultations	0,14
60	**Total**	2
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
18	Class participation	0,60
9	Reading of supplementary texts	0,30
4	Preparation of reports	0,14
9	Preparation for classes	0,30
10	Assignment completion	0,33
10	Personal and on-line consultations	0,33
60	**Total**	2

RECOMMENDED READING:

1. W.R. Stevens, *Programming web applications in Unix*, Scientific and Technical Publishers, Warsaw 1995
2. Carver R., Tai K.: *Modern multithreading*, Wiley Publications, 2006
3. Wei L., Matthews C., Parziale L., Rosselot N., Davis C., Forrester J., Britt D., *TCP/IP Tutorial and Technical Overview*, An IBM Redbooks publication, 2006

OPTIONAL READING:

1. Boese E., *An Introduction to Programming with Java Applets*, Jones and Bartlett publishers, 2009
2. Hart C., Kaufmann J., Sussman D., Ulmann C., *Beginning ASP.NET 2.0*, Wiley Publishing, 2006
3. Stephens R., *Start Here! Fundamentals of Microsoft® .NET Programming*, Microsoft, 2011
4. Ullman Jeffrey D., Widom Jennifer , *A First Course in Database Systems,* Pearson Prentice Hall, 2008

REMARKS: -

COMMUNICATION SYSTEMS

Course code: 06.5-WE-AiR-ASzOŹE-PSWD15_S2S

Type of course: optional

Language of instruction: Polish

Director of studies: Doc. Emil Michta, Ph.D.

Name of lecturer: Doc. Emil Michta, Ph.D.

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
Full-time studies					2
Lecture	15	1	III	Grade	
Laboratory	15	1		Grade	
Part-time studies					
Lecture	9	1	III	Grade	
Laboratory	9	1		Grade	

COURSE OBJECTIVE:

To provide fundamental knowledge in knowledge of the communication systems features. To develop skills and competencies needed to analysis and synthesis communication systems used to object , industrial process and environments automation.

ENTRY REQUIREMENTS:

Computer networks

COURSE CONTENTS:

Evolution of the communication systems. ISO/OSI and ISA models. Classification of the communication systems. Communication model of the automation networked system. Analysis of the communication parameters. Static and dynamic tasks models. Analysis of the time constrains in automation systems - RM, DM and EDF methods. Local communication systems. Fieldbus networks and local area networks in the automation systems. Communication standards of the local communication systems. Analysis and synthesis of the automation systems based on networks: Profibus, CAN, LonWorks and Interbus-S. Analysis and synthesis of the automation systems based on IEEE 802.11 and IEEE 802.15 networks. Industrial Ethernet in local communication systems. Wide area communication systems. Standard and dedicated wide area communication systems in automation. Use of the cable, fiber and wireless telecommunication networks. Internet technologies in distributed automation systems. Time constrains in TCP/IP networks. Protocol tunneling in local systems. Security of the data transfers. Solutions of the communication systems in industrial process and object automation. Integration of the communication systems.

TEACHING METHODS:

Lecture, laboratory exercises.

LEARNING OUTCOMES:

Code	Effects of the course
K2A_W15	Is aware of the importance of communication systems in the area of automatics and robotics
K2A_U20	Can determine communication parameters for chosen communication standards
K2A_U20	Can build and start chosen communication systems
K2A_W15	Has the basic knowledge in the area of standards, construction and operation of communication systems

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lecture – the main condition to get a pass are sufficient marks in written or oral tests conducted at least once per semester.

Laboratory – the passing condition is to obtain positive marks from all laboratory exercises to be planned during the semester.

Calculation of the final grade: lecture 50% + laboratory 50%

STUDENT WORKLOAD:

Full-time studies		
No. of hours	**Type of workload**	**ECTS**
30	Class participation	1,00
15	Preparation for classes	0,50
5	Reading of supplementary texts	0,17
10	Assignment completion	0,33
60	**Total**	2
Part-time studies		
No. of hours	**Type of workload**	**ECTS**
18	Class participation	0,60
19	Preparation for classes	0,63
5	Reading of supplementary texts	0,17
10	Assignment completion	0,33
8	Personal and on-line consultations	0,27
60	**Total**	2

RECOMMENDED READING:

1. Kowalik R., Pawlicki C.: Podstawy teletechniki. Oficyna Wydawnicza Politechniki Warszawskiej. Warszawa, 2006.
2. Michta E.: Modele komunikacyjne sieciowych systemów pomiarowo - sterujących. Wydawnictwo Politechniki Zielonogórskiej. Zielona Góra, 2000.
3. Thompson L.M.: Industrial Data Communication. ISA, 2007.

OPTIONAL READING:

1. Mahalik N.P.: Fieldbus Technology. Springer, 2003
2. Neuman P.: Systemy komunikacji w technice automatyzacji. COSIW, Warszawa, 2003

REMARKS: -