

MEHATRONIKA IN LASERSKE TEHNOLOGIJE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Mehatronika in laserske tehnologije
Course title:	Mechatronics and Laser Technologies
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo - razvojno raziskovalni program, prva stopnja, univerzitetni	Ni členitve (študijski program)	3. letnik	2. semester	obvezni

Univerzitetna koda predmeta/University course code:	0577610
Koda učne enote na članici/UL Member course code:	2034-U

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45		30			50	5

Nosilec predmeta/Lecturer:	prof. dr. Matija Jezeršek, doc. dr. Dominik Kozjek, doc. dr. Gašper Škulj
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Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni splošni predmet /Compulsory general course
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Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:

Izpolnjevanje pogojev za vpis v Univerzitetni študijski program I. stopnje Strojništvo - Razvojno raziskovalni program.

Prerequisites:

Meeting the enrollment conditions for the Academic study programme of Mechanical Engineering - Research and Development program.

Vsebina:

1. Predavanje: Uvod, predstavitev predmeta
2. Predavanje: Številski sistemi in kodiranje
 - Številski sistemi (desetiški, dvojiški, šestnajstiški)
 - Kodiranje podatkov (BCD koda, Kodiranje celih števil, Kodiranje števil s plavajočo vejico, Grayev kod, Komunikacijski kodi)

Content (Syllabus outline):

Lecture 1: Introduction, course outline
Lecture 2: Numerical systems and coding

- Numerical systems (decimal, binary, hexadecimal)
- Data encoding (BCD code, Integer encoding, Floating point number encoding, Gray code, Commun. codes)

3. Predavanje: Mikrokrmilniki • Zgradba in delovanje mikrokrmilnikov • Arduino strojna oprema in programska orodja • Osnovne funkcije knjižnice Arduino 4. Predavanje: Vezja z mikrokrmilniki • Konfiguracije digitalnih vhodov/izhodov • Vezave tipk, stikal, preklopnih senzorjev na vhodne priključke mikrokrmilnika • Vezave relejev, kontaktorjev, motorjev na izhodne priključke mikrokrmilnika • Galvanska ločitev mikrokrmilnika od perifernih enot 5. Predavanje: Programiranje mikrokrmilnikov • Standardni gradniki jezika C 1 (Izrazi, stavki, bloki, Podatkovni tipi, Konstante, Spremenljivke, Operatorji) • Standardni gradniki jezika C 2 (Odločitvene strukture, Ponavljalne strukture, Funkcije) 6. Predavanje: Vmesniki • Števniki, časovniki kot periferne enote, Merjenje frekvence, periode, faze, Generiranje preklopnih signalov (PWM...) • A/D in D/A pretvorniki, dostop preko knjižnice Arduino, uporaba v krmilnih programih • Močnostni vmesniki (H mostič, variante in izvedbe) • Uporabniški vmesniki 7. Predavanje: Krmiljenje elektromotorjev • Krmiljenje DC elektromotorjev (s permanentnimi magneti, z elektromagnetni, krtačni in brezkrtačni) • Izbira in preračun DC motorja Modeliranje (opis z diferencialno enačbo) Statične karakteristike, parametri Merjenje statičnih karakteristik Dinamične karakteristike Termalni preračun • Krmiljenje AC motorjev (sinhroni, asinhroni) • Krmiljenje koračnih motorjev • Krmiljenje servomotorjev 8. Predavanje: Implementacija krmilnih sistemov • Implementacija preklopnih krmilij z mikrokrmilnikom sekvenčni avtomati koračna krmilja • Implementacija proporcionalnih krmilij z mikrokrmilnikom 9. Predavanje: Krmiljenje gibanj • Numerično krmiljenje (arhitektura CNC stroja, arhitektura CNC krmilnika) • G koda (osnovni ukazi, interpolacija, izzivi) • Interpolacija (segmentacija krivulj, interpolacija krivulj, primeri) 10. Predavanje: Mehatronski sistemi • Specifikacije • Metodologija razvoja • Izbrani primer razvoja: mobilni robot za tekmovanje Robot-Sumo 11. Predavanje: Delovanje laserjev	Lecture 3: Microcontrollers - Structure and operation of microcontrollers - Arduino hardware and software tools - Basic functions of the Arduino library Lecture 4: Circuits with microcontrollers - Digital I / O configuration. - Connecting buttons, switches, switching sensors to the input terminals of a microcontroller. - Connecting relays, contactors, motors to the outputs of a microcontroller. - Galvanic isolation of a microcontroller from the peripheral units. Lecture 5: Microcontroller programming - Standard C language building blocks 1 (Terms, statements, blocks, Data types, Constants, Variables, Operators) - Standard C language building blocks 2 (Decision structures, Repetition structures, Functions) Lecture 6: Interfaces - Counters, timers as peripherals, Frequency, period, phase measurement, Switching signal generation (PWM ...) - A / D and D / A converters, access via Arduino library, use in control programs - Power interfaces (H bridge, types and implementations) - User interfaces Lecture 7: Control of electric motors - Control of DC electric motors (with permanent magnets, with electromagnets, brushed and brushless) - DC motor selection and sizing Modeling (differential equation description) Static characteristics, parameters Measurement of static characteristics Dynamic characteristics Thermal consideration - Control of AC motors (synchronous, asynchronous) - Stepper motor control - Servomotor control Lecture 8: Implementation of control systems - Implementation of switching controls with microcontrollers, Sequential automata, SFC language - Implementation of proportional controls with microcontroller Lecture 9: Motion control - Numerical control (CNC machine architecture, CNC controller architecture) - G code (basic commands, interpolation, challenges) - Interpolation (curve segmentation, curve interpolation, examples) Lecture 10: Mechatronic systems - Specifications - Design methodology
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• Gradniki laserskih izvorov • Stimulirana emisija, ojačanje, inverzna populacija • Črpanje, tri-nivojski in štirinivojski sistem • Resonator, laserski rodovi 12. Predavanje: Značilnosti laserske svetlobe • Usmerjenost, enobarvnost, koherenca, intenziteta • Gaussov model • Kvaliteta • Fokussiranje 13. Predavanje: Vrste laserskih izvorov • Plinski laserji (He-Ne, CO₂) • Trdninski laserji (Nd:YAG, Rubin, diskovni, vlakenski) • Polprevodniški laserji 14. Predavanje: Izbrani laserski merilni sistemi • Osnovni merilni principi (triangulacija, interferometrija, čas preleta) • 3D merilni sistemi • Merilniki hitrosti • Merilniki deformacij 15. Predavanje: Izbrani laserski obdelovalni sistemi • Osnovne obdelovalne interakcije • Sistemi za lasersko vrtanje in rezanje • Sistemi za lasersko varjenje • Označevalni in gravirni sistemi	- Selected Design Case: Robot-Sumo mobile robot Lecture 11: Operation of lasers - Laser source building blocks - Stimulated emission, amplification, inverse population - Pumping, three-level and four-level systems - Resonator, laser modes Lecture 12: Laser light properties - Directionality, monochromaticity, coherence, intensity - Gaussian model - Quality - Focusing Lecture 13: Laser types - Gas lasers (He-Ne, CO₂) - Solid-state lasers (Nd:YAG, Ruby, Disc, Fiber) - Semiconductor lasers Lecture 14: Selected laser measuring systems - Basic measurement principles (triangulation, interferometry, time-of-flight) - 3D measuring systems - Speed measurement - Deformation measurement Lecture 15: Selected laser processing systems - Basic machining interactions - Drilling and cutting laser systems - Welding laser systems - Marking and engraving laser systems
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Temeljna literatura in viri/Readings:

1. W. Bolton, Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering 6th Ed. Pearson, 2015 [COBISS.SI-ID [17768499](#)].
2. E. Kannatey-Asibu, Principles of Laser Materials Processing, Wiley, 2009. [COBISS.SI-ID [11303451](#)]

Cilji in kompetence:

Cilji:

1. Spoznati zgradbo in delovanje mehatronskih in laserskih sistemov, njihovo razčlenitev na osnovne gradnike, osvojiti načine opisa takih sistemov, razumeti njihove karakteristike in specifikacije.
2. Spoznati metode razvoja takih sistemov s posebnim poudarkom na interdisciplinarnem pristopu, fizikalnem, matematičnem in numeričnem modeliranju.
3. Spoznati metode in postopke eksperimentalne evaluacije mehatronskih in laserskih sistemov.

Kompetence:

1. S1-RRP + P2-RRP: Sposobnost uporabe pridobljenega strokovnega znanja za reševanje manj zahtevnih nalog s področja mehatronike in laserske tehnologije.
2. P4-RRP: Sposobnost osnovnega fizikalnega, matematičnega in numeričnega modeliranja problemov na področju mehatronike in laserskih

Objectives and competences:

Objectives:

1. To learn the structure and operation of mechatronic and laser systems, their breakdown into basic building blocks, to learn ways to describe such systems, to understand their characteristics and specifications.
2. To learn the methods of development of such systems, with particular emphasis on interdisciplinary approach, physical, mathematical and numerical modeling.
3. To acquire the methods and procedures of experimental evaluation of mechatronic and laser systems.

Competences:

1. S1-RRP + P2-RRP: Ability to use acquired expertise to solve less demanding tasks in the field of mechatronics and laser technology.
2. P4-RRP: Ability to perform basic physical, mathematical and numerical modeling of problems in the field of mechatronics and laser

sistemov z razvito sposobnostjo kritične analize dobljenih rezultatov.	systems with developed ability to critically analyze the results obtained.
3. S8-RRP: Usposobljenost za interdisciplinarno povezovanje s strokovnjaki drugih strok na področju mehatronike in laserskih tehnologij.	3. S8-RRP: Ability to interdisciplinary collaborate with experts in other disciplines in mechatronics and laser technologies.

Predvideni študijski rezultati:

Znanja: Z1: Strokovno teoretično in praktično znanje na področju mehatronike in laserskih tehnologij podprto s širšo teoretično in metodološko osnovo, ki omogočata vključevanje v interdisciplinarne razvojne skupine na teh področjih. Spretnosti: S1.3: Diagnosticiranje in reševanje problemov na področju mehatronike in laserskih tehnologij v različnih specifičnih delovnih okoljih. S2.2 Načrtovanje in vodenje delovnega procesa na podlagi ustvarjalnega reševanja problemov, povezanih z mehatroniko in laserskimi tehnologijami.
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Intended learning outcomes:

Knowledge: Z1: Expert theoretical and practical knowledge in the field of mechatronics and laser technologies, supported by a broader theoretical and methodological basis, enabling integration into interdisciplinary development teams in these fields. Skills: S1.3: Diagnosis and problem solving in the field of mechatronics and laser technologies in various specific work environments. S2.2 Design and guide workflows based on creative problem solving related to mechatronics and laser technologies.
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Metode poučevanja in učenja:

P1 Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov. P2 Obravnava snovi po urejeni in vnaprej razloženi sistematiki. P3 Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri. P4 Laboratorijske vaje z namenskimi didaktičnimi pripomočki (preklopno krmiljenje zapornice, tekočega traku, PID krmiljenje procesa, laserski merilni sistem, laserski obdelovalni sistem). P5 Uporaba študijskega gradiva v obliki e-verzij: predstavitev predavanj, zbirke nalog z vaj, navodil za izvedbo laboratorijskih vaj P14 Virtualni eksperimenti P15 Uporaba video vsebin kot priprava na vaje

Learning and teaching methods:

P1 Lectures by solving selected - typical for eng. disciplines - theoretical and practical examples. P2 Treatment of the substance in an orderly and pre-interpreted systematic manner. P3 Practical classes where theoretical knowledge from lectures is supported by computed examples. P4 Laboratory exercises with dedicated didactic aids (switching gate control, conveyor belt, PID process control, laser measuring system, laser processing system). P5 Use of electronic study materials: presentation of lectures, workbooks, instructions for laboratory work P14 Virtual experiments P15 Use video content to prepare for tutorials

Načini ocenjevanja:

Delež/Weight

Assessment:

Teoretična snov (predavanja).	50,00 %	Theoretical exam (lectures).
Samostojno delo na vajah.	25,00 %	Independent classwork.
Laboratorijsko delo na vajah (vključno s poročili).	25,00 %	Laboratory work (including reports).

Ocenjevalna lestvica:

5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10
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Grading system:

5 - 10, a student passes the exam if he is graded from 6 to 10
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Reference nosilca/Lecturer's references:

Matija Jezeršek:

- JEZERŠEK, Matija**, KRIEGL, Raphael, KRAVANJA, Gaia, HRIBAR, Luka, DREVENŠEK OLENIK, Irena, UNOLD, Heiko, SHAMONIN, Mikhail. Control of droplet impact through magnetic actuation of surface microstructures. Advanced materials interfaces. Apr. 2023, vol. 10, art. no. 2202471, 10 str., ilustr. ISSN 2196-7350. DOI: 10.1002/admi.202202471 [COBISS.SI-ID [145255427](#)]

2. STRAUS, Izidor, KOKOT, Gašper, KRAVANJA, Gaia, HRIBAR, Luka, KRIEGL, Raphael, SHAMONIN, Mikhail, **JEZERŠEK, Matija**, DREVENŠEK OLENIK, Irena. Dynamically tunable lamellar surface structures from magnetoactive elastomers driven by a uniform magnetic field. *Soft matter*. 2023, vol. 19, iss. 18, str. 3357-3365, ilustr. ISSN 1744-683X. DOI: 10.1039/D3SM00012E. [COBISS.SI-ID [149684995](#)]
3. KRIEGL, Raphael, KRAVANJA, Gaia, HRIBAR, Luka, ČOGA, Lucija, DREVENŠEK OLENIK, Irena, **JEZERŠEK, Matija**, KALIN, Mitjan, SHAMONIN, Mikhail. Microstructured magnetoactive elastomers for switchable wettability. *Polymers*. Sep. 2022, vol. 14, art. no. 3883, 22 str., ilustr. ISSN 2073-4360. DOI: 10.3390/polym1418388 [COBISS.SI-ID [121827843](#)]
4. TAŠIČ MUC, Blaž, VELLA, Daniele, LUKAČ, Nejc, KOS, Matjaž, **JEZERŠEK, Matija**. Generation of a focused pressure wave and localized cavitation clouds using a metal-semiconductor Ti/black-TiOx optoacoustic lens. *Results in physics*. Jan. 2021, vol. 20, f. 1-9 + [8], ilustr. ISSN 2211-3797. <https://www.sciencedirect.com/science/article/pii/S2211379720321379?via%3Dihub>, <https://repozitorij.uni-lj.si/IzpisGradiva.php?id=138453>, DOI: 10.1016/j.rinp.2020.103721. [COBISS.SI-ID [43842819](#)]
5. LUKAČ, Nejc, LUKAČ, Matjaž, **JEZERŠEK, Matija**, GREGORČIČ, Peter. Cleaning system = Reinigungssystem = Système de nettoyage : European patent specification EP 3 510 961 B1, 2021-06-09. Munich: European Patent Office, 2021. 32 f., ilustr. <https://worldwide.espacenet.com/patent/search/family/053776282/publication/EP3510961B1?q=EP3510961%20B1>. [COBISS.SI-ID [16243483](#)]

Dominik Kozjek:

1. **KOZJEK, Dominik**, PORTER, Conor, CARTER, Fred M., MOGONYE, Jon-Erik, CAO, Jian. Data-driven prediction of inter-layer process condition variations in laser powder bed fusion. *Additive manufacturing*. [Spletna izd.]. May 2024, vol. 88, [article no.] 104230, str. 1-15, ilustr. ISSN 2214-7810. <https://www.sciencedirect.com/science/article/pii/S2214860424002768?dgcid=coauthor>, DOI: 10.1016/j.addma.2024.104230. [COBISS.SI-ID [198409987](#)].
2. CARTER, Fred M., PORTER, Conor, **KOZJEK, Dominik**, SHIMOYOSHI, Kento, FUJISHIMA, Makoto, IRINO, Naruhiro, CAO, Jian. Machine learning guided adaptive laser power control in selective laser melting for pore reduction. *CIRP annals*. Apr. 2024, str. 1-4, ilustr. ISSN 0007-8506. <https://www.sciencedirect.com/science/article/pii/S000785062400057X>, DOI: 10.1016/j.cirp.2024.04.043. [COBISS.SI-ID [198424067](#)].
3. PORTER, Conor, CARTER, Fred M., **KOZJEK, Dominik**, CARDONA, Andrea, MOGONYE, Jon-Erik, EHMAN, Kornel F., CAO, Jian. Generation and analysis of AlSi10Mg L-PBF single track data set enabling deeper process insights. V: *Solid Freeform Fabrication 2022 : proceedings of the 33rd Annual International Solid Freeform Fabrication Symposium 2022 : an additive manufacturing conference : July 25-27, 2022, [Austin, Texas]*. Austin (Texas): University of Texas at Austin, Laboratory for Freeform Fabrication, cop. 2022. Str. 1542-1550, ilustr. <https://utw10945.utweb.utexas.edu/sites/default/files/2022/Generation%20and%20Analysis%20of%20AlSi10Mg%20L-PBF%20Single%20T.pdf>. [COBISS.SI-ID [170067971](#)].
4. **KOZJEK, Dominik**, VRABIČ, Rok, RIHTARŠIČ, Borut, BUTALA, Peter. Big data analytics for operations management in engineer-to-order manufacturing. V: *WANG, Lihui (ur.). 51st CIRP Conference on Manufacturing Systems, 16-18 May, 2018, Stockholm, Sweden. 51st CIRP Conference on Manufacturing Systems, 16-18 May, 2018, Stockholm, Sweden. [Amsterdam etc.]: Elsevier, 2018. Vol. 72, f. 209-214, ilustr. Procedia CIRP, Vol. 72. ISSN 2212-8271. <https://www.sciencedirect.com/science/article/pii/S2212827118302531?via%3Dihub>, Repozitorij Univerze v Ljubljani – RUL, DOI: 10.1016/j.procir.2018.03.098. [COBISS.SI-ID [16190235](#)].*
5. FAN, Chen, **KOZJEK, Dominik**, PORTER, Conor, CAO, Jian. Acceleration of powder-bed-size thermal simulation considering scanning-path-scale through a pseudo-layer-wise equivalent heat flux model. *Journal of manufacturing processes*. [Online ed.]. 2025, vol. 134, str. 394-409, ilustr. ISSN 2212-4616. <https://www.sciencedirect.com/science/article/pii/S1526612524013379>, DOI: 10.1016/j.jmapro.2024.12.057. [COBISS.SI-ID [221502979](#)].

Gašper Škulj:

1. **ŠKULJ, Gašper**, VRABIČ, Rok, PODRŽAJ, Primož. A wearable IMU system for flexible teleoperation of a collaborative industrial robot. *Sensors*. Sep. 2021, vol. 21, iss. 17, str. 1-19, ilustr. ISSN 1424-8220.

<https://www.mdpi.com/1424-8220/21/17/5871>, [Repozitorij Univerze v Ljubljani – RUL](#), DOI: [10.3390/s21175871](https://doi.org/10.3390/s21175871). [COBISS.SI-ID 76739587]

2. **ŠKULJ, Gašper**, VRABIČ, Rok, BUTALA, Peter, SLUGA, Alojzij. Decentralised network architecture for cloud manufacturing. *International journal of computer integrated manufacturing*. [Print ed.]. 2017, vol. 30, nr. 4/5, str. 395-408, ilustr. ISSN 0951-192X.
<http://www.tandfonline.com/doi/pdf/10.1080/0951192X.2015.1066861>, DOI: [10.1080/0951192X.2015.1066861](https://doi.org/10.1080/0951192X.2015.1066861). [COBISS.SI-ID 14075675]
3. ŽUŽEK, Tena, VRABIČ, Rok, ZDEŠAR, Andrej, **ŠKULJ, Gašper**, BANFI, Igor, BOŠNAK, Matevž, ZALETELJ, Viktor, KLANČAR, Gregor. Simulation-based approach for automatic roadmap design in multi-AGV systems. *IEEE transactions on automation science and engineering*. [Print ed.]. Oct. 2024, vol. 21, no. 4, str. 6190-6201, ilustr. ISSN 1545-5955. <https://ieeexplore.ieee.org/document/10287275>, [Repozitorij Univerze v Ljubljani – RUL](#), DOI: [10.1109/TASE.2023.3323099](https://doi.org/10.1109/TASE.2023.3323099). [COBISS.SI-ID 169026819]
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5. VRABIČ, Rok, ŽUŽEK, Tena, **ŠKULJ, Gašper**, BANFI, Igor, ZALETELJ, Viktor. Improving the flow in multi-robot logistic systems through optimization of layout roadmaps. V: PETROVIC, Ivan (ur.), MENEGATTI, Emanuele (ur.), MARKOVIĆ, Ivan (ur.). *Intelligent autonomous systems 17 : proceedings of the 17th International Conference LAS-17, June 13–16, 2022, Zagreb, Croatia*. Cham: Springer, 2023. Str. 923–934, ilustr. Lecture notes in networks and systems, Vol. 577. ISBN 978-3-031-22216-0, ISBN 978-3-031-22215-3. ISSN 2367-3370. https://link.springer.com/chapter/10.1007/978-3-031-22216-0_62, DOI: [10.1007/978-3-031-22216-0_62](https://doi.org/10.1007/978-3-031-22216-0_62). [COBISS.SI-ID 139695363]