STOCHASTIC AND NON LINEAR SYSTEMS

1. GENERAL

SCHOOL OF	ENGINEERING		
DEPARTMENT OF	INFORMATICS AND COMPUTER ENGINEERING		
LEVEL OF EDUCATION	UNDERGRADUATE		
COURSE CODE	ICE-8206	**SEMESTER OF STUDIES**	8°
COURSE TITLE	STOCHASTIC AND NON LINEAR SYSTEMS		

INDEPENDENT TEACHING ACTIVITIES *in case the credits are awarded in separate parts of the course e.g. Lectures, Laboratory Exercises, etc. If the credits are awarded uniformly for the whole course, indicate the weekly teaching hours and the total number of credits.*	**WEEKLY HOURS OF TEACHING**	**ECTS CREDITS**
Lectures	2	
Practice -Exercises	2	
Add rows if needed. The teaching organization and teaching - methods used are described in detail in 4.	**4**	**5**

COURSE TYPE *Background, General Knowledge, Scientific Area, Skills Development*	Επιστημονικής Περιοχής
PREREQUISITE COURSES:	None
LANGUAGE OF TEACHING AND EXAMS :	Greek
ERASMUS STUDENTS	No
ONLINE COURSE (URL) (if available)	

2. LEARNING OUTCOMES

Learning outcomes

The learning outcomes of the course are described, the specific knowledge, skills and abilities of an appropriate level that students will acquire after the successful completion of the course.

Refer to Appendix A.

- *Description of the Level of Learning Outcomes for each course according to the Qualifications Framework of the European Higher Education Area*
- *Descriptive Indicators Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning and Annex B*
- *Summary Guide for writing Learning Outcomes*

The purpose of the course is the acquisition of theoretical and applied science skills in the field (A) of computer programming for (A1) development of statistical time series models (A2) Chaos and Long Memory Systems analysis, (A3) use of ARIMA and ARMA models, (d) analysis of Non-Linear time series of Systems and (A4) use of methods for modeling the trends of the corresponding time series, as well as in the field (B) of Stochastic Systems through (B1) creation and development of analytical and computational Stochastic Models, (B2) development of innovative Stochastic Model simulation techniques and (B3) development and use of Stochastic Model simulation software.

Upon successful completion of the course the student will be able to:

- Mention the difference between Model and Simulation
- Demonstrate knowledge and critical understanding of Dynamic Systems Programming
- Demonstrate knowledge and critical understanding of the main properties of ARMA, and ARIMA models.
- They use least squares, maximum likelihood, analysis of variance (ANOVA) and regression methods on dynamic time series of systems in relation to contextual data.
- Distinguish time series trends of dynamic systems with statistical models.
- Develop methods used to produce forecasts.

- Describe basic nonlinear time series models of dynamical systems.
- Develop key points of fractal theory.
- Define the term long-memory.
- Define Hurst and Lyapunov exponents.
- They use the spectral density function and the periodogram for the time-space spectral analysis of dynamical systems.
- Apply R/S, R-L and DFA techniques to time series of dynamical systems.
- They apply non-linear analyzes with the lumping technique and the moving window technique.
- Apply Fourier & Wavelets analysis methods to detect power law behavior.
- To create synthetic time series for control of dynamic systems.
- Describe topics related to Support Vector Machines (SVM).
- They describe the stochastic Monte Carlo method.
- Distinguish and classify the parameters of stochastic systems to create Models.
- They describe the implementation steps of two Monte-Carlo algorithms for calculating p.
- They define the fundamental parts for the Monte-Carlo simulation of transport of particles (particles) of dynamic stochastic systems.

General Abilities

Taking into account the general skills that the graduate must have acquired (as they are listed in the Diploma Supplement and are listed below), which of them is intended for the course ?.

Search, analysis and synthesis of data and information, using the necessary technologies *Adaptation to new situations* *Decision making* *Autonomous work* *Teamwork* *Working in an international environment* *Work in an interdisciplinary environment* *Production of new research ideas*	*Project design and management* *Respect for diversity and multiculturalism* *Respect for the natural environment* *Demonstration of social, professional and moral responsibility and sensitivity in gender issues* *Exercise criticism and self-criticism* *Promoting free, creative and inductive thinking*

- Autonomous Work
- Teamwork
- Analysis and synthesis of data and information, using a computer
- Promotion of inductive thinking
- Making Decisions
- Time management
- Working with deadlines

3. COURSE CONTENT

Course Outline

Introduction. Model Creation (Standards) and Simulation. System analyzing and classification. Detailed Models and Simulation Models. Model types and simulation types. Programming with computers – Platforms for use. Static time series models. Probability models. Persistency, Antipersistency, Random-walk – Random processes. Hilbert transform and Autocorrelation. ARMA and ARIMA models.

Fractal theory. Long-memory. Hurst and Lyapunov exponents. Spectral density function, Periodogram, Time-space spectral analysis. Lumping and moving window techniques. Nonlinear models. R/S, R-L, DFA analysis. Fourier Analysis & Wavelets. Power law. Synthetic and natural time series. Time Series Modelling. Monte Carlo analysis. Stochastic systems and stochastic processes. Monte Carlo method. Monte-Carlo code development. EGSnrcMP and GATE/GEANT4 platforms. Numerical and computational methods. Validity and Validation.

Content:

Introduction. Statistical methods for developing time series models of Dynamic Systems. Analysis of Probability Models. Persistence-Antipersistence and Random-walk. Hilbert Transform and Autocorrelation. ARMA and ARIMA models. Introduction to fractal theory. Long-memory Dynamic Systems. Hurst and Lyapunov exponents. Spectral density function, Periodogram, Time-space spectral analysis of Dynamical Systems. Lumping and moving window techniques. R/S, R-L, DFA analysis. Fourier & Wavelets analysis in power law. Development of synthetic time series of Dynamic Systems. for the artificial control of decision-making systems. Decision making and Time Series Modeling of Dynamic Systems. with Support Vector Machines (SVM) methods. Time Series Modeling of Dynamical Systems with Monte Carlo Analysis. Introduction to the Monte-Carlo method. A hit-or-miss calculation problem. Buffon's pin. Markov Chains, Central Limit Theorem, Chebyshev's Inequality, Law of Large Numbers. Monte Carlo variance reduction techniques. Russian Roulette. Monte Carlo programming techniques.

4. TEACHING AND LEARNING METHODS - EVALUATION

METHOD OF DELIVERY *Face to face, Distance education etc.*	In class face to face and in the laboratory
USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES *Use of ICT in Teaching, in Laboratory Education, in Communication with students*	Use of ICT in teaching PC usage Open Source Software
TEACHING ORGANIZATION *The way and methods of teaching are described in detail.* *Lectures, Seminars, Laboratory Exercise, Field Exercise, Bibliography study & analysis, Tutoring, Internship (Placement), Clinical Exercise, Art Workshop, Interactive teaching , Study visits, Study work, artwork, creation. λπ.* *The student study hours for each learning activity are indicated as well as the non-guided study hours so that the total workload at the semester level corresponds to the ECTS standards .*	see table below
STUDENT EVALUATION *Description of the evaluation process* *Assessment Language, Assessment Methods, Formative or Concluding, Multiple Choice Test, Short Answer Questions, Essay Development Questions, Problem Solving, Written Assignment, Report / Report, Oral Examination, Public Presentation, Public Presentation, Others* *Explicitly defined assessment criteria are stated and if and where they are accessible to students.*	I. Written final exam (60%) which includes Formative or Inferential Multiple Choice Test Short Answer Questions Essay Development Questions II. Project (40%) Report / Report on a selected relevant topic. Public Presentation of the work

Activity	***Semester Workload***
Lectures	26
Practice Exercises that focus on the application of methodologies and analysis of studies	26
Assignment Writing	20
Project and Case Analysis	20
Independent Study	48
Total Course Load (25 hours per credit)	**125**

5. RECOMMENDED-BIBLIOGRAPHY

- Suggested Bibliography:

1. Tsanos, A., (1992) "Chaos from Theory to Applications". Plenum Press.
2. Farge, M., Hunt, J.C.R., Vassilicos, J.C. (1993) "Wavelets, Fractals, and Fourier Transforms". Claredon Press.
3. Box, G.E. and Jenkins, G.M. (1976) "Time Series Analysis: Forecasting and Control". Holden Day, San Francisco.
4. Brockwell, P.J., Davis, R.A. (1991) "Time Series: Theory and Methods". Springer, New York.
5. Diggle, P.J. (1990) "Time Series- A Biostatistical Introduction". Clarendon Press, Oxford.
6. Fuller, W.A. (1996) "Introduction to Statistical Time Series". John Wiley, New York.
7. GATE Manual, OpenGateCollaboration (2017), http://www.opengatecollaboration.org/sites/default/files/GATE-UsersGuideV7.2.pdf (2017)
8. EGSnrcMP, PIRS 701, http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/egsnrc_index.html (2017).

- Related scientific journals:

1. Chaos, Solitons and Fractals
2. Physical Review Letters
3. Physical Review E
4. Chaos
5. Journal of Time Series Analysis
6. Computational Statistics & Data Analysis