

DISKRETNİ KRMILNI SISTEMI

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Diskretni krmilni sistemi
Course title:	Discrete Control Systems
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo - Razvojno raziskovalni program, druga stopnja, magistrski	Mehatronika in laserska tehnika (smer)	1. letnik	2. semester	obvezni

Univerzitetna koda predmeta/University course code:	0566814
Koda učne enote na članici/UL Member course code:	6057-M

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30		30			65	5

Nosilec predmeta/Lecturer:	prof. dr. Primož Podržaj
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Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

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.
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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.
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Vsebina:

Content (Syllabus outline):

1. Predavanje: Uvod
 - Splošna shema krmilnega sistema
 - Zvezni, diskretni in hibridni sistem
 - AD, DA pretvorba
 - Diferencialna/diferenčna enačba
2. Predavanje: Reševanje diferenčnih enačb
 - Primeri sistemov popisljivih z dif. enačbami
 - Postopek reševanja
3. Predavanje: Z transformacija
 - Definicija
 - Lastnosti
 - Primeri
 - Primerjava z Laplaceovo transformacijo
4. Predavanje: Reševanje dif. enačb s pomočjo Z transformacije
 - Razširitev na parc. ulomke
 - Postopek reševanja
5. Predavanje: Diskretne prenosne funkcije
 - Primerjava med zvezno in diskretno P.F.
 - Vpliv lege polov na odziv
 - Stabilnost
6. Predavanje: Korenska krivulja
 - Zvezna
 - Diskretna
7. Predavanje: Sinteza digitalnih krmilnih sistemov
 - Tipične zahteve v časovni domeni
 - Zahteve v smislu lege korenov
8. Predavanje: Diskretni PID krmilnik
 - Eulerjeva aproksimacija
 - Tustinova aproksimacija
9. Predavanje: Zvezna Fourier-jeva transformacija
 - Definicija
 - Lastnosti
 - Frekvenčna karakteristika
 - Frekvenčni diagrami
10. Predavanje: Diskretna Fourierjeva transformacija
 - DFT
 - FFT
11. Predavanje: Diskretno filtriranje
 - Vloga filtrov
 - FIR in IIR filtri
 - Tipi
12. Predavanje: Diskretni filtri v več dimenzijah
 - Uporaba na slikah
 - Konvolucija
13. Predavanje: Metoda prostora stanj
 - Matrike stanja
 - Stabilnost sistema na osnovi sistemske

1. Lecture: Introduction
 - General scheme of a control system
 - Continuous, discrete and hybrid system
 - AD, DA conversion
 - Differential/difference equation
2. Lecture: Solving difference equations
 - Examples of systems modelled by dif. equations
 - Solving procedure
3. Lecture: Z transform
 - Definition
 - Properties
 - Examples
 - Comparison with the Laplace transform
4. Lecture: Solving dif. equations using Z transform
 - Partial fraction expansion
 - Solving procedure
5. Lecture: Discrete transfer function
 - Comparison between continuous and discrete T.F.
 - Influence of pole location on the response
 - Stability
6. Lecture: Root locus
 - Continuous
 - Discrete
7. Lecture: Digital control system synthesis
 - Typical time domain requirements
 - Root location requirements
8. Lecture: Discrete PID controller
 - Euler's approximation
 - Tustin's approximation
9. Lecture: Continuous Fourier transform
 - Definition
 - Properties
 - Frequency transfer function
 - Frequency plots
10. Lecture: Discrete Fourier transform
 - DFT
 - FFT
11. Lecture: Discrete filtering
 - Role of filters
 - FIR and IIR filters
 - Types
12. Lecture: Discrete filters in several dimensions
 - Image related applications
 - Convolution
13. Lecture: State space method
 - State matrices
 - System stability based on the system matrix
14. Lecture: Application of Matlab/Simulink

matrike 14. Predavanje: Uporaba Matlab/Simulink-a - Sinteza v Matlabu - Simulink 15. Predavanje: Prostor stanj v Matlabu - Računanje z matrikami - Control System Toolbox	- Matlab based synthesis - Simulink 15. Lecture: State space in Matlab - Matrix calculations - Control System Toolbox
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Temeljna literatura in viri/Readings:

1. M. Sami Fadali: Digital Control Engineering: Analysis and Design, Academic Press, 2009, [COBISS.SI-ID [1540002783](#)] e-knjiga
2. Alan V. Oppenheim: Signals and Systems, Prentice Hall, 1983, [COBISS.SI-ID [747291](#)]
3. Katsuhiko Ogata: Discrete-Time Control Systems (2nd Ed.), Pearson, 1995, [COBISS.SI-ID [18158853](#)]

Cilji in kompetence:

Cilji: 1. Razviti sposobnost kritičnega analitičnega ovrednotenja diskretnih krmilnih sistemov in njihovo sintezo. 2. Razviti sposobnost prenosa teoretično pridobljenega znanja na realne diskretne krmilne sisteme. 3. Razviti sposobnost modeliranja različnih v praksi pojavljajočih se diskretnih sistemov. Kompetence: 1. S2-MAG: Širitev sposobnosti kritičnega, analitičnega in sintetičnega mišljenja na področju diskretnih krmilnih sistemov. 2. S7-MAG: Usposobljenost za uporabo pridobljenih znanj pri samostojnem reševanju tehničnih problemov na področju diskretnih krmilnih sistemov. 3. P4-MAG: Sposobnost modeliranja diskretnih sistemov z razvito sposobnostjo kritične analize rezultatov. 4. P6-MAG: Sposobnost samostojnega razvoja diskretnih krmilnih sistemov. 5. P7-MAG: Na osnovi analize in sinteze razvita sposobnost iskanja optimalnih diskretnih krmilnikov.
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Objectives and competences:

Objectives: 1. Develop the capability of critical analytical assessment of discrete control systems and their synthesis. 2. Develop the capability to transfer the theoretical knowledge to real discrete control systems. 3. Develop the capability to model various discrete system common in the real environment. Competences: 1. S2-MAG: Improved capability of critical, analytical and synthetical thinking in the field of discrete control systems. 2. S7-MAG: The qualification to use the attained knowledge to autonomously solve technical problems in the field of discrete control systems. 3. P4-MAG: The ability for modelling of discrete system with the developed capability of critical assessment of the results. 4. P6-MAG: The ability to autonomously develop discrete control systems. 5. P7-MAG: The ability to find optimal discrete controllers based on analysis and synthesis.

Predvideni študijski rezultati:

Znanja: Z1: Poglobljeno teoretično, metodološko in analitično poznavanje analize in sinteze diskretnih krmilnih sistemov Spretnosti:
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Intended learning outcomes:

Knowledge: Z1: Deeper theoretical, methodological and analytical knowledge of discrete control system analysis and synthesis Skills:
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S2.1: Obvladovanje zelo zahtevnih, kompleksnih matematičnih postopkov za analizo in sintezo diskretnih krmilnih sistemov.	S2.1: Mastering very demanding and complex mathematical procedures for discrete control system analysis and synthesis.
S2.3: Sposobnost izvirnih dognanj na področju diskretnih krmilnih sistemov.	S2.3: Ability of unique innovations in the field of discrete control systems.

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. P4 Laboratorijske vaje z namenski didaktičnimi pripomočki kot so mikrokrmilniki (Arduino) ali računalnik Raspberry Pi.	P1 Auditorial lectures with solving selected field-specific theoretical and applied use cases. P2 Presenting the content according to the explained system. P4 Laboratory exercises with special-purpose didactic devices (microcontrollers (Arduino) or Raspberry Pi computer.
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Learning and teaching methods:

Načini ocenjevanja:

Delež/Weight

Assessment:

Pisni izpit.	50,00 %	Written examination.
Ustno izpraševanje.	30,00 %	Oral examination.
Projekt.	20,00 %	Project.

Ocenjevalna lestvica:

Grading system:

5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10	5 - 10, a student passes the exam if he is graded from 6 to 10
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Reference nosilca/Lecturer's references:

Primož Podržaj:

1. REZNICHENKO, Igor, **PODRŽAJ, Primož**, PEPERKO, Aljoša. Magnetic coil's performance optimization with nonsmooth search algorithms. Mathematics. 2025, [vol.] 13, [no.] 15, [article no.] 2490, str. 1-19, ilustr. ISSN 2227-7390. <https://www.mdpi.com/2227-7390/13/15/2490>, Repozitorij Univerze v Ljubljani – RUL, DOI: 10.3390/math13152490. [COBISS.SI-ID [244918019](#)].
2. REZNICHENKO, Igor, **PODRŽAJ, Primož**, PEPERKO, Aljoša. Calculation of stationary magnetic fields based on the improved quadrature formulas for a simple layer potential. Mathematics. 2024, vol. 12, iss. 1, [article no.] 21, str. 1-16, ilustr. ISSN 2227-7390. <https://www.mdpi.com/2227-7390/12/1/21>, <https://repozitorij.uni-lj.si/IzpisGradiva.php?id=154324>, DOI: 10.3390/math12010021. [COBISS.SI-ID [184054275](#)].
3. REZNICHENKO, Igor, **PODRŽAJ, Primož**, POŽRL, Tomaž, ŠKULJ, Gašper. Python as a tool in feedback control system analysis and design. V: 2025 IEEE 22nd International multi-conference on systems, signals & devices (SSD). [Piscataway]: IEEE, 2025. Str. 141-146, ilustr. International Multi-Conference on Systems, Signals, and Devices (Online). ISBN 979-8-3315-4272-6. ISSN 2474-0446. <https://ieeexplore.ieee.org/document/10989835>, DOI: 10.1109/SSD64182.2025.10989835. [COBISS.SI-ID [237469187](#)].
4. CORN, Marko, ROŽMAN, Nejc, **PODRŽAJ, Primož**, BERLEC, Tomaž, POŽRL, Tomaž, VRABIČ, Rok. Concept of blockchain-based micro-service control strategy for a domestic water heater. V: [2023] IEEE 32nd International Symposium on Industrial Electronics (ISIE) : 19 - 21 June, 2023, Helsinki-Espoo, Finland : proceedings. Piscataway (NJ): IEEE, 2023. Str. 1-5, ilustr. ISBN 979-8-3503-9971-4.

<https://ieeexplore.ieee.org/document/10228045>, DOI: 10.1109/ISIE51358.2023.10228045.
[COBISS.SI-ID [170473475](#)].

5. REZNICHENKO, Igor, **PODRŽAJ, Primož**, PEPERKO, Aljoša. Control theory and numerical analysis of magnetic field involving mechanical systems. V: DROBNE, Samo (ur.), et al. SOR '23 : proceedings of the 17th International Symposium on Operational Research in Slovenia : Bled, Slovenia, September 20-22, 2023. 1st electronic version. Ljubljana: Slovenian Society Informatika - Section for Operational Research, 2023. Str. 53-56. ISBN 978-961-6165-61-7. <https://drustvo-informatika.si/uploads/documents/6a1c2595-7d3f-4dd2-ab6c-9ed9b168c19d/SOR23Proceedings.pdf>. [COBISS.SI-ID [166105859](#)].