NAPREDNA RAČUNALNIŠKA ORODJA

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Napredna računalniška orodja
Course title:	High-end computing tools
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo - razvojno raziskovalni program, prva stopnja, univerzitetni (od študijskega leta 2024/2025 dalje)	Ni členitve (študijski program)	3. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0562777
Koda učne enote na članici/UL Member course code:	2036-U

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			40	4

Nosilec predmeta/Lecturer:	Janez Povh, Leon Kos

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Splošni izbirni predmet /Elective general course

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

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

Vsebina:	**Content (Syllabus outline):**
1. Uvod v predmet. Uvod v Github: Osnovna uporaba GIT orodij. 2. Uvod v Linux: • Kaj je Linux. • Opis najbolj razširjenih Linux operacijskih sistemov. • Linux: shell, terminal in konzola, osnovne operacije nad datotekami, navigiranje med direktoriji. 3. Uvod v MATLAB: spoznavanje MATLAB sintakse, izvajanje vhodno izhodnih operacij, izvajanje temeljnih računskih operacij v MATLAB-u. MATLAB v oblaku. 4. MATLAB: izvajanje zahtevnejših numeričnih izračunov (reševanje enačb, faktorizacija matrik, numerično integriranje in odvajanje), pisanje kompleksnejših projektov, paralelizacija računanja. 5. MATLAB: napredno programiranje. 6. Linux: napredni ukazi, vhodno/izhodno preusmerjanje tokov. 7. C++: Osnovni ukazi, tipi spremenljivk, standardni input in output iz konzole, zanke, funkcije. 8. C++: Pisanje in branje tekstovnih datotek.	1. Introduction to the Subject. Introduction to Github: Basic Use of GIT Tools. 2. Introduction to Linux: • What is Linux. • Description of the most common Linux operating systems. • Linux: shell, terminal, and console, basic file operations, directory navigation. 3. Introduction to MATLAB: getting to know MATLAB syntax, performing input-output operations, performing basic computational operations in MATLAB. MATLAB in the cloud. 4. MATLAB: performing more advanced numerical calculations (solving equations, matrix factorization, numerical integration and differentiation), writing more complex projects, computation parallelization. 5. MATLAB: advanced programming. 6. Linux: Advanced Commands, Input/Output Stream Redirection. 7. C++: Basic commands, variable types, standard input and output from the console, loops, functions. 8. C++: Writing and reading text files.

9. C++: Objektno orientirano programiranje, razredi, strukture. 10. C++: kazalci in reference, array-i. 11. Uvod v Visokozmogljivo računalništvo (HPC): Kaj je HPC, pregled razpoložljivih zmogljivosti, zgodovina, trendi, prijava na HPC FS. Kako oddati preprosto računsko nalogo na HPC. Enostavna paralelizacija for zanke v C++ z OpenMP in poganjanje na HPC. 12. HPC: Paralelizacija v OpenMP. 13. 3D znanstvena vizualizacija (oblaki točk) in meritve, ParaView, VirtualGL, Vizualizacija mrež. 14. Simulacije z odprtokodnimi okolji: • Pregled modulov SALOME. • Uporaba zunanjih solverjev z modulom za paketno obdelavo na HPC. • Integracija in programiranje vmesnikov za solverje na HPC. 15. Predstavitev in pregled dodatnih okolij, ki so na voljo na HPC-ju.	9. C++: Object-oriented programming, classes, structures. 10. C++: Pointers and references, arrays. 11. Introduction to High-Performance Computing (HPC): What is HPC, overview of available capabilities, history, trends, application for HPC FS. How to submit a simple computational task to HPC. Simple parallelization of for loop in C++ with OpenMP and execution on HPC. 12. HPC: Parallelization in OpenMP. 13. 3D scientific visualization (point clouds) and measurements, ParaView, VirtualGL, Mesh Visualization. 14. Simulations with open-source environments: • Overview of SALOME modules. • Using external solvers with batch processing module on HPC. • Integration and programming of solver interfaces on HPC. 15. Presentation and overview of additional environments available in HPC.

Temeljna literatura in viri/Readings:

1. J. Petrišič, Uvod v MATLAB : za inženirje, FS 2013, [COBISS.SI-ID 269571072]
2. M.Zavešnik in M. Juvan Vaje iz programiranja : C, C ++ in Mathematica, Ljubljana : Študentska založba, 2000 [COBISS.SI-ID 109207552]
3. Slobodan Dmitrović. Modern C++ for Absolute Beginners: A Friendly Introduction to C++ Programming Language and C++11 to C++20 Standards. Apress, 2020. DOI: 10.1007/978-1-4842-6047-0 (e-knjiga dostopna iz UL)
4. Eijkhout, V. Introduction to High-Performance Scientific Computing, http://pages.tacc.utexas.edu/~eijkhout/istc/istc.html

Cilji in kompetence:	**Objectives and competences:**
Cilji: 1. Naučiti študente osnov Linuxa in kako uporabljati računalniško orodja za kreiranje kompleksnih dokumentov ter za sočasno projektno delo. 2. Naučiti študente osnov Matlaba in C++.	Objectives: 1. To teach students the basics of Linux and how to use computer tools to create complex documents and usage for collaborative tasks. 2. Introduce students to fundamentals of Matlab and C++. 3. Prepare students to be able using

3. Naučiti študente, da uporabljajo superračunalnike kot orodja za reševanje zahtevnih računskih problemov.
4. Naučiti študente, da znajo prenesti težke naloge iz svojih prenosnih ali namiznih računalnikov na superračunalnik in jih tam rešiti.
5. Naučiti študente, kako izvajati s sodobnimi računalniškimi orodji priprave, simulacije, analize in prikaz rezultatov različnih fizikalnih modelov.

Kompetence:

1. S1-RRP: Sposobnost za opredelitev, razumevanje in ustvarjalno reševanje strokovnih izzivov z uporabo naprednih računalniških orodij.
2. S2-RRP: Razvijanje sposobnosti kritičnega, analitičnega in sintetičnega mišljenja s poudarkom na reševanju različnih inženirskih problemov z naprednimi računalniškimi orodji in na kritični presoji dobljenih rešitev.
3. S5-RRP: Sposobnost uporabe IKT, še posebej superračunalniške tehnologije, za reševanje težkih računskih problemov s področja strojništva.
4. S4-RRP: Sposobnost strokovnega sporazumevanja in pisnega izražanja, vključno z uporabo tujega strokovnega jezika in naprednih računalniških orodij za pisanje kompleksnih dokumentov in za obvladovanje kompleksne dokumentacije, ki nastaja v projektnih timih.
5. P2-RRP: Študent se zna prijaviti na enega od slovenskih superračunalnikov in tam izvajati osnovne naloge v okolju Linux.
6. P2-RRP: Študent zna kreirati kompleksne dokumente v okolju Latex.
7. P2-RRP: Študent zna prenesti podatke o svojem problemu na superračunalnik in tam zagnati sodobna programska orodja za reševanje teh problemov.

supercomputers as a tools to solve complex computational problems;
4. To teach students how to model and transfer computationally demanding tasks from their laptops or desktop computers to supercomputers and solve them remotely.
5. To teach students how to prepare, simulate, analyze and visualise the results of various physical models using advanved computer tools.

Competences:

1. S1-RRP: The ability to define, understand and creatively solve professional challenges using advanced computing tools.
2. S2-RRP: Development of creative, analytical and synthetic thinking with an emphasis on (i) solving various engineering problems using advanced computer tools and (ii) on critical evaluations of the solutions.
3. S5-RRP: The ability to use ICT, especially supercomputer technology, to solve difficult computational problems related to mechanical engineering.
4. S4-RRP: Professional communication and writing communication skills, including the use of foreign technical language and advanced computer tools to write complex documents and to master complex documentation generated by project teams.
5. P2-RRP: Student can login to one of the Slovenian supercomputers and perform basic tasks in Linux environment.
6. P2-RRP: Student is able to create complex documents in the Latex environment.
7. P2-RRP: Student is able to transfer data of a computational problem to a supercomputer and run advanced software tools to solve these problems.
8. P2-RRP, P4-RRP: Student can write basic programs in C++ and MATLAB and utilizing advantage of

8. P2-RRP, P4-RRP: Študent zna napisati osnovne programe v okoljih C++ in MATLAB, ki izkoriščajo možnost paralelizacije na superračunalnikih. 9. P6-RRP: Študent zna uporabljati okolje Git za obvladovanje sprememb pri skupinskem razvoju programske kode ali druge dokumentacije. 10. P4-RRP: Študent zna uporabiti napredna računalniška orodja, kot so Salome, za reševanje kompleksnih inženirskih problemov.	parallelization on supercomputers. 9. P6-RRP: Student knows how to use the Git environment to control code or documentation changes within collaborative development environment. 10. P4-RRP: Student can use advanced computing tools, such as Salome, to solve complex engineering problems.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanja: Z1: Poglobljeno strokovno teoretično in praktično znanje na določenem področju, podprto s širšo teoretično in metodološko osnovo: razumevanje in sposobnost uporabe naprednih računalniških orodij za reševanje inženirskih problemov ter za obvladovanje kompleksne dokumentacije; Spretnosti: S1.1: Sposobnost uporabe nekaterih standardnih računalniških programov, ki jih študentje srečajo tekom študija, na superračunalniku in z njimi učinkovito reševati težke inženirske probleme. S1.2: Sposobnost obvladovati kompleksno dokumentacijo z orodji Git. S1.4: Študentje se naučijo osnov programskega jezika C++ ter uporabe knjižnic za komunikacijo v okoljih z deljenim in porazdeljenim spominom. S1.4: Študentje se naučijo napisati preproste računalniške programev okoljih Matlab in C++, ki vključujejo paralelizacijo izvajanja nad sodobnimi superračunalniškimi arhitekturami.	Knowledge: Z1: In-depth professional theoretical and practical knowledge in a specific field, supported by a broader theoretical and methodological basis: understanding and ability to use advanced computer tools to solve engineering problems and to master complex documentation; Skills: S1.1: Ability to use some standard computer programs encountered by students during their studies, on a supercomputer to efficiently solve hard engineering problems. S1.2: Ability to handle complex documentation using Git tools. S1.4: Students learn the basics of the C++ programming language and how to link libraries for processor communication in shared and distributed memory systems. S1.4: Students learn to write simple computer programs in Matlab and C++ languages, which include parallelization over modern supercomputing architectures.

Metode poučevanja in učenja:	**Learning and teaching methods:**
P1: Avditorna predavanja z reševanjem izbranih - za področje značilnih -	P1 Auditorial lectures with solving selected domain-specific theoretical and

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: • namizni računalnik s primerno programsko oporemo, • programi za oddaljeni dostop, • okolje za pisanje programske kode v C++, • okolje za izvajanje analiz velepodatkov, • oddaljeni superračunalnik. P5 Uporaba študijskega gradiva v obliki: • Zapiskov in drsnic, • Tiskanih in e-knjig, • e-verzije predavanj (video predavanja). P6 Interaktivna predavanja. P8 Izdelava in predstavitev aplikativnih seminarskih nalog. P12 Individualizirane domače naloge v spletni učilnici. P13 Individualizirani kolokviji in izpiti s samodejnim popravljanjem. P15 Uporaba video vsebin kot priprava na predavanja in vaje.	applied use cases. P2 Presenting the content according to the explained systematics. P3 Auditorial tutorials, where the theoretical content from the lectures is supplemented with practical examples. P4 Laboratory exercises with special-purpose didactic devices: • Desktop computer with appropriate software, • Clients for remote access, • C++ programming environment • Big Data analysis tools , • supercomputer via remote access. P5 Application of different study materials: • lecture notes and slides, • printed and eBooks, • e-versions of lectures (video lectures). P6 Interactive Lectures. P8 Preparation and presentation of application oriented seminars. P12 Individualized homeworks in e-classrooms. P13 Individualized mid-term exams and self-evaluating exams. P15 Video contents for preparing students for lectures and tutorials.

Načini ocenjevanja:	**Delež/ Weight**	**Assessment:**
Izpit.	40,00 %	Exam.
Projekt.	40,00 %	Project.
Domače naloge.	20,00 %	Coursework.

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

Reference nosilca/Lecturer's references:

Janez Povh:

1. ČEGOVNIK, Tomaž, DOBROVOLJC, Andrej, **POVH, Janez**, TOMŠIČ, Pavel. Electricity consumption prediction using artificial intelligence. *Central European journal of operations research*. 2023, vol. 31, str. 833–851, ilustr. ISSN 1613-9178
2. MALOD-DOGNIN, Noël, PETSCHNIGG, Julia, WINDELS, Sam F. L., **POVH, Janez**, HEMMINGWAY, Harry, KETTELER, Robin, PRŽULJ, Nataša. Towards a data-integrated cell. *Nature communications*, ISSN 2041-1723, Feb. 2019, [Vol.] 10, f. 1-13, ilustr. https://www.nature.com/articles/s41467-019-08797-8, doi: 10.1038/s41467-019-08797-8. [COBISS.SI-ID 16484379];
3. GUSMEROLI, Niccolò, HRGA, Timotej, LUŽAR, Borut, **POVH, Janez**, SIEBENHOFER, Melanie, WIEGELE, Angelika. BiqBin: a parallel branch-and-bound solver for binary quadratic problems with linear constraints. *ACM transactions on mathematical software*. June 2022, vol. 48, iss. 2, art. 15 (31 str.). ISSN 0098-3500. https://dl.acm.org/doi/10.1145/3514039, DOI: 10.1145/3514039. [COBISS.SI-ID 116309507]
4. URBAS, Uroš, HRGA, Timotej, **POVH, Janez**, VUKAŠINOVIĆ, Nikola. Novel alignment method for optical 3D gear metrology of spur gears with a plain borehole. *Measurement : journal of the International Measurement Confederation*. [Print ed.]. Mar. 2022, vol. 192, str. 1-10, ilustr. ISSN 0263-2241. https://www.sciencedirect.com/science/article/pii/S0263224122001336, Repozitorij Univerze v Ljubljani – RUL, DOI: 10.1016/j.measurement.2022.110839. [COBISS.SI-ID 98561539]
5. BENEDIK, Blaž, RIHTARŠIČ, Janez, **POVH, Janez**, TAVČAR, Jože. Failure modes and life prediction model for high-speed bearings in a through-flow universal motor. *Engineering failure analysis*. Oct. 2021, vol. 128, str. 1-17, ilustr. ISSN 1350-6307. https://www.sciencedirect.com/science/article/pii/S1350630721003952, Repozitorij Univerze v Ljubljani – RUL, DOI: 10.1016/j.engfailanal.2021.105535. [COBISS.SI-ID 68629507]

Leon Kos:

1. KRISHNASAMY, Ezhilmathi, VASILESKA, Ivona, **KOS, Leon**, BOUVRY, Pascal. Hybrid programming and multiple GPUs implementation for particle-in-cell. V: *ICCCS 2023 : 2023 8th International Conference on Computer and Communication Systems, 21-23 April 2023, Guangzhou, China*. [S. l.]: IEEE, 2022. Str. 725-731, ilustr. ISBN 978-1-6654-5612-8. https://ieeexplore.ieee.org/document/10150523, DOI: 10.1109/ICCCS57502023.10150523. [COBISS.SI-ID 166995715]
2. HOELZL, Matthias, HUIJSMANS, Guido, PAMELA, Stanislas, BÉCOULET, Marina, NARDON, Eric, ARTOLA, Francisco Javier, NKONGA, Boniface, ATANASIU, Calin, BANDARU, Vinodh, BHOLE, Ashish, **KOS, Leon**, PENKO, Dejan (konzultant), et al. The JOREK non-linear extended MHD code and applications to large-scale instabilities and their control in magnetically confined fusion plasmas. *Nuclear fusion*. 2021, vol. 61, no. 6, str. 1-71, ilustr. ISSN 0029-5515. https://iopscience.iop.org/article/10.1088/1741-4326/abf99f, DOI: 10.1088/1741-4326/abf99f. [COBISS.SI-ID 61762819]
3. **KOS, Leon**, PITTS, R. A., SIMIČ, G., BRANK, Matic, ANAND, H., ARTER, W.

SMITER : a field-line tracing environment for ITER. *Fusion engineering and design*, ISSN 0920-3796. [Print ed.], Sep. 2019, vol. 146, pt. B, str. 1796-1800, ilustr. [COBISS.SI-ID 16530203]; https://www.sciencedirect.com/science/article/pii/S092037961930359X?via%3Dihub, doi: 10.1016/j.fusengdes.2019.0037.

4. ANAND, H., PITTS, R. A., VRIES, P. C. de, SNIPES, J. A., NESPOLI, F., LABIT, B., GALPERTI, C., CODA, S., BRANK, Matic, **KOS, Leon**. Experimental implementation of a real-time power flux estimator for the ITER first wall on the TCV tokamak. *Fusion engineering and design*, ISSN 0920-3796. [Print ed.], Oct. 2019, vol. 147, str. 1-7, ilustr. [COBISS.SI-ID 16703771]; https://www.sciencedirect.com/science/article/pii/S0920379619307203#!, doi: 10.1016/j.fusengdes.2019.111242.
5. **KOS, Leon**, JELIĆ, Nikola, GYERGYEK, Tomaž, KUHN, S., TSKHAKAYA, David. Modeling and simulations of plasma and sheath edges in warm-ion collision-free discharges. *AIP advances*, ISSN 2158-3226, Oct. 2018, vol. 8, no 10, str. 1-23, ilustr. [COBISS.SI-ID 12219988]; https://aip.scitation.org/doi/pdf/10.1063/1.5044664?class=pdf, doi: 10.1063/1.5044664