UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Humanoidna in servisna robotika
Course title:	Humanoid and Service Robotics

Študijski program in stopnja Study programme and level	Modul Module	Letnik Academic year	Semester Semester
Informacijske in komunikacijske tehnologije, 3. stopnja	Inteligentni sistemi in robotika	1	1
Information and Communication Technologies, 3rd cycle	Intelligent Systems and Robotics	1	1

Vrsta predmeta / Course type Izbirni / Elective

Univerzitetna koda predmeta / University course code: IKT3-623

Predavanja Lectures	Seminar Seminar	Sem. vaje Tutorial	Lab. vaje Laboratory work	Druge oblke	Samost. delo Individ. work	ECTS
30	**30**			**30**	**210**	**10**

**Navedena porazdelitev ur velja, če je vpisanih vsaj 15 študentov. Drugače se obseg izvedbe kontaktnih ur sorazmerno zmanjša in prenese v samostojno delo. / This distribution of hours is valid if at least 15 students are enrolled. Otherwise the contact hours are linearly reduced and transfered to individual work.*

Nosilec predmeta / Lecturer: Doc. dr. Bojan Nemec
Doc. dr. Andrej Gams

Jeziki / Languages:		
	Predavanja / Lectures:	Slovenščina, angleščina / Slovenian, English
	Vaje / Tutorial:	

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Zaključena druga stopnja bolonjskega študija ali diploma univerzitetnega študijskega programa. Pri tem predmetu je potrebno predznanje matematike, fizike, znanje o sistemih vodenja in programiranja. Priporočeni predmeti: • inteligentni sistemi vodenja robotov • robotski vid	Completed Bologna second cycle study program or an equivalent pre-Bologna university study program. This course requires profound knowledge of mathematics, physics, theory of control systems and computer programming. Recommended courses: • Intelligent robot control • Robot vision

Vsebina:	**Content (Syllabus outline):**
Osnovne značilnosti humanoidnih in servisnih robotov Predstavitev nalog v parametrični obliki: Diskretne in periodične naloge Predstavitve s skritimi markovskimi modeli,	Basic structure of humanoid and service robots Parametric policy representation Discrete and periodic policies, Representations using Hidden Markov model, Gaussian mixture model, Gaussian

skupek Gaussovih porazdelitev, mešana Gaussova regresija, dinamični generatorji giba, verjetnostni generatorji giba, interaktivni generatorji giba, podajni generatorji giba. Učenje robotov: S posnemanjem Spodbujevano učenje Posploševanje gibanja: Statistične metode posploševanja Avtonomno prilagajanje gibanja: Z uporabo učečih regulatorjev Z uporabo spodbujevanega učenja Z uporabo nevronskih mrež Učenje in prilagajanje robotskih nalog v latentnih prostorih: Zapis nalog v latentnih prostorih Učenje in izvajanje gibanja v latentnih prostorih Optimalno vodenje robotov: Optimalni regulator za linearne sisteme Razširitev optimalnega vodenja za nelinearne sisteme Prediktivno vodenje s pomočjo modelov Humanoidni in servisni roboti v človekovem okolju: Sodelovanje človeka z robotom Fizična interakcija človek – robot in robot - okolje Sinhronizacija gibanja Dvoročna manipulacija: Pristop gospodar–suženj Pristop s simetrično dekompozicijo nalog Lokomocija Navigacija: SLAM Navigacija v zaprtih prostorih Navigacija na prostem Senzorski sistemi za zaznavo okolja: RGBD kamere Laserski detektorji Detektorji bližine Uporaba servisnih robotov	mixture regression, Dynamic motion primitives, Probability motion primitives, Interactive motion primitives, Compliant motion primitives Learning for humanoid and service robots: Imitation learning Reinforcement learning Motion generalization: Statistical generalization methods Autonomous motion adaptation: Using iterative learning control Using reinforcement learning Using neural networks Robot learning and adaptation in latent spaces Latent space policy representation Learning and task execution in latent spaces Optimal robot control Using linear quadratic regulator Extension to non-linear robot dynamics Model predictive control in robotics Humanoid and service robots in human environments: Human – robot cooperation Physical human – robot and robot – environment interaction Motion synchronization and adaptation Bimanual robot control Master-slave approach Symmetrical task decomposition Locomotion Navigation: SLAM Indoor navigation Outdoor navigation Advanced sensory systems for environment detection and localization: RGBD cameras Laser scanners Proximity sensors Service robot applications

Temeljna literatura in viri / Readings:

Izbrana poglavja iz naslednjih knjig: / Selected chapters from the following books:

- Siciliano, B., and Khatib, O. (eds.) Springer Handbook of Robotics, Springer-Verlag Berlin Heidelberg, 2016. ISBN 978-3-319-32552-1
- Corke, P. Field and Service Robotics, Springer, 2006. ISBN 10 3-540-33452-1
- Calinon, S. Robot Programming by Demonstration, EPFL Press 2009, ISBN-13: 978-1439808672

- Vadakkepat, P. and Goswami, A. (eds.) Humanoid Robotics: A Reference, Springer, 2017, ISBN 978-94-007-6045-5
- Haddadin, S.: Towards Safe Robots, Springer Berlin Heidelberg, 2014
- Kober, J. and Peters, J. Learning Motor Skills from Algorithms to Robot Experiments. Heidelberg: Springer-Verlag, 2014. ISBN 978-3-319-03193-4
- Nemec, B., and Ude, A. Robot skill acquisition by demonstration and explorative learning, In New Trends in Medical and Service Robotics, Springer 2014, ISBN 978-3-319-05431-8
- Calinon, S. A Tutorial on Task-Parameterized Movement Learning and Retrieval, Intelligent Service Robotics (Springer), 9:1, 1-29, 2016.
- Herzog, A., Rotella, N., Mason, S., Grimminger, S., Schaal, S., Righetti, L. Momentum control with hierarchical inverse dynamics on a torque-controlled humanoid, Autonomous Robot 40: 473, 2016.
- Chen, N., Karl, M., van der Smagt, P. Dynamic Movement Primitives in Latent Space of Time-Dependent Variational Autoencoders. Proc. 16th IEEE-RAS International Conference on Humanoid Robots, 2016.

Cilji in kompetence:

Cilj predmeta je osvojiti znanja iz osnov humanoidne in servisne robotike, vodenja, učenja ter uporabe humanoidnih in servisnih robotov. Poudarek je na sodobnih pristopih vključevanja robotskih mehanizmov v človekovo okolje.

Pridobljena znanja bodo omogočila študentom razumevanje principov gibanja in obvladovanje osnov sodobnih tehnologij s področja servisne robotike ter prenos teh tehnologij v prakso.

Objectives and competences:

The objective of this course to obtain theoretical and practical knowledge of the basics of service and humanoid robotics, control, learning and applications of service and humanoid robots. The emphasis is on modern approaches of the integration of robot systems into human-like environments.

The obtained knowledge will allow the students to understand the basic principles of motion and handle modern technologies of service robotics and to apply these technologies into real practice.

Predvideni študijski rezultati:

Študenti bodo z uspešno opravljenimi obveznostmi tega predmeta pridobili:

- razumevanje pomena in strukture humanoidnih in servisnih robotov;
- poznavanje vrste servisnih robotov, razlikovanje med servisnimi in humanoidnimi roboti, poznavanje njihovih značilnosti in tipičnih področji uporabe servisnih ter humanoidnih robotov,
- razumevanje sodobnih oblik zapisov trajektorij gibanja,
- razumevanje pomena ter principov avtonomne adaptacije gibanja robotov,
- razumevanje principov vodenja z uporabo generatorjev gibov oz. z optimizacijo,
- razumevanje osnov zapisa in izvajanja gibanja v latentnem prostoru,
- razumevanje sistemov navigacije, vodenja in učenja z demonstracijo,
- razumevanje pomena uporabe kompleksnih

Intended learning outcomes:

Students successfully completing this course will acquire:

- understanding of the structure and the aim of humanoid and service robots;
- knowledge of main characteristics of the various types of service robots and knowledge of the most common areas of applications for service robots and reasons for application of humanoid robots,
- understanding of contemporary form of encoding trajectories of motion
- understanding of principles of autonomous motion adaptation,
- understanding of control principles using motion primitives and optimization
- understand the basics of encoding and executing motion in latent spaces
- understanding of navigation, control and programming by demonstration principles,
- understanding of the importance of the complex

senzorskih sistemov v robotskih sistemih in razumevanje razlogov za uvajanje servisnih robotov ter razlogov za uvajanje humanoidnih robotov.	sensory system in robotics, and knowledge of limitation and motivations for application of service and humanoid robots.

Metode poučevanja in učenja:	**Learning and teaching method**
Predavanja, seminar, konzultacije, individualno delo	Lectures, seminar, consultancy, individual work

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Ustni izpit	50 %	Oral exam
Seminarska naloga	25 %	Seminar work
Ustni zagovor	25 %	Oral defense

Reference nosilca / Lecturer's references:

- **A. Gams**, **B. Nemec**, A. J. Ijspeert, A. Ude. Coupling movement primitives : interaction with the environment and bimanual tasks. IEEE transactions on robotics, 30 (49), 816-830, 2014.
- R. Vuga, **B. Nemec**, A. Ude. Speed adaptation for self-improvement of skills learned from user demonstrations. *Robotica*, 34(12), 2806-2822, 2016.
- **A. Gams**, T. Petrič, M. Do, **B. Nemec**, J. Morimoto, T. Asfour, A. Ude. Adaptation and coaching of periodic motion primitives through physical and visual interaction. *Robotics and autonomous systems*, 75,340-351, 2016.
- F. Abu Dakka, **B. Nemec**, J. Jørgensen, T.R. Savarimuthu, N. Krüger, A. Ude. Adaptation of manipulation skills in physical contact with the environment to reference force profiles. *Autonomous robots*, 39 (2),199-217, 2016.
- M. Deniša, **A. Gams**, A. Ude, T. Petrič. Learning compliant movement primitives through demonstration and statistical generalization. IEEE/ASME transactions on mechatronics, 21(5), 2581-2594, 2016.