Univerza v Mariboru

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Fakulteta za naravoslovje in matematiko

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Nelinearni dinamični sistemi
Course title:	Nonlinear Dynamical Systems

Študijski program in stopnja **Study programme and level**	**Študijska smer** **Study field**	**Letnik** **Academic year**	**Semester** **Semester**
Fizika 2. st.		1	**2**
Physics 2nd degree		1	**2**

Vrsta predmeta / Course type	Izbirni/optional
Univerzitetna koda predmeta / University course code:	

Predavanja **Lectures**	**Seminar** **Seminar**	**Sem. vaje** **Tutorial**	**Lab. vaje** **Laboratory work**	**Teren. vaje** **Field work**	**Samost. delo** **Individ. work**	**ECTS**
15		**30**				**5**

Nosilec predmeta / Lecturer:	Marko Marhl

Jeziki / Languages:	**Predavanja / Lectures:**	slovenski/Slovenian in/and angleški/English
	Vaje / Tutorial:	slovenski/Slovenian in/and angleški/English

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisits:**
Predznanje modelske fizike in fizike kompleksnih sistemov	Preknowledge of physics of complex systems and physics modelling

Vsebina:	**Content (Syllabus outline):**
Nelinearni dinamični sistemi v 1D, 2D in 3D Linearizacija in linearna stabilnostna analiza, bifurkacijska analiza. **2. Nelinearni oscilatorji** Regularni oscilatorji kot konzervativni in disipativni sistemi (center, limitni cikel), bifurkacije, bifurkacijski diagram, lokalne in globalne bifurkacije. **3. Kvaziperiodičnost, kaos**	**Nonlinear dynamical systems (1D-, 2D-, 3D- systems)** Linearization and the linear stability analysis, the bifurcation analysis. **2. Nonlinear oscillators** Regular oscillators as conservative and dissipative systems (centre, limit cycle), bifurcations, bifurcation diagram, local and global bifurcations. **3. Quasiperiodicity, chaos**

Fourierjeva transformacija in avtokorelacija, Lyapunovi eksponenti, kaos	Fourier transformation and autocorrelation, Lyapunov exponents.
4. Fraktali in fraktalne dimenzije.	**4. Fractals and fractal dimension**
5. Stohastično modeliranje (Gillespiev algoritem)	**5. Stochastical modelling** (Gillespie's algorithm)
6. Aplikacije Pomen dinamičnih sistemov v fiziki in na drugih področjih: dinamični sistemi v biologiji, okoljevarstvu, ekonomiji, ...	**6. Applications** The role of dynamical systems in physics and in other fields: dynamical systems in biology, environmental science, economy, …
7. Uporaba računalniških programov Uporaba računalniških programov za implementacijo dinamičnih sistemov: DynaSys, Stella, Madonna, C++, ...	**7. Using of computer programs** Computer programmes for the implementation of dynamical systems: DynaSys, Stella, Madonna, C++, ...

Temeljni literatura in viri / Readings:

- Steven H. Strogatz, Nonlinear Dynamics and Chaos with Applications to Physics, Biology, Chemistry, and Engineering. Perseus Pub., Cambridge, 1994.
- J. B. Snape, I. J. Dunn, J. Ingham, J. E. Prenosil, Dynamics of Environmental Bioprocesses, Modelling and Simulation, VCH Verlagsgesellschaft, Weinheim, 1995.
- Natali Hritonenko, Yuri Yatsenko, Mathematical Modeling in Economics, Ecology and the Environment, Springer, New York, 1999.
- Strokovni in znanstveni članki v revijah / Articles published in professional and scientific journals.

Cilji in kompetence:

- Razvijati sposobnosti za opravljanje kvantitativne analize dinamike kompleksnih sistemov.
- Predstaviti ključne razlike in karakteristike dinamičnih sistemov v različnih dimenzijah.
- Poudariti uporabnost znanja o dinamičnih sistemih v naravnih sistemih in prenos znanja na druga področja.
- Uporaba računalniških programov za implementacijo dinamičnih sistemov.

Objectives and competences:

- Developing skills for quantitative analysis of the dynamics of complex systems.
- Presenting basic differences and characteristics of dynamical systems in different dimensions.
- Pointing out the applicability of knowledge about dynamical systems in the nature and the transfer of knowledge to other fields.
- Using computer programs for the implementation of dynamical systems.

Predvideni študijski rezultati:

Znanje in razumevanje:

- Usvojiti metode za kvantitativno analizo dinamike kompleksnih sistemov.
- Spoznati ključne razlike in karakteristike dinamičnih sistemov v različnih dimenzijah.
- Pomen deterministicnega in stohastičnega modeliranja.
- Spoznati uporabnost znanja o dinamičnih sistemih v fiziki in prenos znanja na druga področja.
- Znati uporabljati računalniške programe za implementacijo dinamičnih sistemov.

Prenesljive/ključne spretnosti in drugi atributi:

- Metode kvantitativne analize dinamičnih sistemov so univerzalne in jih je mogoče uporabiti na najrazličnejših področjih.
- Poudarek je na prenosu znanja s primerov iz fizike na področja biologije, ekologije, ekonomije, …

Intended learning outcomes:

Knowledge and Understanding:

- Be able to use methods for quantitative analysis of the dynamics of complex systems.
- Know basic differences and characteristics of dynamical systems in different dimensions.
- Importance of deterministic and stochastic modelling.
- Be able to apply the knowledge about dynamical systems in physics to other fields.
- Using computer programs for the implementation of dynamical systems.

Transferable/Key Skills and other attributes:

- Methods for quantitative analysis of dynamical system are universal and can be implemented in different fields of research.

In particular, a knowledge transfer from examples in physics to examples in biology, ecology, economics, etc. is emphasised.

Metode poučevanja in učenja:

- Predavanja
- Teoretične vaje
- Vaje na računalniku
- Seminarske vaje

Learning and teaching methods:

- Lectures
- Theoretical exercises
- Computer exercises
- Seminar

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
• ustni izpit	**40**	• oral exam
• pisni izpit	**40**	• written exam
• projektna naloga	**20**	• projektna naloga

Reference nosilca / Lecturer's references:

BODENSTEIN, Christian, GOSAK, Marko, SCHUSTER, Stefan, MARHL, Marko, PERC, Matjaž. Modeling the seasonal adaptation of circadian clocks by changes in the network structure of the suprachiasmatic nucleus. *PLOS comput. biol.*, Sep. 2012, vol. 8, iss. 9, e1002697-1-e1002697-12.

MARHL, Marko, GOSAK, Marko, PERC, Matjaž, ROUX, Etienne. Importance of cell variability for calcium signaling in rat airway myocytes. *Biophysical chemistry*. [Print ed.], 2010, vol. 148, iss. 1/3, str. 42-50.

GOSAK, Marko, KOROŠAK, Dean, MARHL, Marko. Optimal network configuration for maximal coherence resonance in excitable systems. *Phys. rev., E Stat. nonlinear soft matter phys. (Print)*, 2010, vol. 81, iss. 5, str. 056104-1-056104-7.

GRUBELNIK, Vladimir, DUGONIK, Bogdan, OSEBIK, Davorin, MARHL, Marko. Signal amplification in biological and electrical engineering systems : universal role of cascades. *Biophysical chemistry*. [Print ed.], aug. 2009, vol. 143, iss. 3, str. 132-138.

MARHL, Marko, GOSAK, Marko, PERC, Matjaž, DIXON, C. Jane, GREEN, Anne K. Spatio-temporal modelling explains the effect of reduced plasma membrane Ca[sup]2+ efflux on intracellular Ca[sup]2+ oscillations in hepatocytes. *J. theor. biol.*, 2008, vol. 252, iss. 3, str. 419-426.