

| UČNI NAČRT PREDMETA / COURSE SYLLABUS (leto / year 2017/18)                  |                           |   |                              |                                    |                                      |             |
|--|---------------------------|---|------------------------------|------------------------------------|--------------------------------------|-------------|
| <b>Predmet:</b>  |                           | Digitalno procesiranje signalov                                       |                              |                                    |                                      |             |
| <b>Course title:</b>   |                           | Digital signal processing   |                              |                                    |                                      |             |
| <b>Študijski program in stopnja</b><br>Study programme and level             |                           | <b>Študijska smer</b><br>Study field                                  |                              | <b>Letnik</b><br>Academic year     | <b>Semester</b><br>Semester          |             |
| Interdisciplinarni magistrski študijski program Računalništvo in matematika  |                           | ni smeri  |                              | 1 ali 2                            | prvi                                 |             |
| Interdisciplinary Master's study programme Computer Science and Mathematics  |                           | none  |                              | 1 or 2                             | first                                |             |
| <b>Vrsta predmeta / Course type</b>  |                           |   |                              | izbirni / elective                 |                                      |             |
| <b>Univerzitetna koda predmeta / University course code:</b>                 |                           |   |                              | 63516                              |                                      |             |
| <b>Predavanja</b><br>Lectures  | <b>Seminar</b><br>Seminar | <b>Vaje</b><br>Tutorial   | <b>Klinične vaje</b><br>work | <b>Druge oblike študija</b>        | <b>Samost. delo</b><br>Individ. work | <b>ECTS</b> |
| 45   | 10                        | 20  |                              |                                    | 105                                  | 6           |
| <b>Nosilec predmeta / Lecturer:</b>  |                           | prof. dr. Patricio Bulić  |                              |                                    |                                      |             |
| <b>Jeziki / Languages:</b>   |                           | <b>Predavanja / Lectures:</b> slovenski / Slovene, angleški / English |                              |                                    |                                      |             |
|  |                           | <b>Vaje / Tutorial:</b> slovenski / Slovene, angleški / English       |                              |                                    |                                      |             |
| <b>Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:</b> |                           |   |                              | <b>Prerequisites:</b>              |                                      |             |
| Vpis v letnik študija.   |                           |   |                              | Enrolment in the programme.        |                                      |             |
| <b>Vsebina:</b>  |                           |   |                              | <b>Content (Syllabus outline):</b> |                                      |             |

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| <p>1. Zvezni in diskretni signali, zaporedja, enotni impulz.</p> <p>2. Diskretni linearni časovno-invariantni sistemi, lastna funkcija, kavzalnost, stabilnost.</p> <p>3. Diferenčne enačbe in z-transformacija.</p> <p>4. Vzorčenje zveznih signalov, posplošeno vzorčenje, decimacija in interpolacija.</p> <p>5. Analiza diskretnih sistemov v frekvenčnem prostoru, idealni filtri, sistemi z minimalno in linearno fazo.</p> <p>6. Strukture za realizacijo diskretnih sistemov: direktna, kaskadna in paralelna.</p> <p>7. Metode za načrtovanje digitalnih filtrov z neskončnim enotnim odzivom: bilinearna transformacija analognih filtrov, načrtovanje z uporabo linearnega programiranja.</p> <p>8. Metode za načrtovanje digitalnih filtrov s končnim enotnim odzivom: okenske funkcije, frekvenčno vzorčenje, Remezov algoritem.</p> <p>9. Diskretna Fourierova transformacija in FFT algoritem.</p> <p>10. Hitro računanje diskretne konvolucije in korelacije.</p> | <p>1. Continuous and discrete signals, sequences, unit impulse.</p> <p>2. Discrete linear time-invariant systems, eigenfunction, causality, stability.</p> <p>3. Difference equations and z-transform.</p> <p>4. Sampling of continuous signals, sampling generalization, decimation and interpolation.</p> <p>5. Analysis of discrete systems in the frequency domain, ideal filters, systems with minimal and linear phase.</p> <p>6. Structures for discrete system: direct, cascade and parallel forms.</p> <p>7. Methods for infinite impulse response digital filter design: bilinear transformation of analog filters, design with linear programming.</p> <p>8. Methods for finite impulse response digital filter design: window functions, frequency sampling, Remez algorithm.</p> <p>9. Discrete Fourier transform and FFT algorithm.</p> <p>10. Fast discrete convolution and correlation.</p> <p>11. Spectral analysis: nonparametric and parametric methods. LPC analysis.</p> <p>12. Signal processors: properties, special</p> |
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| <p>11. Spektralna analiza: neparametrične in parametrične metode. LPC analiza.</p> <p>12. Signalni procesorji: lastnosti, posebnosti, programiranje in uporaba.</p> <p>13. Uporaba digitalnega procesiranja signalov pri govornih in video signalih.</p> | <p>functions and application.</p> <p>13. Application of digital signal processing speech and video signals.</p> |
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**Temeljni literatura in viri / Readings:**

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| <p>1. A.V. Oppenheim, R.W. Shafer: Discrete-Time Signal Processing, 2nd Edition, Prentice Hall, 1999, poglavja 1 do 10.</p> <p>2. J. G. Proakis, D.G. Manolakis: Digital Signal Processing, 4th Edition, Prentice Hall, 2006.</p> |
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**Cilji in kompetence:**

Cilj predmeta je predstaviti področje obdelave signalov z digitalnimi metodami in še posebej uporabo računalnikov na tem področju. Poleg teoretičnih znanj, ki so osnova za razumevanje uporabljenih metod, je predmet namenjen tudi pridobivanju praktičnih izkušenj na resničnih problemih. Poseben poudarek je dan pregledu naprav in dejavnosti, pri katerih se uporabljajo metode iz digitalnega procesiranja signalov.

**Objectives and competences:**

The objective is to present the processing of signals by digital techniques, including the application of computers in this area. The theory which is the basis for understanding the processing methods is combined with practical projects that are derived from the real world problems. Special attention is given to devices and activities that use the digital signal processing methods.

**Predvideni študijski rezultati:**

**Intended learning outcomes:**

**Znanje in razumevanje:**

Osnovni cilj je razumevanje principov digitalnega procesiranja signalov vključno s primerjavo in oceno različnih metod, ki se v njem uporabljajo.

**Uporaba:**

Digitalno procesiranje signalov je danes prisotno v mnogih izdelkih, od mobilnih telefonov do računalnikov. Razumevanje delovanja in sposobnost za presojo kvalitete različnih rešitev je koristno v mnogih primerih.

**Refleksija:**

Povezava matematično-teoretičnih metod s praktičnimi izkušnjami in s tem povečanje možnosti za poklicni uspeh diplomanta.

Prenosljive spretnosti - niso vezane le na en predmet:

Predmet se dopolnjuje s predmeti s področja algoritmov, programiranja in arhitekture.

**Knowledge and understanding:**

Understanding the principles of digital signal processing including the comparison and evaluation of different methods.

**Application:**

Digital signal processing is the basis of many products manufactured today, from mobile phones to computers. Understanding it and being able to evaluate the quality of different solutions is essential in many cases.

**Reflection:**

Combination of mathematical-theoretical methods with practical experience increase the chances for graduate's successful career.

**Transferable skills:**

This course complements the courses from the area of algorithms, programming and architecture.

**Metode poučevanja in učenja:**

Predavanja, laboratorijske vaje in domače naloge. Poseben poudarek je na praktičnem laboratorijskem delu. Študenti s pomočjo programskih orodij in signalnih procesorjev

**Learning and teaching methods:**

Lectures, laboratory and homework. Special emphasis is given to practical laboratory work. Students use programming tools and digital signal processors to get hands on knowledge of

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| spoznavajo digitalno procesiranje signalov in njegovo uporabnost. | digital signal processing and its application. |
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|  |  | Delež (v %) /<br>Weight (in %) | Assessment:  |
|--|--|--------------------------------|--|
| Načini ocenjevanja:  |  |                                |  |
| Način (pisni izpit, ustno izpraševanje, naloge, projekt):        |  |                                | Type (examination, oral, coursework, project):                                   |
| Sprotno preverjanje (domače naloge, kolokviji in projektno delo) |  |                                | Continuing (homework, midterm exams, project work)                               |
| Končno preverjanje (pisni in ustni izpit)                        |  |                                | Final (written and oral exam)  |
| Ocene: 6-10 pozitivno, 1-5 negativno<br>(v skladu s Statutom UL) |  | 50%                            | Grading: 6-10 pass, 1-5 fail (according to the rules of University of Ljubljana) |
|  |  | 50%                            |  |

#### Reference nosilca / Lecturer's references:

AVRAMOVIĆ, Aleksej, BABIĆ, Zdenka, RAIČ, Dušan, STRLE, Drago, BULIĆ, Patricio. An approximate logarithmic squaring circuit with error compensation for DSP applications. *Microelectronics journal*, ISSN 0959-8324. [Print ed.], 2014, vol. 45, iss. 3, str. 263-271. , doi: . [COBISS.SI-ID 10373972]

ČEŠNOVAR, Rok, RISOJEVIĆ, Vladimir, BABIĆ, Zdenka, DOBRAVEC, Tomaž, BULIĆ, Patricio. A GPU implementation of a structural-similarity-based aerial-image classification. *The journal of supercomputing*, ISSN 0920-8542, Aug. 2013, vol. 65, no. 2, str. 978-996, ilustr. , doi: . [COBISS.SI-ID 9619028]

BULIĆ, Patricio, GUŠTIN, Veselko, ŠONC, Damjan, ŠTRANCAR, Andrej. An FPGA-based integrated environment for computer architecture. *Computer applications in engineering education*, ISSN 1061-3773. [Print ed.], Mar. 2013, vol. 21, no. 1, str. 26-35, ilustr. , doi: . [COBISS.SI-ID 7696212]

LOTRIČ, Uroš, BULIĆ, Patricio. Applicability of approximate multipliers in hardware neural networks. *Neurocomputing*, ISSN 0925-2312. [Print ed.], Nov. 2012, vol. 96, str. 57-65, ilustr. [COBISS.SI-ID 9160276]

BABIĆ, Zdenka, AVRAMOVIĆ, Aleksej, BULIĆ, Patricio. An iterative logarithmic multiplier. *Microprocessors and microsystems*, ISSN 0141-9331. [Print ed.], 2011, vol. 35, no. 1, str. 23-33, ilustr. [COBISS.SI-ID 7837780]

