GDAŃSK UNIVERSITY OF TECHNOLOGY

Subject card

Subject name and code	Probability Methods and Statistics, PG_00067428		
Field of study	Automatic Control, Cybernetics and Robotics		
Date of commencement of studies	October 2026	Academic year of realisation of subject	2026/2027
Education level	first-cycle studies	Subject group	Obligatory subject group in the field of study Subject group related to scientific research in the field of study
Mode of study	Full-time studies	Mode of delivery	at the university
Year of study	1	Language of instruction	Polish
Semester of study	2	ECTS credits	4.0
Learning profile	general academic profile	Assessment form	exam
Conducting unit	Department of Decision Systems and Robotics -> Faculty of Electronics Telecommunications and Informatics -> Faculties of Gdańsk University of Technology		
Name and surname of lecturer (lecturers)	Subject supervisor	dr inż. Sebastian Dziedziewicz	
	Teachers	mgr inż. Tomasz Nowak mgr inż. Michał Kopczyński dr inż. Sebastian Dziedziewicz	

Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	15.0	30.0	0.0	0.0	0.0	45
	E-learning hours included: 0.0						

Learning activity and number of study hours	Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
	Number of study hours	45	4.0	51.0	100

Subject objectives

The course aims to master modern probability theory and practical statistical methods necessary to describe, analyse, and model random phenomena in control systems, measurements, and robotics. After completing the course, the student:

- can formulate an engineering problem in the terminology of probability theory
- determines and applies appropriate tools of probability and statistics
- is freely using the approach of one-dimensional and multidimensional distributions (Gauss, Poisson, Rayleigh)
- can determine moments, use Bayes' law, and limit theorems to estimate risk and design decision algorithms
- critically interprets results, assessing uncertainty and decision risk

The competencies acquired in the course provide a solid foundation for use in further stages of education. The ability to precisely assess measurement uncertainty and quantisation errors will be helpful in the design and analysis of digitally implemented control systems. Knowledge of maximum trustworthiness estimators and the Monte Carlo method proves crucial during the calibration of dynamic models and the analysis of experimental data. Understanding the theory of moments and covariance matrices enables the efficient processing of information from multiple sensors. The concepts of entropy and information measures support the selection of cost functions and the assessment of the generalizability of predictive models. This provides the student with a coherent, practically oriented foundation that facilitates further education in the areas of adaptive control, system diagnostics, and intelligent methods of processing engineering data.

Learning outcomes	<table><tr><th>Course outcome</th><th>Subject outcome</th><th>Method of verification</th></tr><tr><td>[K6_U07] can apply methods of process and function support, specific to the field of study</td><td>The student applies estimation and statistical tests to data from automation systems and interprets the results to select a control strategy or diagnose the condition of an object.</td><td>[SU1] Assessment of task fulfilment [SU2] Assessment of ability to analyse information</td></tr><tr><td>[K6_W01] knows and understands, to an advanced extent, mathematics necessary to formulate and solve simple issues related to the field of study</td><td>The student analyses the properties of distributions (moments, variance, and covariance) and explains their influence on measurement accuracy and control quality, as well as assessing the reliability of measurement data.</td><td>[SW1] Assessment of factual knowledge</td></tr><tr><td>[K6_U01] can apply mathematical knowledge to formulate and solve complex and non-typical problems related to the field of study and perform tasks, in an innovative way, in not entirely predictable conditions, by:n- appropriate selection of sources and information obtained from them, assessment, critical analysis and synthesis of this information,n- selection and application of appropriate methods and toolsn</td><td>The student formulates and solves probabilistic engineering problems: constructs a random model (selects a distribution and its parameters), performs calculations, and, based on this, assesses the risk or determines the parameters of the control system.</td><td>[SU4] Assessment of ability to use methods and tools [SU3] Assessment of ability to use knowledge gained from the subject</td></tr></table>
Subject contents	Course content – lecture 1. Fundamentals of probability theory: definitions of random events and event algebra, axiomatic definition of probability, classical and frequentist interpretations. 2. Conditional probability and independence of events, theorem of total probability, Bayes' theorem. Applications in decision systems and data filters in automation. 3. Discrete and continuous random variables: distribution function and its role in describing distributions, as well as the basic properties of the probability density function. 4. Multivariate random distributions: common distribution function, marginal distributions and analysis of dependencies between variables in signals and measurement systems. 5. Conditional distributions: determination and application in simple decision algorithms and control systems with uncertainty. 6. Expected value and conditional mean: importance in prediction and parameter selection, e.g., controllers in the presence of uncertainty. 7. Higher order moments, variance and standard deviation: definitions, interpretation of the distribution dispersion and applications in the analysis of measurement errors. 8. Moments of multivariate random variables: correlation, covariance and their use in signal detection, fault diagnosis and improvement of control efficiency. 9. Discrete probability distributions (including two-point, binomial, and Poisson): examples of applications in reliability, queuing analysis and binary signal generation. 10. Basic continuous distributions (Gaussian, exponential, Weibull, Rayleigh): modelling disturbances, element lifetime and random phenomena in signal engineering. 11. Multivariate normal distribution: properties and generation, with applications in filters (e.g., Kalman filter) for state estimation and noise reduction in control systems. 12. Functions of random variables: the transformation of distributions in the case of discrete and continuous variables, practical use in modelling signals and nonlinear systems. 13. Types of convergence (almost specific, in a distribution), Chebyshev's inequalities, the law of large numbers and the central limit theorem: importance in assessing the quality of control with a large number of measurements. 14. Entropy and information theory: measures of uncertainty in probability distributions, information flow in telecommunications channels and analogies in assessing disturbances in control systems. 15. Elements of mathematical statistics: parameter estimation, simulation methods (e.g. Monte Carlo) and the basics of Markov processes. Analysis and modelling of noise in measurement signals and practical applications in selecting controller settings.
Prerequisites and co-requisites	The student should be able to freely apply differential and integral calculus of functions of one and several variables, in particular, understand the concepts of derivatives, definite and multiple integrals, and fundamental limit theorems of mathematical analysis. Knowledge of linear algebra elements is also required, including operations on matrices, the concept of eigenvalues and eigenvectors, and their geometric interpretation and computational applications. Such preparation ensures the smooth assimilation of probabilistic methods discussed in the course and enables the independent solution of statistical tasks. An additional advantage (although not formally required) is knowledge of programming languages, especially Python, which will facilitate numerical calculations and the visualisation of solutions.
Assessment methods and criteria	<table><tr><th>Subject passing criteria</th><th>Passing threshold</th><th>Percentage of the final grade</th></tr><tr><td>Two tests during the semester (calculus tasks)</td><td>50.0%</td><td>50.0%</td></tr><tr><td>Written exam (open-ended essay questions)</td><td>60.0%</td><td>40.0%</td></tr><tr><td>Activity during exercises (solving tasks at the board)</td><td>0.0%</td><td>5.0%</td></tr><tr><td>Homework (numerical calculations)</td><td>0.0%</td><td>5.0%</td></tr></table>

Recommended reading	Basic literature	1. R. Hanus and O. W. P. Rzeszowskiej, Rachunek prawdopodobieństwa i statystyka matematyczna: podstawy statystyki : laboratorium / Robert Hanus.pol. Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej, 2009, ISBN: 9788371995927 2, J. Jakubowski and R. Sztencel, Wstęp do teorii prawdopodobieństwa / Jacek Jakubowski, Rafał Sztencel. pol, Wyd. 4. rozsz. Warszawa: Script, 2010, ISBN: 9788389716194
	Supplementary literature	1.A. Papoulis and S. U. Pillai, Probability, Random Variables, and Stochastic Processes, Fourth. Boston: McGraw Hill, 2002, ISBN: 9780071122566 2.H. S. Kushner, A. Chojnowska-Michalik, J. Koronacki, and P.W.N. Wydawca, Wprowadzenie do teorii sterowania stochastycznego / Harold Kushner; [z ang. tł. Anna Chojnowska-Michaliki Jacek Koronacki]. pol, Wydanie I., ser. BNI Biblioteka Naukowa Inżyniera. Warszawa: Państ. Wydaw. Naukowe, 1983, ISBN: 8301022124 3. S.Särkkä and L.Svensson, Bayesian Filtering and Smoothing, ser. Institute of Mathematical Statistics Textbooks. Cambridge University Press, 2023, ISBN: 9781108912303.
	eResources addresses	
Example issues/ example questions/ tasks being completed	**Sample exam question:** *Explain how the entropy of the measurement signal limits the throughput of the data transmission path in an automatic control system.* **Sample task to be solved during exercises/tests:** *Determine the distribution function and mass of the probability distribution of a random event for the failure of device A or device B. Both devices work independently. The probability of failure of device A is 0.2, and of device B is 0.3.* **Sample homework:** *Select and implement in Python a maximum trustworthiness estimator of the Rayleigh distribution parameters for a sample data set from a LiDAR radar.*	
Practical activites within the subject	Not applicable	

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