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| **UČNI NAČRT PREDMETA / COURSE SYLLABUS** | | | | | | | | | | | | | | | | | |
| **Predmet:** | | | Haptični roboti | | | | | | | | | | | | | | |
| **Course title:** | | | Haptic Robots | | | | | | | | | | | | | | |
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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 | | | | | | | | 2 | | 1 | | |
| 2nd cycle masters study programme in Electrical Engineering | | | | | Robotics | | | | | | | | 2 | | 1 | | |
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| **Vrsta predmeta / Course type** | | | | | | | | | | | | Obvezni-strokovni / Compulsory professional | | | | | |
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| **Univerzitetna koda predmeta / University course code:** | | | | | | | | | | | | 64296 | | | | | |
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| **Predavanja**  **Lectures** | **Seminar**  **Seminar** | | | **Vaje**  **Tutorial** | | | **Klinične vaje**  **work** | | | | **Druge oblike študija** | | | **Samost. delo**  **Individ. work** | |  | **ECTS** |
| 45 |  | | | 30 | | |  | | | |  | | | 75 | |  | 6 |
|  | | | | | | | | | | | | | | | | | |
| **Nosilec predmeta / Lecturer:** | | | | | Matjaž Mihelj | | | | | | | | | | | | |
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| **Jeziki /**  **Languages:** | | **Predavanja / Lectures:** | | | | slovenski / Slovenian | | | | | | | | | | | |
| **Vaje / Tutorial:** | | | | slovenski / Slovenian | | | | | | | | | | | |
| **Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:** | | | | | | | | |  | **Prerequisits:** | | | | | | | |
| Vpis v drugi letnik predmeta | | | | | | | | |  | Enrolment in the year of the course | | | | | | | |
| **Vsebina:** | | | | | | | |  | | **Content (Syllabus outline):** | | | | | | | |
| Uvod (definicija, značilnosti in uporaba haptičnih robotov), človeški faktor (haptične zaznave; motorični sistem; kognitivne sposobnosti), haptični roboti (kinestetični in taktilni vmesniki, kinematika, dinamika); haptično zaznavanje dotika (merjenje dotika v realnih ter zaznavanje dotika v navideznih okoljih, haptično modeliranje navideznega sveta), haptično prikazovanje dotika (prazen prostor, togi objekti, trenje, dinamika gibanja objektov), vodenje in stabilnost haptične interakcije (impedančno in admitančno vodenje, četveropolni model haptične interakcije, transparentnost in Z-širina, navidezna sklopitev, pasivnost sistema), teleoperacija, mikro/nanomanipulacija, rehabilitacijska robotika, biomedicinska robotika. | | | | | | | |  | | Introduction (definition, characteristics and applications for haptic robots), human factor (haptic perceptions; motor system; cognitive capabilities), haptic robots (kinesthetic and tactile interfaces, kinematics, dynamics); collision detection (in real and virtual environments, haptic virtual environment modelling), haptic rendering (free space, stiff objects, friction, dynamics of moving objects), control and stability analysis for haptic interaction (impedance and admittance control, two-port model for haptic interaction, transparency and Z-width, virtual coupling, system passivity), teleoperation, micro/nanomanipulation, rehabilitation and medical robotics. | | | | | | | |

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| **Temeljni literatura in viri / Readings:** | | | | | |
| 1. Mihelj, Matjaž, Haptični roboti, Založba FE in FRI, 2007. 2. MIHELJ, Matjaž, PODOBNIK, Janez. Haptics for virtual reality and teleoperation, Springer, 2012. | | | | | |
| **Cilji in kompetence:** | |  | | **Objectives and competences:** | |
| Predmet obravnava uporabo robotov v tesnem stiku s človekom (z neposredno fizično interakcijo) za prenos kinestetičnih in taktilnih dražljajev med človekom in robotom. Analizira fizikalne osnove, tehnološke izzive ter možnosti in omejitve pri gradnji haptičnih robotov. Poudarek je na konceptih potrebnih za razumevanje človekovih odzivov na sintetično generirane haptične dražljaje (kinestetične in taktilne informacije). Pridobljeno znanje o haptičnih interakcijah v navideznih okoljih je razširjeno na teleoperacijske sisteme, rehabilitacijske in medicinske robote. Nanomanipulacija je analizirana kot specifičen primer uporabe haptičnega vmesnika. Praktična znanja študenti pridobijo v laboratoriju ob izvajanju interdisciplinarnih skupinskih projektov. | |  | | Course deals with the use of robots in close physical contact with a human (direct physical interaction) for the purpose of exchanging kinesthetic and tactile stimuli between the human and the robot. It analyses physical background, technological challenges and limitations related to the design of haptic robots. The emphasis is on concepts required for understanding human responses to artificially generated haptic stimuli (kinesthetic and tactile). The concept of haptic interaction is extended to teleoperation systems, which are further examined from the point of view of tele-micro and nanomanipulation. Students obtain practical knowledge in the laboratory while executing interdisciplinary research projects. | |
| **Predvideni študijski rezultati:** | | |  | **Intended learning outcomes:** | |
| Znanje in razumevanje delovanja haptičnih robotov; načrtovanje mehanizmov haptičnih robotov; vodenje in stabilnost robotov v stiku s človekom.  Študenti bodo znali načrtovati naloge in sisteme, ki zahtevajo fizični kontakt med robotom in človekom, vključno s teleoperacijskimi sistemi. | | |  | Knowledge and understanding of haptic robots; design of haptic robot mechanisms; control and stability of robots in contact with humans.  Students will be able to plan tasks and design systems that require physical contact between the robot and the human, including teleoperation systems. | |
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| **Metode poučevanja in učenja:** | | |  | **Learning and teaching methods:** | |
| Študenti imajo na voljo učbenik. Na predavanjih je poudarek na teoretičnih osnovah haptičnih robotov. Zaradi specifičnosti predmeta, se del predavanj izvaja s pomočjo multimedijskih predstavitev. Najnovejši dosežki s področja haptičnih robotov so predstavljeni v "video predavanjih". Praktične vaje potekajo v laboratoriju, ki je opremljen z večjim številom sodobnih haptičnih robotov. Študentje delajo v interdisciplinarnih projektnih skupinah, kjer se posamezen študent ukvarja z določenim problemom interakcije človek-robot. | | |  | Students have a textbook. Lectures focus on theoretical basis of haptic robots. Because of the specificity of the course, part of the lectures is performed in the form of multimedia presentations. Latest developments in the field of haptic robot are presented in the "video lectures." Practical exercises are performed in the laboratory, which is equipped with a number of modern haptic robots. Students work in interdisciplinary project teams, where each student deals with the specific problem of human-robot interaction. | |
| **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 final grade:  laboratory exercises  written exam  oral examination |
| **Reference nosilca / Lecturer's references:** | | | | | |
| 1. MIHELJ, Matjaž, NOVAK, Domen, BEGUŠ, Samo*. Virtual reality technology and applications*, Springer, 2014. 2. MIHELJ, Matjaž, PODOBNIK, Janez. Haptics for virtual reality and teleoperation, Springer, 2012. 3. TRLEP, Matic, MIHELJ, Matjaž, MUNIH, Marko. Skill transfer from symmetric and asymmetric bimanual training using a robotic system to single limb performance. Journal of neuroengineering and rehabilitation, 2012, vol. 9, no. 43, str. 1-14. 4. TRLEP, Matic, MIHELJ, Matjaž, PUH, Urška, MUNIH, Marko. Rehabilitation robot with patient-cooperative control for bimanual training of hemiparetic subjects. *Advanced robotics*, 2011, vol. 25, no. 15, str. 1949-1968. 5. NOVAK, Domen, MIHELJ, Matjaž, MUNIH, Marko. Psychophysiological responses to different levels of cognitive and physical workload in haptic interaction. *Robotica*, 2011, vol. 29, no. 3, str. 367-374 | | | | | |