UČNI NAČRT PREDMETA/COURSE SYLLABUS	
Predmet:	ROBOTSKI SISTEMI V LOGISTIKI
Course title:	ROBOTIC SYSTEMS IN LOGISTICS

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
LOGISTIKA SISTEMOV 2.stopnja		2.	3.
SYSTEM LOGISTICS 2nd degree		2.	3.

Vrsta predmeta (obvezni ali izbirni) /
Course type (compulsory or elective)

IZBIRNI
ELECTIVE

Univerzitetna koda predmeta / University course code:

MAG

Predavanja Lectures	Sminar Seminar	Vaje Tutorial				Klinične vaje Clinical Training	Druge oblike študija Other forms of study	Samost. delo Individ. work	ECTS
16 e-P 24 a-P		AV	EV	LV	RV			100	6
			15	25					

Nosilec predmeta / Course coordinator:

TONE LERHER, DARKO HERCOG

Jeziki / Languages:

Predavanja / Lectures: | SLOVENSKI / SLOVENE |
|---|

Vaje / Tutorial: | SLOVENSKI / SLOVENE |
|---|

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites for enrolling in the course or for performing study obligations:**
Ni posebnih pogojev.	No special requirements.

Vsebina (kratek pregled učnega načrta):

1. Uvod, osnovne definicije, uporaba robotskih sistemov v logistiki.
2. Industrijski in kolaborativni roboti: zgodovina robotike, osnovne definicije, osnovne komponente, zgradba robotskega krmilnika, konfiguracije robotov, koordinatni sistemi, prostostne stopnje, direktni in inverzni kinematični model, homogene transformacije, senzorji, aktuatorji, prijemala, razvojna orodja, programiranje robotov, robotsko komisioniranje z uporabo 2D in 3D strojnega vida.
3. Mobilni roboti (avtonomna in avtomatsko vodena vozila): uporaba mobilnih robotov v logistiki, konfiguracije pogonskega in krmilnega sistema, senzorji, aktuatorji, varnostni laserski skenerji, robotski operacijski sistem (ROS), lokacijski sistemi, navigacijski sistemi, centralno nadzorni sistemi, virtualna robotska eksperimentalna orodja.
4. Brezpilotni zrakoplovi (droni): uporaba brezpilotnih zrakoplovov v logistiki, konfiguracije zrakoplovov, senzorji, aktuatorji, lokacijski sistemi, navigacijski sistemi, zemeljski nadzorni sistemi, zakonodaja.

Content (Syllabus outline):

1. Introduction, basic definitions, use of robotic systems in logistics.
2. Industrial and collaborative robots: history of robotics, basic definitions, basic components, structure of robot controller, robot configurations, coordinate systems, degrees of freedom, direct and inverse kinematic model, homogeneous transformations, sensors, actuators, grippers, development tools, robot programming, robot commissioning using 2D and 3D machine vision.
3. Mobile robots (autonomous and automated-guided vehicles): the use of mobile robots in logistics, configurations of drive and steering systems, sensors, actuators, safety laser scanners, robotic operating system (ROS), location systems, navigation systems, central control systems, virtual robotic experimental tools.
4. Unmanned aircrafts (drones): the use of drones in logistics, drone configurations, sensors, actuators, location systems, navigation systems, ground control stations, legislation.

5. Komponente in postavitve prilagodljivih proizvodnih in logističnih sistemov. Modeliranje in simulacija diskretnih dogodkovnih sistemov (discrete event systems - DES). Modeliranje DES z uporabo Petrijevih mrež.	5. Components and layouts of flexible production and logistics systems. Modeling and simulation of discrete event systems (DES). Modeling of DES using Petri nets.

Temeljna literatura in viri / Reading materials:

1. E-gradivo predmeta.
2. Mihelj, M., et al. (2019), Robotics, Springer, ISBN: 978-3030102852.
3. Ross, L. T., Fardo, S. W., & Walach, M. F. (2017). Industrial Robotics Fundamentals: Theory and Applications. Goodheart-Willcox, ISBN: 978-1631269417.
4. Günter Ullrich (2016). Automated Guided Vehicle Systems: A Primer with Practical Applications. Springer, ISBN: 978-3662448137.
5. J. Banks, J. S. Carson, B. L. Nelson, D. M. Nicol. Discrete-Event System Simulation (5th Edition), Pearson Education Limited, 2020, ISBN: 978-0136062127.
6. Zhou, M., & Wu, N. (2018). System modeling and control with resource-oriented Petri nets (Vol. 35). CRC Press. ISBN: 978-1439808849.
7. D. A. Coley. Introduction To Genetic Algorithms For Scientists And Engineers, World Scientific Publishing Co., 2003.

Cilji in kompetence:	**Objectives and competences:**
Cilji predmeta:	Course objectives:
– Nadgraditi znanje na področju mehatronike s predstavitvijo sodobnih robotskih sistemov. – Opredeliti pomen in vlogo robotskih sistemov v logistiki. – Pojasniti principe delovanja industrijskih, kolaborativnih in mobilnih robotov ter brezpilotnih zrakoplovov. – Pojasniti principe delovanja senzorjev, aktuatorjev in robotskih prijemal. – Pojasniti teoretične principe modeliranja in vodenja robotskih mehanizmov. – Pojasniti komponente in postavitve prilagodljivih intralogističnih procesov. – Pojasniti komponente in principe delovanja robotskega komisioniranja, sestave, sortiranja, paletiranja in strege.	– Upgrade knowledge in the field of mechatronics by presenting modern robotic systems. – Define the meaning and the role of robotic systems in logistics. – Explain the principles of operation of industrial, collaborative, mobile robots and drones. – Explain the principles of operation of sensors, actuators and robotic grippers. – Explain theoretical principles of modelling and control of robotic mechanisms. – Explain components and layouts of flexible intralogistics processes. – Explain components and principles of operation of robotic bin picking, assembling, sorting, palletizing and loading/unloading.
Kompetence študenta:	Student competences:
– Spozna in razume delovanje različnih robotskih sistemov in njihovih pomembnejših komponent. – Spozna, razume in je sposoben izbrati primerne robotske sisteme in prijemala pri načrtovanju prilagodljivih intralogističnih sistemov. – Sposoben je izdelati in simulirati prilagodljiv intralogistični proces. – Zna simulirati in implementirati osnovne robotske aplikacije. – Sposoben je oceniti in izbrati optimalna prijemala pri robotskem komisioniranju, sestavi, sortiranju, paletiranju in stregi.	– Knows and understands the operation of various robotic systems and their major components. – Knows, understands and is able to select suitable robotic systems and grippers when planning flexible intralogistics processes. – Able to design and simulate a flexible intralogistics process. – Knows how to simulate and implement basic robotic applications. – Able to evaluate and select the optimal grippers for robotic bin picking, assembling, sorting, palletizing and loading/unloading.

Predvideni študijski rezultati:

Intended learning outcomes:

Študent je ob zaključku predmeta zmožen:	At the end of the course, the student is able to:
– Razumeti in podrobneje razložiti delovanje različnih robotskih sistemov in njihovih komponent. – Oceniti potencial uporabe robotskih sistemov v intralogistiki. – Analizirati, kritično ovrednotiti ter izbrati primerne robotske sisteme za izboljšanje intralogističnih procesov. – Formulirati matematične modele robotskih mehanizmov. – Uporabljati računalniška orodja za simulacijo in programiranje robotskih sistemov. – Modelirati in simulirati diskretne dogodkovne sisteme. – Načrtovati, analizirati in optimirati intralogistične procese z uporabo sodobnih robotskih sistemov. – Aplicirati intralogistične procese (sestava, sortiranje, komisioniranje, paletiranje, strega) z uporabo sodobnih robotskih sistemov.	– Understand and explain in more detail principle of operation of various robotic systems and their components. – Assess the potential of the use of robotic systems in intralogistics. – Analyze, critically evaluate and select suitable robotic systems to improve intralogistics processes. – Formulate mathematical models of robotic mechanisms. – Use of computer tools for simulation and program of robotic systems. – Model and simulate discrete event systems. – Design, analyze and optimize intralogistics processes using modern robotic systems. – Apply intralogistics processes (assembling, sorting, bin picking, palletizing, loading/unloading) using modern robotic systems.

Metode poučevanja in učenja:

Learning and teaching methods:

Predavanja: pri predavanjih študent spozna teoretične vsebine predmeta. Del predavanj se izvaja na klasični način v predavalnici, del pa v obliki e-predavanj (e-predavanja se lahko izvajajo na videokonferenčni način ali s pomočjo posebej v ta namen didaktično pripravljenih e-gradiv v virtualnem elektronskem učnem okolju). Vaje: pri vajah študent utrdi teoretično znanje in spozna aplikativne možnosti. Del vaj se izvaja na klasični način v predavalnici, del pa v obliki e-vaj (e-vaje se lahko izvajajo na videokonferenčni način ali s pomočjo posebej v ta namen didaktično pripravljenih e-gradiv v virtualnem elektronskem učnem okolju).	Lectures: Students understand the theoretical frameworks of the course. Part of the lecture course is in a classroom while the rest is in the form of e-learning (e-lectures may be given via video-conferencing or with the help of specially designed e-material in a virtual electronic learning environment). Tutorials: Students enhance their theoretical knowledge and are able to apply it. Part of the seminar is in a classroom while the rest is in the form of e-learning (e-tutorials may be given via video-conferencing or with the help of specially designed e-material in a virtual electronic learning environment).

Načini ocenjevanja:	Delež (v %) / Weight (in %)	Assessment methods:
Način (pisni izpit, ustno izpraševanje, naloge, projekt):		Method (written or oral exam, coursework, project):
– Seminarska (projektna) naloga.	20 %	– Seminar (project) work.
– Laboratorijske vaje.	30 %	– Lab. exercises.
– Pisni izpit (teoretično znanje).	50 %	– Written exam (theoretical knowledge).
Opravljene obveznosti e-predavanj in e-vaj so pogoj za pristop k izpitu.		Successful completion of e-lectures and e-tutorials is a prerequisite for entering the exam.

Reference nosilca / Course coordinator's references:

1. EKREN, Banu Y., AKPUNAR, Anil, SARI, Zaki, LERHER, Tone. A tool for time, variance and energy related performance estimations in a shuttle-based storage and retrieval system. Applied mathematical modelling. [Print ed.]. Nov. 2018, vol. 63, str. 109-127, ilustr. ISSN 0307-904X. DOI: 10.1016/j.apm.2018.06.037. [COBISS.SI-ID 21531926].
2. KÜÇÜKYAŞAR, Melis, EKREN, Banu Y., LERHER, Tone. Cost and performance comparison for tier-captive and tier-to-tier SBS/RS warehouse configurations. International transactions in operational research, ISSN 1475-3995. [Online ed.]. https://doi-org.ezproxy.lib.ukm.si/10.1111/itor.12864, doi: 10.1111/itor.12864. [COBISS.SI-ID 25139715].
3. RAJKOVIĆ, Miloš, ZRNIĆ, Nenad Đ., KOSANIĆ, Nenad, BOROVINŠEK, Matej, LERHER, Tone. A Multi-Objective Optimization model for minimizing cost, travel time and CO2 emission in an AS/RS. FME Transactions. 2017, vol.

45, no. 4, str. 620-629, ilustr. ISSN 1451-2092. http://www.mas.bg.ac.rs/_media/istrazivanje/fme/vol45/4/23_mrajkovic_et_al.pdf, DOI: 10.5937/fmet1704620R. [COBISS.SI-ID 512851517].

4. D. Hercog, D. Sedonja, B. Recek, M. Truntič, and B. Gergič, Smart Home Solution Using Open Source Home Automation Software and Custom Developed Wi-Fi-based Hardware, Technical Gazette, vol. 27, no. 4, 2020.

5. B. Gergič and D. Hercog, "Design and implementation of a measurement system for high-speed testing of electromechanical relays," Measurement, vol. 135, pp. 112-121, 2019.

6. D. Hercog and B. Gergič, "A Flexible Microcontroller-Based Data Acquisition Device," Sensors, vol. 14, no. 6, pp. 9755-9775, 2014.