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| **UČNI NAČRT PREDMETA / COURSE SYLLABUS** | | | | | | | | | | | | | | | | | |
| **Predmet:** | | | Vodenje robotov | | | | | | | | | | | | | | |
| **Course title:** | | | Robot control | | | | | | | | | | | | | | |
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| **Študijski program in stopnja**  **Study programme and level** | | | | | **Študijska smer**  **Study field** | | | | | | | | **Letnik**  **Academic year** | | **Semester**  **Semester** | | |
| Podiplomski magistrski študijski program druge stopnje Elektrotehnika | | | | | Robotika | | | | | | | | 1 | | 2 | | |
| 2nd cycle masters study programme in Electrical Engineering | | | | | Robotics | | | | | | | | 1 | | 2 | | |
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| **Vrsta predmeta / Course type** | | | | | | | | | | | | Obvezni-strokovni / Compulsory professional | | | | | |
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| **Univerzitetna koda predmeta / University course code:** | | | | | | | | | | | | 64236 | | | | | |
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| **Predavanja**  **Lectures** | **Seminar**  **Seminar** | | | **Vaje**  **Tutorial** | | | **Klinične vaje**  **work** | | | | **Druge oblike študija** | | | **Samost. delo**  **Individ. work** | |  | **ECTS** |
| **30** |  | | | **45** | | |  | | | |  | | | **75** | |  | **6** |
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| **Nosilec predmeta / Lecturer:** | | | | | Matjaž Mihelj | | | | | | | | | | | | |
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| **Jeziki /**  **Languages:** | | **Predavanja / Lectures:** | | | | **Slovenščina (na voljo ustrezen učbenik v angleščini)** | | | | | | | | | | | |
| **Vaje / Tutorial:** | | | | **Slovenščina (dodatna razlaga lahko v angleščini)** | | | | | | | | | | | |
| **Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:** | | | | | | | | |  | **Prerequisits:** | | | | | | | |
| Vpis v letnik. | | | | | | | | |  | Enrolment in the year of the course. | | | | | | | |
| **Vsebina:** | | | | | | | |  | | **Content (Syllabus outline):** | | | | | | | |
| Celotna vsebina je razdeljena v tri večje podsklope:   * vodenje odprtih kinematičnih verig (robotski senzorji, vodenje v notranjih koordinatah in vodenje v zunanjih koordinatah), * vodenje zaprtih kinematičnih verig na osnovi sile interakcije (merjenje sil in navorov, impedančna regulacija sile, direktna regulacija sile) in * vodenje na osnovi robotskega vida (senzor robotskega vida, izračunavanje lege, vodenje na osnovi izračunane lege in slike kamere). | | | | | | | |  | | The entire content is divided into three major topics: - Control of open kinematic chains (robotic sensors, joint space control and operational space control) - Control of closed kinematic chains based on interaction forces (measurement of forces and torques, impedance control, direct force control) and - Visual servoing (robot vision sensor, pose computation, computed pose based control and image based control). | | | | | | | |

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| **Temeljni literatura in viri / Readings:** | | | | | |
| 1. MIHELJ, Matjaž, BAJD, Tadej, MUNIH, Marko. Vodenje robotov. Ljubljana: Založba FE in FRI, 2011. 2. SICILIANO Bruno, SCIAVICCO, Lorenzo, VILLANI, Luigi, ORIOLO, Giuseppe.: Robotics - Modelling, Planning and Control, Springer 2009. 3. CRAIG, J. John: Introduction to Robotics - Mechanics and Control, Pearson, Prentice Hall, 2005 4. SPONG, W. Mark, HUTCHINSON, Seth, VIDYASAGAR, Mathukumalli: Robot Modeling and Control, John Wiley&Sons, Inc., 2006 | | | | | |
| **Cilji in kompetence:** | |  | | **Objectives and competences:** | |
| (a) Spoznati teoretične osnove vodenja odprtih in zaprtih kinematičnih verig ter vodenja na osnovi robotskega vida.  (b) Preveriti lastnosti izbranih shem vodenja na realnih sodobnih mehanizmih v laboratoriju.  (c) Združitev znanj Osnov robotike, Kinematike in dinamike robotov, ter vsebine tega predmeta v funkcionalen mehatronski sistem. | |  | | (a) To understand theoretical basis of control of open and closed kinematic chains and visual servoing. (b) Validation of properties of the chosen control schemes on real robot mechanisms in the Laboratory of robotics. (c) Integration of knowledge gained in courses Introduction to robotics, Kinematics and dynamics of robots and Robot control in functional mechatronic system. | |
| **Predvideni študijski rezultati:** | | |  | **Intended learning outcomes:** | |
| Znanje in razumevanje:  Znanje načinov vodenja odprtih in zaprtih kinematičnih verig ter uporabe robotskega vida. Razumevanje in definiranje parametrov regulacijskih sistemov za stabilnost. Uporaba relacij kinematike, diferencialne kinematike, statike in dinamike v namene vodenja industrijskih mehanizmov, haptičnih robotov ter pri vodenju drugih mehanskih sistemov. Izbira ustreznega pristopa in kompleksnosti vodenja glede na konkreten mehanizem in predvidene naloge. Reševanje konkretnega primera, sodelovanje v delovni skupini, javna predstavitev opravljenega dela. | | |  | Knowledge and understanding:  Knowledge of robot control methods for open and closed kinematic chains as well as visual servoing. Understanding and defining controller parameters for stability. Using knowledge of kinematics, differential kinematics, statics and dynamics for the purposes of controlling industrial robot, haptic interfaces and other mechanical systems. Selection of the right approach and the complexity of control method for the specific mechanism and planned tasks. Problem solving, team work, public presentation of completed work. | |
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| **Metode poučevanja in učenja:** | | |  | **Learning and teaching methods:** | |
| Predavanja, laboratorijsko delo v manjših skupinah, reševanje kompleksnejše nalog vodenja robota. Praktične vaje potekajo na večjem številu sodobnih industrijskih in drugih robotov, dodatno opremljenih s senzorji sil. Študenti imajo na voljo učbenik Vodenje robotov z vsebino predmeta. Vabljeni so gostujoči predavatelji iz slovenske industrije. Pri predmetu je posebna pozornost posvečena varnosti pri delu z roboti. | | |  | Lectures, laboratory work in small groups, complex robot control problem solving. Practical exercises take place on a number of modern industrial and other robots equipped with additional force sensors. The students have a textbook “Vodenje robotov” or equivalent English textbook with course content. Invited are guest speakers from the Slovenian industry. In this course, special attention is paid to safety. | |
| **Načini ocenjevanja:** | Delež (v %) /  Weight (in %) | | | | **Assessment:** |
| Način: laboratorijske vaje, pisni izpit, ustni izpit.  Ocene od 1 do vključno 5 so negativne, ocene od vključno 6 do 10 so pozitivne.  Pozitivna ocena laboratorijskih vaj je pogoj za pristop k izpitu.  Zahtevana je obvezna prisotnost pri praktičnih vajah. Študent lahko opravičeno izostane največ od ene vaje. Študent na koncu semestra zagovarja svoj projekt.  Pisni izpit obsega reševanje primerov ter teoretična vprašanja iz posameznih poglavij.  Študent opravlja tudi ustni izpit, kjer so vprašanja postavljena predvsem na osnovi odgovorov pismenega izpita.  Prispevki k oceni:   * laboratorijske vaje * pisni izpit * ustni izpit | 40%  40%  20% | | | | Type: laboratory exercises, written exam, oral exam.  Negative grades: from 1 to 5, positive grades: from 6 to 10.  Positive evaluation of laboratory exercises is a prerequisite for the exam.  Mandatory presence at practical courses. Student can justifiably miss maximally one practical course time slot. Students defend their project at the end of semester.  Written exam is based on problem solving as well as theoretical questions related to course topics.  Oral exam is based primarily on the basis of answers in the written exam.  Contributions to the final grade:   * laboratory exercises * written exam * oral examination |
| **Reference nosilca / Lecturer's references:** | | | | | |
| 1. MIHELJ, Matjaž, BAJD, Tadej, MUNIH, Marko. Vodenje robotov. Ljubljana: Založba FE in FRI, 2011. 2. MIHELJ, Matjaž, PODOBNIK, Janez. Haptics for virtual reality and teleoperation, Springer, 2012. 3. KOENIG, Alexander, NOVAK, Domen, OMLIN, Ximena, PULFER, Michael, PERREAULT, Eric, ZIMMERLI, Lukas, MIHELJ, Matjaž, RIENER, Robert. Real-time closed-loop control of cognitive load in neurological patients during robot-assisted gait training. IEEE transactions on neural systems and rehabilitation engineering, ISSN 1534-4320. [Print ed.], Aug. 2011, vol. 19, no. 4, str. 453-464. 4. ŽBONTAR, Klemen, MIHELJ, Matjaž, PODOBNIK, Boštjan, POVŠE, Franc, MUNIH, Marko. Dynamic symmetrical pattern projection based laser triangulation sensor for precise surface position measurement of various material types. *Appl. opt.*, 2013, vol. 52, no. 12, str. 2750-2760. 5. ČINKELJ, Justin, KAMNIK, Roman, ČEPON, Peter, MIHELJ, Matjaž, MUNIH, Marko. Closed-loop control of hydraulic telescopic handler. *Autom. constr.*. 2010, vol. 19, no. 7, str. 954-963. | | | | | |