UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Robotski sistemi - MAG
Course title:	ROBOTIC SYSTEMS - MAG
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	**Študijska smer**	**Letnik**	**Semestri**
Strojništvo - Razvojno raziskovalni program, druga stopnja, magistrski	Mehatronika in laserska tehnika (smer)	1. letnik	1. semester

Univerzitetna koda predmeta/University course code:	0566809
Koda učne enote na članici/UL Member course code:	6055-M

Predavanja	**Seminar**	**Vaje**	**Klinične vaje**	**Druge oblike študija**	**Samostojno delo**	**ECTS**
30		30			65	5

Nosilec predmeta/Lecturer:	Rok Vrabič

Vrsta predmeta/Course type:	Obvezni strokovni predmet na smeri Mehatronika in laserska tehnika, ki je izbirni strokovni predmet na ostalih smereh./Compulsory specialised course in the study of Mechatronics and laser technology, which is an elective specialised course in other fields of study.

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Izpolnjevanje pogojev za vpis v Magistrski študijski program II. stopnje Strojništvo - Razvojno raziskovalni program.	Meeting the enrollment conditions for the Master's study programme of Mechanical Engineering - Research and Development program.

Vsebina:	**Content (Syllabus outline):**
1. Predavanje: Uvod - Predstavitev predmeta - Uvod v robotiko - Predstavitev tipov in delitve robotov - Pregled področij uporabe robotov 2. Predavanje: Koordinatni sistemi v robotiki	1. Lecture: Introduction - Course overview - Introduction to robotics - Types of robots - Areas of application 2. Lecture: Coordinate systems in robotics

- Rotacijske matrike v 2D in 3D - Homogena transformacija v 2D - Opis rotacije v 3D - Kvaternioni 3. Predavanje: Direktna kinematika - Koordinatni sistem sklepov - Denavit-Hartenbergov zapis - Preračun direktne kinematike 4. Predavanje: Inverzna kinematika - Analitična rešitev - Geometrična rešitev - Numerična rešitev 5. Predavanje: Hitrostne razmere - Jakobijeva matrika za robotske roke - Transformacija hitrosti med koordinatnimi sistemi - Jakobijeva matrika pod- in pre-aktuiranih robotov - Statični model sil in navorov - Singularnosti 6. Predavanje: Dinamika - Enačbe gibanja robotskih rok, Newton-Eulerjev in Lagrangeov pristop - Direktna dinamika 7. Predavanje: Planiranje poti - Trajektorije - Interpolacija po točkah - Interpolacija rotacije, kvaternionov 8. Predavanje: Krmiljenje - Krmiljenje robotskih aktuatorjev - Krmiljenje sklepov - Krmiljenje položaja - Krmiljenje navora 9. Predavanje: Aplikacije industrijskih robotov - SCARA roboti, primi-položi - Robotske roke, manipulacija objektov - Integracija robotov z drugimi sistemi - Interakcija robot-človek 10. Predavanje: Kinematika kolesnih robotov - Kinematika diferencialnega pogona - Kinematika holonomnih pogonov 11. Predavanje: Navigacija - Reaktivna navigacija - Planiranje poti na karti - Algoritmi A*, D*, Voronoievi diagram, RRT 12. Predavanje: Kalmanov filter - Kalmanov filter - 1D in 2D primer - Aplikacije v mobilni robotiki 13. Predavanje: Lokalizacija - Lokalizacija s Kalmanovim filtrom - Monte-Carlo lokalizacija 14. Predavanje: Hkratno kartiranje in lokalizacija - Princip - Razširitev opisa stanja z značilkami okolja - Negotovost položaja	- Rotational matrices in 2D and 3D - Homogeneous transformation in 2D - Description of rotation in 3D - Quaternions 3. Lecture: Direct kinematics - Joint coordinate frame - Denavit-Hartenberg notation - Direct kinematics calculation 4. Lecture: Inverse kinematics - Analitical solution - Geometric solution - Numerical solution 5. Lecture: Velocity kinematics - The manipulator Jacobian - Transformation of velocities between coordinate systems - Jacobian of under- and over-actuated robots - Static force and torque model - Singularities 6. Lecture: Dynamics - Robot arm dynamics, Newton-Euler and Lagrange approaches - Direct dynamics 7. Lecture: Path planning - Trajectories - Point-by-point interpolation - Interpolation of rotation, quaternions 8. Lecture: Control - Control of robotic actuators - Joint control - Position control - Torque control 9. Lecture: Applications of industrial robots - SCARA robots, pick-and-place - Robotic arms, object manipulation - Robot integration - Human-robot interaction 10. Lecture: Kinematics of wheeled robots - Differential drive kinematics - Holonomic drive kinematics 11. Lecture: Navigation - Reactive navigation - Path planning on a map - A*, D* algorithms, Voronoi diagrams, RRT 12. Lecture: Kalman filter - Kalman filter - 1D and 2D examples - Applications in mobile robotics 13. Lecture: Localization - Kalman filter localization - Monte-Carlo localization 14. Lecture: Simultaneous localization and mapping - Approach - Extended state representation

15. Predavanje: Industrijske aplikacije mobilnih robotov - Sistemi in tehnologije samodejno vodenih vozičkov (AGV) - Upravljanje flote - Storitveni roboti	- Pose uncertainty 15. Lecture: Industrial application of mobile robots - Systems and technologies of autonomous guided vehicles (AGVs) - Fleet management - Service robots

Temeljna literatura in viri/Readings:

1. Peter Corke: Robotics, Vision and Control, Springer-Verlag Berlin Heidelberg, 2011
2. Tadej Bajd, Matjaž Mihelj, Marko Munih: Introduction to Robotics, Springer Dordrecht Heidelberg New York London, 2013
3. J. Norberto Pires: Industrial Robots Programming, Springer Science+Business Media, 2007
4. Roland Siegwart, Illah R. Nourbakhsh: Introduction to Autonomous Mobile Robots, MIT Press, 2004
5. Gregor Klančar, Andrej Zdešar, Sašo Blažič, Igor Škrjanc: Wheeled Mobile Robotics, Butterworth-Heinemann, 2017
6. Morgan Quigley, Brian Gerkey, William D. Smart: Programming Robots with ROS, O'Reilly Media, 2015
7. Joseph Lentin: Mastering ROS for Robotics Programming, Packt Publishing, 2015.

Cilji in kompetence:	**Objectives and competences:**
Cilji: 1. Spoznati delovanje vseh vrst robotov, uporabljenih v industriji. 2. Spoznati upravljanje, programiranje in razvoj lastnih aplikacij v robotiki. 3. Spoznati načine integracije industrijskih robotov z drugimi sistemi. 4. Spoznati programske in strojne vmesnike v robotiki. Kompetence: 1. S1-MAG + P2-MAG: Sposobnost razumevanja delovanja vseh vrst industrijskih robotov. 2. S6-MAG: Sposobnost razvoja namenskega programja in lastnih aplikacij v robotiki. 3. S7-MAG: Sposobnost integracije industrijskih robotov z drugimi sistemi. 4. P6-MAG: Sposobnost nadgrajevanja robotov in gradnje novih robotskih komponent.	Objectives: 1. Understanding all kinds of industrial robotics. 2. Understanding control, programming, and development of custom robotic applications. 3. Understanding integration of robots with other industrial systems. 4. Understanding software and hardware interfaces in robotics. Competences: 1. S1-MAG + P2-MAG: Understanding the operation of all kinds of industrial robots. 2. S6-MAG: Development of custom robotic software and applications. 3. S7-MAG: The ability to integrate industrial robots with other systems. 4. P6-MAG: The ability to upgrade existing robots and develop new robotic components.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanja: Z2: Predmet je namenjen spoznavanju robotskih sistemov in njihove uporabe v industrijskih aplikacijah. Obravnavani so robotski manipulatorji (robotske roke) in industrijski samodejno vodeni vozički (mobilni roboti). S pridobljenimi kompetencami so študenti sposobni razvoja robotskih aplikacij, integracije robotov z drugimi sistemi ter razvoja robotskih komponent in programja. Spretnosti:	Learning outcomes: Z2: The course focuses on robotic systems and their industrial applications. Both articulate robots (robot arms) as well as mobile robots (autonomous guided vehicles) are considered. The acquired student competences include the abilities to develop custom robotic applications, to integrate robots with other industrial systems, and to develop robotic software and hardware components.

S2.1: Uporaba in programiranje industrijskih robotov s pomočjo učnih enot, namenskih programskih jezikov in odprtokodnih vmesnikov. S2.2: Načrtovanje in izvedba integracije industrijskih robotov z drugimi sistemi na osnovi povezovanja robotskih krmilnikov. S2.3: Načrtovanje in implementacija lastnih robotskih gradnikov in sistemov.	Skills: S2.1: Using and programming of industrial robots by using teach pendants, programming languages, and open-source interfaces. S2.2: Design and implementation of integration of industrial robots with other systems based on the understanding robotic controllers. S2.3: Design and implementation of custom robotic building blocks and systems.

Metode poučevanja in učenja:	**Learning and teaching methods:**
P1 Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov. P2 Obravnava snovi po urejeni in vnaprej razloženi sistematiki. P4 Laboratorijske vaje z namenskimi didaktičnimi pripomočki: industrijskimi roboti, mobilnimi roboti, prenosnimi računalniki, namensko programsko opremo. P8 Izdelava in predstavitev aplikativnih seminarskih nalog. P11 Uporaba izvršljivih knjig. P14 Virtualni eksperimenti.	P1 Formal lectures with domain-specific theoretical and practical examples. P2 Contents treated in orderly and pre-explained systematic manner. P4 Laboratory work with dedicated teaching aids (industrial robots, mobile robots, laptops, domain-specific software). P8 Design and presentation of applicative seminar papers. P11 Use of executable notebooks. P14 Virtual Experiments.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Teoretične vsebine (predavanja), preverjane pisno.	50,00 %	Theory (lectures) graded with written exams.
Praktične vsebine (vaje), preverjane pisno.	50,00 %	Practical work (tutorials) graded with written exams.

Reference nosilca/Lecturer's references:

Rok Vrabič:

1. MAKINDE, O. A., MPOFU, Khumbulani, **VRABIČ, Rok**, RAMATSETSE, B. I. A bio-inspired approach for the design of a multifunctional robotic end-effector customized for automated maintenance of a reconfigurable vibrating screen. Robotics and biomimetics, 4/1:1-29, 2017.
2. MALUS, Andreja, KOZJEK, Dominik, **VRABIČ, Rok**. Real-time order dispatching for a fleet of autonomous mobile robots using multi-agent reinforcement learning. CIRP annals, 69/1, accepted, in press, 2020.
3. BUTALA, Peter, **VRABIČ, Rok**, ŠKULJ, Gašper, OOSTHUIZEN, Gert. Robotics competitions as motivator for project oriented learning in mechatronics. In: RobMech 2013 : proceedings, 6th Robotics and Mechatronics Conference, 30 & 31 October 2013, Durban, South Africa, 140-145, 2013.
4. **VRABIČ, Rok**, KOZJEK, Dominik, MALUS, Andreja, ZALETELJ, Viktor, BUTALA, Peter. Distributed control with rationally bounded agents in cyber-physical production systems. CIRP annals, 67/1:507-510, 2018.
5. ŠKULJ, Gašper, SLUGA, Alojzij, BRAČUN, Drago, BUTALA, Peter, **VRABIČ, Rok**. Energy efficient communication based on self-organisation of IoT devices for material flow tracking. CIRP annals, 68/1:495-498, 2019.