DOCTORAL SCHOOL OF WROCŁAW UNIVERSITY OF SCIENCE AND TECHNOLOGY

SUPERVISOR/TEAM/ DECLARING/CONDUCTING COURSE: Prof. of WUST, Włodzimierz Brząkała, PhD,Eng.
DEPARTMENT: Civil Engineering Department
SCIENTIFIC DISCIPLINE: Civil Engineering and Transport

COURSE CARD

Course name in Polish: Symulacje *Monte Carlo* w obliczeniach inżynierskich
Course name in English: *Monte Carlo* simulations in engineering problems
Course language: Polish / ~~English~~*
University-wide general course type*:
The course is intended for all PhD students: YES / NO
1) BASIC COURSE
~~2) SPECIALIST COURSE~~
~~3) SEMINAR~~
~~4) HUMANISTIC COURSE~~
~~5) LANGUAGE~~

Subject code: ILQ100023W

* delete as applicable

	Lecture	Foreign language course	Seminar	Mixed forms
Number of hours of organized classes in university (ZZU)	30	-	-	-
Grading	Exam	Exam	Oral presentation	Exam, inspection, evaluation classes
Number of ECTS points	**0**	-	-	-

PREREQUISITES RELATING TO KNOWLEDGE, SKILLS AND OTHER COMPETENCES

1. Has a background in elementary mathematical analysis (calculus) and algebra.
2. Has basic practical knowledge regarding probability calculus, mathematical statistics and fundamentals of computer sciences.
3. Understands the impact of input random parameters on output random fluctuations of the results obtained in system analyses.
4. Appreciates the importance of numerically simulated behaviour of real systems.

COURSE OBJECTIVES

C1. Expansion of knowledge towards theoretical foundations of the probability theory and mathematical statistics.
C2. The ability to generate sequences of pseudo-random numbers and their applications.
C3. Computer generation of pseudo-random numbers with uniform distribution on the interval (0; 1).
C4. Proficiency in transforming single random variables, random vectors, stochastic processes and random fields; transformations of probability distributions.
C5. Properties of generators of pseudo-random numbers: types of distribution, independence,

convergence (testing of generators and sequences of random numbers); shaping the awareness of the so-called *numerical traps* and *apparent accuracy*.
C6. Selected applications to modeling of phenomena and decision-making processes.

PROGRAM CONTENTS

Form of classes – lecture (Lec)		Number of hours
Lec1	Introduction: motivation (random systems), the scope of the lecture, credit conditions. Example – different simulations applied to an estimation of the number π (Buffon's needle). Definition, scheme and characteristic features of Monte Carlo methods	1 1
Lec2	Elements of the probability calculus - random variables, cumulative distribution functions	2
Lec3	Elements of probability calculus - random vectors, joint distributions	2
Lec4	Elements of the probability theory: - the law of large numbers - the central limit theorem	1 1
Lec5	Elements of mathematical statistics – parameter estimation and confidence intervals	2
Lec6	Elements of mathematical statistics - testing of distribution types and independence	2
Lec7	Generating pseudo-random numbers of the uniform distribution	2
Lec8	Generators of random variables - general methods (the inversion of cumulative distributions)	2
Lec9	Generators of random variables - general methods (the elimination method)	2
Lec10	Generators of random variables - special methods for selected distributions	2
Lec11	Different methods for generating Gaussian random variables/vectors	2
Lec12	Generating random vectors, stochastic processes and random fields	2
Lec13	Special methods of calculating integrals focused on weighted simulation	2
Lec14	Application - random strength of a bearing member with material imperfections (bending of a nonhomogeneous wooden beam); comparison with the exact solution	2
Lec15	Application - mass service system (queue theory)	2
	Total hours:	**30**

TEACHING TOOLS USED

N1. Providing a repository in the form of photocopies discussed in detail during the first six lectures.
N2. Derivations and computational transformations performed directly on the board; proofs of the simplest dependencies and conclusions.
N3. Frequent reference to practical examples and knowledge of the probability theory.
N4. Shared photocopies of complete calculations to follow a modelling process and the entire simulation algorithm.
N5. Working in groups during the Lecture No.1 = simulation calculations using various physical generators (dice, coins, tables of random numbers, calculator, phone book, Buffon's needle, internet programs);
discussion of problems in a group of students - also applies to other lectures than the No.1.

ACHIEVED SUBJECT LEARNING OUTCOMES		
Type of learning outcome	Code of learning outcome	Assessment of learning outcome
Knowledge	P8U_W	Student knows "topography", basic directions and contemporary development trends of the Monte Carlo Methods: from the first attempts by Pascal and Buffon, to contemporary simulations like Importance Sampling and simulations on fuzzy sets or linguistic variables - special emphasis is paid on issues arising from the needs of the practice.
Knowledge	P8S_WG	Control and improvement of knowledge in the field of basic subjects through frequent (interdisciplinary) questions addressed to students; as part of the content covered by the lecture, course students are able to self-assess the value of research work of other authors using Monte Carlo simulations in terms of: correctness of the algorithm, presentation of results, innovative elements, their rank and usefulness.
Knowledge	P8S_WK	The listener perceives the Monte Carlo simulation as an interdisciplinary method of modeling phenomena in the field of technology, the economic sphere and social reactions.
Skills	P8U_U	Students skill of the universal scheme of Monte Carlo Methods and sees the possibility of their use in the analysis of own original research problems.
Skills	P8S_UW	The student improves computational skills (derivation of relations, transformations of expressions, numerical examples); the lecture contains frequent repetitions of the most important facts, references to the facts and basic knowledge known from the studies; course participant can show examples from his own research interests which could be analyzed by Monte Carlo simulation.
Skills	P8S_UK	Final exam containing theoretical questions (knowledge) but also mini-computational tasks which students solve and present to the whole group during the exam.
Skills	P8S_UO	Organization of work in a small team (group work on a simulation example within the lecture Lec1).
Skills	P8S_UU	Own literature studies and own concepts on issues expanding the content of the lecture (e.g. in terms of the possibility of improving the quality of the pseudorandom number generator).
Social competence	P8U_K, P8S_KK	Open discussion on problems arising during the lecture.

PRIMARY AND SECONDARY LITERATURE

PRIMARY LITERATURE:

[1] R.Y.Rubinstein, Simulation and the Monte Carlo Metod. J.Wiley&Sons, NY 1981. (there exist also updated editions, co-authored ones).
[2] I.M.Sobol, Metoda Monte Carlo (in Russian, in English). Nauka, Moskwa 1985.
[3] R.Wieczorkowski, R.Zieliński, Komputerowe generatory liczb losowych. WNT, Warszawa 1997. (in Polish only).

SECONDARY LITERATURE:

[1] J.R.Benjamin, C.A.Cornell, Probability, Statistics, and Decisions for Civil Engineers. McGraw-Hill, NY 1970.
[2] G.E.P.Box, G.M.Jenkins, and G.C. Reinsel, G. C. Time Series Analysis: Forecasting and Control. 3rd ed., Prentice-Hall, Englewood Cliffs, N. J., 1994.
[3] S.Brandt, Data Analysis. Statistical and Computational Methods for Scientists and Engineers. Springer 1999.
[4] A.Papoulis, S.U.Pillai, Probability, Random Variables and Stochastic Processes, 4th Edition, MgGraw-Hill, 2002.
[5] T.T.Soong, Probabilistic Modeling and Analysis in Science and Engineering. J.Wiley & Sons, NY 1981.
[6] Journals *Structural Safety*, *Probabilistic Engineering Mechanics* a.o.

SUBJECT SUPERVISOR (NAME AND SURNAME, E-MAIL ADDRESS)

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