# Programiranje energijsko omejenih napravUčni načrt predmeta/Course syllabus

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| Predmet: | Programiranje energijsko omejenih naprav |
| Course title: | Programming of Energy-Constrained Devices  |
| Članica nosilka/UL Member: | UL FRI |

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| Študijski programi in stopnja | Študijska smer | Letnik | Semestri | Izbirnost |
| Računalništvo in informatika, prva stopnja, visokošolski strokovni(v postopku) | Ni členitve (študijski program)  |  | 1. semester | izbirni |

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| Univerzitetna koda predmeta/University course code: | 0643451 |
| Koda učne enote na članici/UL Member course code: | 63776 |

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| Predavanja/Lectures | Seminar/Seminar | Vaje/Tutorials | Klinične vaje/Clinical tutorials | Druge oblike študija/Other forms of study | Samostojno delo/Individual student work | ECTS |
| 45 | 15 | 15 |  |  | 105 | 6 |

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| Nosilec predmeta/Lecturer: | Veljko Pejović  |

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| Vrsta predmeta/Course type: | izbirni-strokovni/elective-vocational |

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| Jeziki/Languages: | Predavanja/Lectures: | Angleščina, Slovenščina  |
|  | Vaje/Tutorial: | Angleščina, Slovenščina  |

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| Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti: | Prerequisites: |
| Vpis v letnik. | Enrollment in the study year. |

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| Vsebina: | Content (Syllabus outline): |
| Na desetine milijard naprav interneta stvari (IoT) skupaj s približno enim pametnim telefonom na vsakega prebivalca tega planeta obljubljajo izpolnitev vizije računalništva, ki ga lahko izvajamo kadarkoli in kjerkoli. Ti računalniki že zagotavljajo storitve na področjih, ki segajo od zdravstva, prek upravljanja s pametnimi domovi, do kmetijstva. Mobilne naprave in naprave IoT kljub svoji raznolikosti odlikuje skupna zmačilnost – napajajo se preko baterij omejenih kapacitet. Posledično je učinkovito upravljanje z viri ključnega pomena.V tem predmetu pokrivamo temelje trajnostnega mobilnega in IoT računalništva. Konkretno:* Predstavimo električne mehanizme, ki povzročajo disipacijo energije, nato pa se naučimo, kako oceniti porabo energije tako celotnih sistemov kot posebnih komponent v okviru naprav IoT.
* Predstavimo različne tehnike za varčno računalništvo na ravni operacijskega sistema in aplikacij.
* Predstavimo prilagoditev delovnega cikla in hierarhično aktiviranje senzorjev za učinkovito uporabo energije baterije pri vzorčenju senzorjev, ene izmed najbolj zahtevnih nalogah naprav IoT.
* Pregledamo brezžično komunikacijo in predstavimo načine za zmanjšanje porabe energije z občasno povezljivostjo in prilagajanjem hitrosti prenosa.
* Predstavimo osnove upravljanja z energijo v mobilnih sistemih.
* Na primeru Androida, najbolj priljubljenega mobilnega operacijskega sistema na svetu, preučimo učinkovito paketno obdelavo opravil v ozadju.
* Izvedemo praktični projekt na Androidu, ki študente seznani s sodobnim ogrodjem za učinkovito mobilno zaznavanje in razporejanje računalniških nalog na napravi.
* Raziskujemo človeške vidike uporabe mobilnega telefona in načine zaznavanja vpletenosti uporabnika, da bi preprečili zapravljanje virov v mobilnem računalništvu.
* Predstavimo pregled najsodobnejših tehnik približnega mobilnega računalništva, paradigme, ki omogoča nadzorovano zmanjšanje natančnosti računanja, če rezultat, dosežen s takim računanjem, ostane sprejemljiv za končnega uporabnika.
 | Tens of billions of Internet of Things (IoT) devices together with roughly one smartphone per each inhabitant of this planet promise to fulfil the vision of anytime-anywhere computing. These computers already provide indispensable services in areas reaching from personal health, over smart home management, to precision agriculture. Despite their diversity, mobile and IoT devices are almost all characterised by a common trait - they are powered through small-capacity batteries. Consequently, resource-efficient operation is crucial.In this course we cover the foundations of sustainable mobile and IoT computing. More specifically, we:* Introduce the electrical mechanisms that cause power to be dissipated, and then learn how to assess power consumption of both whole systems and specific components of IoT devices.
* Present different techniques for resource-efficient computing at the level of operating system and applications.
* Discuss adaptive duty cycling and hierarchical sensor activation for judicious use of battery energy in sensing, one of the most resource-demanding affordances of IoT devices.
* Discuss wireless communication and present means of reducing energy consumption through intermittent connectivity and transmission rate adaptation.
* Present the basics of energy management in mobile systems.
* On the example of Android, the most popular mobile OS in the world, we demonstrate batching for resource-efficient background task processing.
* Conduct a practical Android project that introduces students to a modern framework for resource efficient mobile sensing and task scheduling.
* Investigate human aspects of mobile usage and means of detecting a user's involvement in order to prevent resource wastage in mobile computing.
* Present an overview of the cutting-edge techniques in approximate mobile computing, a paradigm that allows a controlled reduction of computation accuracy, if the result achieved through such computation remains acceptable by the end user.
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| Temeljna literatura in viri/Readings: |
| **Kruglov, A., & Succi, G. (2023).** Developing Sustainable and Energy-Efficient Software Systems.**Dastbaz, M., Pattinson, C., & Akhgar, B. (2015).** Green information technology: A sustainable approach. Morgan Kaufmann.**Feng, W. C. (Ed.). (2014).** The Green Computing Book: Tackling Energy Efficiency at Large Scale. CRC Press.**Nguemaleu, R. A. C., & Montheu, L. (2014).** Roadmap to Greener Computing. CRC Press.**Paradiso, J. A., & Starner, T. (2005).** Energy scavenging for mobile and wireless electronics. IEEE Pervasive computing, 4(1), 18-27.**Carrano, R. C., Passos, D., Magalhaes, L. C., & Albuquerque, C. V. (2013)**. Survey and taxonomy of duty cycling mechanisms in wireless sensor networks. IEEE Communications Surveys & Tutorials, 16(1), 181-194.**Machidon, O., Asprov, J., Fajfar, T., & Pejović, V. (2022).** Context-aware adaptation of mobile video decoding resolution. Multimedia Tools and Applications, 1-32.**Pejović, V. (2019)**. Towards approximate mobile computing. GetMobile: Mobile Computing and Communications, 22(4), 9-12. |

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| Cilji in kompetence: | Objectives and competences: |
| Cili predmeta so:Cilj predmeta je seznaniti študente s trajnostjo kot pomembnim vidikom sodobnega mobilnega in IoT računalništva.Splošne kompetence:* Sposobnost nadgradnje predhodno pridobljenega znanja.
* Razviti sposobnosti kritičnega, analitičnega in sintetičnega mišljenja.
* Sposobnost prepoznavanja in ocenjevanja izzivov pri oblikovanju in izgradnji računalniških rešitev.
* Sposobnost uporabe pridobljenega znanja na praktičnih problemih.
* Razviti veščine, povezane z razumevanjem specifikacije naloge, sledenjem navodilom in prikazom samostojnega dela na področju računalništva.

Predmetno-specifične kompetence:* Sposobnost razumevanja medsebojnega delovanja med kibernetskimi, fizičnimi in človeškimi vidiki računalniških sistemov.
* Sposobnost kritične analize kompromisa med uporabo virov in zmogljivostjo v IoT in mobilnem računalništvu.
* Praktična znanja in veščine, povezane z razvojem učinkovitih mobilnih in IoT računalniških rešitev.
 | The goals and core skills of the module are to:The aim of the course is to familiarise students with sustainability as an important aspect of modern mobile and IoT computing.General competences:* Ability to upgrade previously acquired knowledge.
* Develop skills in critical, analytical and synthetic thinking.
* Ability to recognise and assess challenges in designing and building computing solutions.
* Ability to apply the obtained knowledge on practical problems.
* Develop skills related to understanding a task specification, following instructions, and demonstrating individual work in the domain of computing.

Subject-specific competences:* Ability to understand the interplay between the cyber, the physical, and the human aspects of computing systems.
* Ability to critically analyse the trade-off between resource usage and performance in IoT and mobile computing.
* Practical knowledge and skills related to building resource-efficient solutions in mobile and IoT domains.
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| Predvideni študijski rezultati: | Intended learning outcomes: |
| Po uspešno zaključenem predmetu bodo študenti zmožni:* Identificirati ustrezna orodja in z njimi izmeriti porabo energije IoT sistemov in komponent v laboratorijskem okolju.
* Našteti in opisati tehnike varčevanja z energijo na ravni operacijskega sistema in aplikacije v IoT računalništvu.
* Opisati kako vzorčenje senzorjev vpliva na porabo energije in navesti tehnike za vzorčenje z zmanjšano porabo energije.
* Navesti ključne postulate oblikovanja sodobnih mobilnih operacijskih sistemov, ki vodijo k energijsko varčnemu delovanju.
* Implementirati mobilno računalniško rešitev, ki izkorišča najboljše prakse pri obdelavi nalog v ozadju.
* Oceniti kompromise pri uporabi različnih metod za učinkovito rabo virov v mobilnem in IoT računalništvu.
* Razumeti človeško vedenje kot dejavnik, ki vpliva na porabo energije, in razviti učinkovite računalniške rešitve, ki ocenjujejo in upoštevajo vedenje končnega uporabnika.
 | After successful completion of the module, the participants will be able to:* Identify the appropriate tools and measure energy consumption of IoT systems and components in a laboratory environment
* List and describe power saving techniques on the level of operating system and application in IoT computing.
* Describe how sensor sampling impacts energy consumption and list techniques for reduced-power sampling.
* State the key postulates of modern mobile operating system design that lead to energy-efficient operation.
* Implement a mobile computing solution that harnesses best practices in background task processing.
* Evaluate trade-offs when using different methods for resource efficiency in mobile and IoT computing
* Acknowledge human behaviour as a factor impacting energy usage and develop resource efficient computing solutions that assess and take into account the behaviour of an end user.
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| Metode poučevanja in učenja: | Learning and teaching methods: |
| Predavanja, praktične vaje in demonstracije, projektni način dela pri seminarjih in vajah. | Lectures, lab work, home assignments, project work. |

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| Načini ocenjevanja: | Delež/Weight | Assessment: |
| Način (pisni izpit, ustno izpraševanje, naloge, projekt) |  | Type (examination, oral, coursework,project) |
| naloge, projekt) Sprotno preverjanje (domače naloge, projektno delo) | 50,00 % | Continuous (home assignments, project work) |
| Končno preverjanje (praktična aplikacija naučenega in zagovor) | 50,00 % | End-of-Year exam (write-up of a practical application of knowledge and oral defense). |
| Ocene: 6-10 pozitivno, 5 negativno (v skladu s Statutom UL) |  | Scale: 6-10 pass, 5 and below fail (According to the rules and ordnances of the University of Ljubljana) |

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| Reference nosilca/Lecturer's references: |
| **A. Machidon and V. Pejovic,** Deep Learning Techniques for Compressive Sensing-Based Reconstruction and Inference - A Ubiquitous Systems Perspective, Artificial Intelligence Review (2022).**A. Machidon and V. Pejovic,** Enabling Resource-Efficient Edge Intelligence with Compressive Sensing-Based Deep Learning, ACM Computing Frontiers, May 2022**O. Machidon, J. Asprov, T. Fajfar, and V. Pejovic**, Context-aware adaptation of mobile video decoding resolution, Multimedia Tools and Applications (2022)**T. Knez, O. Machidon, and V. Pejovic,** Self-Adaptive Approximate Mobile Deep Learning, Electronics (2021)**V. Pejovic and E. M. Belding,** WhiteRate: A Context-aware Approach to Wireless Transmission Adaptation, IEEE Transactions on Mobile Computing, Vol 13 (2014) |