ПРОГРАМ
И ЗБОРНИК АПСТРАКАТА

LXX конференције ЕТРАН
и 13. међународне конференције ИцЕТРАН

PROGRAM
AND BOOK OF ABSTRACTS

LXX ETRAN Conference
and 13th International Conference IcETRAN

Сребрно језеро, 8 - 11. јуна 2026. године
Silver Lake, Serbia, 8 - 11, June, 2026.

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Електроника
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Програм и зборник апстраката
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3. Љубљана, новембра 1958. год.
4. Загреб, новембра 1959. год.
5. Београд, новембра 1960. год.
6. Сарајево, новембра 1961. год.
7. Нови Сад, новембра 1962. год.
8. Загреб, новембра 1963. год.
9. Блед, новембра 1964. год.
10. Београд, новембра 1965. год.
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65. Етно село Станишићи, БиХ, септембра 2021. год.
66. Нови Пазар, јуна 2022. год.
67. Источно Сарајево, БиХ, јуна 2023. год.
68. Ниш, јуна 2024. год.
69. Чачак, Јуна 2025. год.

Поштовани учесници LXX конференције ЕТРАН и
13. конференције ИцЕТРАН,

Зборник радова конференција ЕТРАН и IcETRAN представља преглед најновијих достигнућа великог броја аутора и истраживачких тимова из земље и иностранства. Анализа радова представљених на овим конференцијама омогућава увид у актуелне правце развоја и напредак у областима електротехнике и рачунарства у Србији, региону и свету.

За овогодишње конференције ЕТРАН и IcETRAN поднето је 293 рада, од којих су, након вишеструког рецензентског поступка, прихваћена 263, што представља стопу прихваћености од 89,8%. Радови потичу од аутора из 27 земаља, што потврђује изражен међународни карактер конференција и њихову високу научну релевантност. У процесу рецензије био је ангажован пул од 911 међународно признатих рецензената, од којих је активно учествовало 475. Прихваћени радови распоређени су у оквиру пет пленарних сесија, шест придружених сесија и 17 редовних сесија током четири конференцијска дана.

На уводном и осталим пленарним заседањима биће одржано пет позваних (keynote) предавања, која представљају најсавременија истраживања у различитим областима електротехнике и рачунарства. Предавање професора Драјића посвећено је историјату конференције и садржи осврт на најзначајније догађаје и промене које су обележиле рад Друштва за ЕТРАН. Предавање колеге Филипа Свободе бави се развојем телекомуникација, са посебним освртом на 6G технологију. Професор Јозо Дујмовић представиће истраживања из области логике доношења одлука у здравству, док ће колега Горан Стојановић говорити о технологијама израде електронских кола у облику текстила. Предавање колеге Страхиње Дошена посвећено је новој генерацији бионичких веза.

У оквиру „Индустријског дана“ предвиђен је простор за представљање три спонзора, где ће бити приказана најновија достигнућа компанија из области електротехнике и рачунарства. Планирана је и панел-дискусија посвећена изазовима и перспективама развоја нуклеарне енергетике, као и улози нуклеарне енергије у енергетском систему Србије.

Као и претходних година, секције ће на посебним седницама изабрати најбоље радове (Best Paper Award), као и најбоље радове младих аутора (Best Young Author Award), док ће награде бити уручене на свечаности конференције. Удружење за ЕТРАН одржаће редовну годишњу скупштину, уз низ пратећих активности. Посебна пажња посвећена је и стручно-културном програму, у оквиру кога је планирано крстарење Дунавом до Голубачке тврђаве и назад.

Овогодишње конференције ЕТРАН и IcETRAN потврђују континуирани раст интересовања за овај вид научне комуникације и непосредне размене научних резултата, истраживачких достигнућа и практичних искустава. Оне истовремено представљају важну прилику за успостављање нових сарадњи и развој будућих пројеката. Упркос сложеним друштвеним околностима, број пријављених и прихваћених радова остаје висок, а очекује се присуство око 300 учесника.

Конференције се организују под покровитељством Министарства науке, технолошког развоја и иновација Републике Србије, уз техничку подршку научних удружења ЦИРЕД, ТЕЛФОР, Енергетска електроника и компаније ANT Computers, која је обезбедила рачунарску подршку. Технички коспонзор конференције је и IEEE, највеће светско удружење инжењера електротехнике и електронике, посредством Региона 8, као и секција и подружница у Србији и Црној Гори, те Босни и Херцеговини. Захваљујући сарадњи са IEEE-ом, радови са конференције IcETRAN биће уврштени у дигиталну библиотеку IEEE Xplore, чиме ће добити широку међународну видљивост и потенцијалну цитираност у релевантним светским базама, као што су Web of Science, Scopus и Google Scholar.

После седам година, ЕТРАН се поново одржава на Сребрном језеру, пре свега захваљујући ентузијазму и посвећености Програмског одбора и наших традиционалних сарадника из Академске мисли. Гостопримство домаћина, изузетни просторни и технички услови, као и пријатна атмосфера, представљају чврсту основу за успешну реализацију конференције.

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Министарство науке, технолошког развоја и иновација Републике Србије

ПОДРШКА

IEEE – Institute of Electrical and Electronics Engineers
IEEE Region 8 Europe, Middle East, and Africa
IEEE Serbia and Montenegro Section,
IEEE Bosnia and Herzegovina Section
IEEE Power & Energy Chapter of the IEEE S&M Section
IEEE Serbia and Montenegro Section Comp. Soc. Chapter
Ant Computers
Друштво за енергетску електронику Србије
CIRED, Србија
ТЕЛФОР, Србија
IFMBE - International Federation for Medical and Biological Engineering
Српско друштво за квалитет ваздуха

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Мирјана Јованић, Друштво за ЕТРАН
Златко Јарневић, Друштво за ЕТРАН

ДЕСК ЗА РЕГИСТРАЦИЈУ

Радно време Деска:	
Недеља 7. јун 2026.	17:00 - 18:00
Понедељак, 8. јун 2026.	08:45 - 14:00 и 15:00 - 16:30
Уторак, 9. јун 2026.	08:45 - 13:00 и 14:00 - 16:30
Среда, 10. јун 2026.	08:45 - 10:30
Четвртак, 11. јун 2026.	08:45 - 10:30

Скраћенице:

	IcETRAN	ЕТРАН
Електроника	ELI	ЕЛ
Телекомуникације	TEI	ТЕ
Рачунарство	RTI	РТ
Аутоматика	AUI	АУ
Нуклеарна техника	NTI	НТ
Акустика	AKI	АК
Антене и простирање	API	АП
Вештачка интелигенција	VII	ВИ
Електрична кола, електрични системи и обрада сигнала	EKI	ЕК
Електроенергетика	EEI	ЕЕ
Биомедицинска техника	BTI	БТ
Метрологија	MLI	МЛ
Нови материјали	NMI	НМ
Микроелектроника и оптоелектроника	MOI	МО
Микроталасна техника, технологије и системи	MTI	МТ
Роботика и флексибилна аутоматизација	ROI	РО
Едукација	EDUI	ЕДУ

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1. Електротехнички факултет, Београд
2. Електронски факултет, Ниш
3. Институт за нуклеарне науке „Винча“, Универзитет у Београду, Институт од националног значаја за Републику Србију
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6. Факултет техничких наука, Чачак
7. Електротехнички факултет, Источно Сарајево
8. Саобраћајни факултет, Београд
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12. Факултет техничких наука, Косовска Митровица
13. Технолошко металуршки факултет,Београд
14. Универзитет Сингидунум, Београд
15. Институт Ирител а.д, Београд
16. Институт Михајло Пупин, Београд
17. Институт техничких наука САНУ, Београд
18. Иновациони центар Електротехничког факултета, Београд
19. Машински факултет, Београд
20. НТ парк Чачак
21. Факултет организационих наука, Београд
22. Београдска академија пословних и уметничких струковних студија, Београд
23. Академија техничко-уметничких струковних студија Београд - Одсек Висока школа за информационе и комуникационе технологије, Београд
24. Академија техничко-уметничких струковних студија Београд - Одсек Висока школа електротехнике и рачунарства, Београд
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26. Академија струковних студија косовско метохијска, Лепосавић

Распоред дешавања на LXX Конференцији ЕТРАН

Понедељак, 8. јун 2026 у 17:30 (Сала 1)
СВЕЧАНО ОТВАРАЊЕ
Проф. др. Зоран Чича: Поздравне речи
Др Славко Димовић: Поздравне речи
Проф. др Слободан Вукосавић: Поздравне речи

Понедељак, 8. јун у 18:00 (Сала 1)
УВОДНА ПРЕДАВАЊА

Душан Драјић
Електротехнички факултет, Универзитет у Београду
„Преглед историјата Друштва за ЕТРАН“

Philipp Svoboda
Institut for Telecommunication, Technische Universität Wien, Austria
„Differentiable Digital Twins and AI: Towards the Realization of 6G and Smart Railway Systems”

Јозо Дујмовић
San Francisco State University, USA
„Graded Logic for Explainable Decision Making in Healthcare”

Понедељак, 8. јун 2026. у 19:30
КОКТЕЛ

Уторак, 9. јун 2026. у 9:00 – 16:00 (Тераса хотела)
Изложба компанија – спонзора
Координатор: др Иван Лазовић

Уторак, 9. јун 2026. у 10:00 – 12:00 (Тераса хотела)
Представљање компанија
Златни и сребрни спонзори

Уторак, 9. јун 2026. у 11:00 – 11:45 (Сала 4)
Скупштина Друштва за квалитет ваздуха

Уторак, 9. јун 2026. у 12:00 – 12:45 (Сала 5)
Предавање: 170 година од рођења Николе Тесле
Братислав Стојиљковић, *Музеј Николе Тесле, Београд*

Уторак, 9. јун 2026. у 13:30 – 14:30
КОКТЕЛ КОМПАНИЈА

Уторак, 9. јун 2026. у 16:45 – 17:30 (Сала 1)
УВОДНА ПРЕДАВАЊА

Горан Стојановић
Универзитет у Новом Саду, ФТН, Нови Сад
„Текстилна електроника "од главе до пете" за тераностику нашег здравља"

Страхиња Дошен
Department of Health Science and Technology, Aalborg University, Denmark
„A new generation of smart connected bionic limbs"

Уторак, 9. јун 2026. у 17:30 (Сала 1)
СКУПШТИНА ДРУШТВА ЗА ЕТРАН
Проф. др Слободан Вукосавић
In Memoriam: проф. др Братислав Миловановић
In Memoriam: проф. др Милић Стојић
In Memoriam: проф. др Владимир Катић
In Memoriam: проф. др Вељко Поткоњак

Уторак, 9. јун 2026. у 20:00 Свечана сала – „Белведере"
ДОДЕЛА НАГРАДА ЗА НАЈБОЉЕ РАДОВЕ ЕТРАН-ИЦЕТРАН 2026

СВЕЧАНА ВЕЧЕРА

Среда, 10. јун 2026. у 11:15 - 16:00
Излет – вожња бродом до тврђаве Голубац

Electronics
Telecommunications
Computing
Automatics
Nuclear engineering

Program and

Book of Abstracts

LXX Conference ETRAN
and
13th International Conference IcETRAN 2026

Silver Lake, Republic of Serbia
June 8 - 11, 2026.

An Overview of previous ETAN/ETRAN conferences

1. Beograd, novembra 1955. god.
2. Beograd, novembra 19d.
3. Ljubljana, novembra 1958. god.
4. Zagreb, novembra 1959. god.
5. Beograd, novembra 1960. god.
6. Sarajevo, novembra 1961. god.
7. Novi Sad, novembra 1962. god.
8. Zagreb, novembra 1963. god.
9. Bled, novembra 1964. god.
10. Beograd, novembra 1965. god.
11. Niš, juna 1967. god.
12. Rijeka, juna 1968. god.
13. Subotica, juna 1969. god.
14. Sarajevo, juna 1970. god.
15. Split, juna 1971. god.
16. Velenje, juna 1972. god.
17. Novi Sad, juna 1973. god.
18. Ulcinj, juna 1974. god.
19. Ohrid, juna 1975. god.
20. Opatija, juna 1976. god.
21. Banja Luka, juna 1977. god.
22. Zadar, juna 1978. god.
23. Maribor, juna 1979. god.
24. Priština, juna 1980. god.
25. Mostar, juna 1981. god.
26. Subotica, juna 1982. god.
27. Struga, juna 1983. god.
28. Split, juna 1984. god.
29. Niš, juna 1985. god.
30. Herceg Novi, juna 1986. god.
31. Bled, juna 1987. god.
32. Sarajevo, juna 1988. god.
33. Novi Sad, juna 1989. god.
34. Zagreb, juna 1990. god.
35. Ohrid, juna 1991. god.
36. Kopaonik, septembra 1992. god.
37. Beograd, septembra 1993. god.
38. Niš, juna 1994. god.
39. Zlatibor, juna 1995. god.
40. Budva, juna 1996. god.
41. Zlatibor, juna 1997. god.
42. Vrnjačka Banja, juna 1998. god.
43. Zlatibor, septembra 1999. god.

44. Sokobanja, juna 2000. god.
45. Bukovička Banja, juna 2001. god.
46. Banja Vrućica, juna 2002. god.
47. Herceg Novi, juna 2003. god.
48. Čačak, juna 2004. god.
49. Budva, juna 2005. god.
50. Beograd, juna 2006. god.
51. Herceg Novi, juna 2007. god.
52. Palić, juna 2008. god.
53. Vrnjačka Banja, juna 2009. god.
54. Donji Milanovac, juna 2010. god.
55. Banja Vrućica, juna 2011. god.
56. Zlatibor, juna 2012. god.
57. Zlatibor, juna 2013. god.
58. Vrnjačka Banja, juna 2014. god.
59. Srebrno Jezero, juna 2015. god.
60. Zlatibor, juna 2016. god.
61. Kladovo, juna 2017. god.
62. Palić, juna 2018. god.
63. Srebrno Jezero, juna 2019. god.
64. Beograd, Novi Sad, Čačak, Niš, septembra 2020. god.
65. Etno selo Stanišići, Republika Srpska, septembar 2021. god.
66. Novi Pazar, jun 2022. god.
67. Istočno Sarajevo, BiH, jun 2023. god.
68. Niš, jun 2024. god.
69. Čačak, Jun 2025. god.

Dear participants of the LXX ETRAN Conference and the 13th IcETRAN Conference,

The Proceedings of the ETRAN and IcETRAN conferences present an overview of the latest achievements of a numerous of authors and research teams from the country and abroad. The analysis of the papers presented at these conferences provides insight into current development trends and progress in the fields of electrical engineering and computer science in Serbia, the Region and the World.

293 papers were submitted for this year's ETRAN and IcETRAN conferences, of which 263 were accepted after a multiple peer review process, which represents an acceptance rate of 89.8%. The papers come from authors from 27 countries, which confirms the international character of the conferences and their high scientific relevance. A pool of 911 internationally recognized reviewers was engaged in the review process, of which 475 actively participated. Accepted papers were distributed within opening session, six associated sessions and 17 regular sessions over the four conference days.

Five keynote lectures will be held at the opening, presenting the most up-to-date research in various fields of electrical engineering and computing. Professor Drajić's lecture is dedicated to the history of the conference and contains a review of the most significant events and changes that have marked the work of the ETRAN Society. The lecture by colleague Filip Svoboda deals with the development of telecommunications, with a special focus on 6G technology. Professor Jozo Dujmović will present research in the field of decision-making logic in healthcare, while colleague Goran Stojanović will talk about technologies for manufacturing electronic circuits in the form of textiles. The lecture by colleague Strahinja Došen is dedicated to the new generation of bionic limbs.

As part of the "Industry Day", it is planned for the presentation of three sponsors, where the latest achievements of companies in the field of electrical engineering and computing will be presented. A panel discussion dedicated to the challenges and prospects of the development of nuclear energy, as well as the role of nuclear energy in the energy system of Serbia, is also planned.

As in previous years, the sections will select the best papers (Best Paper Award) at sessions, as well as the best papers by young authors (Best Young Author Award), while the awards will be presented at the conference ceremony. The ETRAN Association will hold a regular annual assembly, with a series of accompanying activities. Special attention is also paid to the professional and cultural program, within which a cruise on the Danube to the Golubac Fortress and back is planned.

This year's ETRAN and IcETRAN conferences confirm the continuous growth of interest in this type of scientific communication and direct exchange of

scientific results, research achievements and practical experiences. At the same time, they represent an important opportunity for establishing new collaborations and developing future projects. Despite the complex social circumstances, the number of submitted and accepted papers remains high, and the attendance of about 300 participants is expected.

The conferences are organized under the auspices of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, with the technical support of the scientific associations CIRED, TELFOR, Energetska elektronika and the company ANT Computers, which provided computer support. The technical co-sponsor of the conference is also IEEE, the world's largest association of electrical and electronics engineers, through Region 8, as well as sections and branches in Serbia and Montenegro, and Bosnia and Herzegovina. Thanks to the cooperation with IEEE, the papers from the IcETRAN conference will be included in the IEEE Xplore digital library, thus gaining wide international visibility and potential citations in relevant world databases, such as Web of Science, Scopus and Google Scholar.

After seven years, ETRAN is being held again at Srebrno Jezero, primarily thanks to the enthusiasm and dedication of the Program Committee and our traditional collaborators from Academic Thought. The hospitality of the hosts, the exceptional spatial and technical conditions, as well as the pleasant atmosphere, represent a solid foundation for the successful implementation of the conference

Vice President of the Society for ETRAN

Prof. dr Slobodan Vukosavić

IcETRAN – International Conference on Electrical, Electronic and Computing Engineering

Kneza Miloša 9/IV, 11000 Belgrade, Serbia
Phone: +381 11 3233 957, E-mail: office@etran.rs, https://www.etran.rs

ORGANIZERS

ETRAN Society, Belgrade
Vinča Institute of nuclear sciences, University of Belgrade
National Institute of The Republic of Serbia

Under the auspices of

Ministry of Science, Technological Development and Innovation
of the Republic of Serbia

WITH THE SUPPORT OF

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IEEE Power & Energy Chapter of the IEEE S&M Section
IEEE Serbia and Montenegro Section Comp. Soc. Chapter
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Prof. Jelica Protić, Belgrade, Serbia

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MSc Sanja Baranac Stojičić, Vinča Institute of Nuclear Sciences, Vinča – Belgrade, Serbia

EXHIBITION CHAIR:

MSc Uzahir Ramadani, Vinča Institute of Nuclear Sciences, Vinča – Belgrade, Serbia

INFORMATION CONTACT:

Mrs. Mirjana Jovanic, Belgrade, Serbia

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Dr Milica Rajačić, Senior Research Associate, Vinča Institute of Nuclear Sciences, Vinča – Belgrade, Serbia

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Mrs. Mirjana Jovanić, ETRAN
Mr. Zlatko Jarnević, ETRAN

CONFERENCE DESK

The registration desk of the IcETRAN conference will operate:	
Sunday, June 7th, 2026	17:00 – 18:00
Monday, June 8th, 2026	08:45 – 14:00 & 15:00 – 16:30
Tuesday, June 9th, 2026	08:45 – 13:00 & 14:00 – 16:30
Wednesday, June 10th, 2026	8:45 – 10:45
Thursday, June 11th, 2026	8:45 – 10:45

Acronyms:

	International	National
Electronics	ELI	EL
Telecommunications	TEI	TE
Computing and information engineering	RTI	RT
Automation	AUI	AU
Nuclear engineering and technology	NTI	NT
Acoustics	AKI	AK
Antennas and propagation	API	AP
Artificial intelligence	VII	VI
Power engineering	EKI	EK
Electric circuits and systems and signal processing	EEI	EE
Biomedical engineering	BTI	BT
Metrology	MLI	ML
Microelectronics and optoelectronics	MOI	MO
Microwave technique, technologies and systems	MTI	MT
New materials in electrical and electronic engineering	NMI	NM
Robotics and flexible automation	ROI	RO
Education in Electrical, Electronic and Computing Engineering	EDUI	EDU

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2. Faculty of Electronics, University of Niš, Serbia
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6. Faculty of Technical Sciences, University of Kragujevac, Čačak, Serbia
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8. Faculty of Transport and Traffic Engineering, Belgrade, Serbia
9. Institute of Chemistry, Technology and Metallurgy, Belgrade, Serbia
10. Vlatakom, Institute of High Technologies, Belgrade
11. State University of Novi Pazar, Novi Pazar, Serbia
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20. Science Technology Park Čačak
21. Faculty of Organizational Sciences
22. Belgrade Business and Art Academy of Applied Studies, Belgrade
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24. Academy of Technical and Art Applied Studies - School of Electrical and Computer Engineering
25. The Academy of applied technical and preschool studies, Nis Serbia
26. Kosovo and Metohija Academy of Applied Studies, Leposavić, Serbia

13th IcETRAN Events Program

Monday, June 8th, 2026, 17:30 (Hall 1)

OPENING CEREMONY

Prof. dr. Zoran Čiča: Welcome speech

Dr. Slavko Dimović: Welcome speech

Prof. dr Slobodan Vukosavić: Welcome speech

Monday, June 8th, 2026, 18:00 (Hall 1)

KEY NOTE LECTURES

Dušan Drajić

School of Electrical Engineering, University of Belgrade, Belgrade, Serbia

„Overview of the history of the Society for ETRAN“

Philipp Svoboda

Institut for Telecommunication, Technische Universität Wien, Austria

„Differentiable Digital Twins and AI: Towards the Realization of 6G and Smart Railway Systems”

Jozo Dujmović

San Francisco State University, USA

„Graded Logic for Explainable Decision Making in Healthcare”

Monday, June 8th, 2026, 19:30

COCKTAILS

Tuesday, June 9th, 2026, 9:00 – 16:00 (The Cultural Centre of Čačak (Atrium))

EXHIBITION OF COMPANIES (SPONSORS)

Coordinator: Dr Ivan Lazović

Tuesday, June 9th, 2026, 10:00 – 12:00 (Hotel Terrace)

Company Presentations:

Gold & Силвер sponsors

Tuesday, June 9th, 2026, 11:00 – 11:45 (Hall 4)

General Assembly of Serbian Society for Air Quality

Tuesday, June 9th, 2026, 12:00 – 12:45 (Hall 5)

Lecture on the occasion of 170th Anniversary of birth of Nikola Tesla

Moderator: Bratislav Stojiljković, Nikola Tesla Museum

Tuesday, June 9th, 2026, 13:30 – 14:30 (Hotel Terrace)

COMPANY COCTAIL

Tuesday, June 9th, 2026, 16:45 – 17:30 (Hall 1)

KEY NOTE LECTURES

Prof. Goran Stojanović

Faculty of Technical Sciences, University of Novi Sad, Serbia

„Textile electronics "all over the body" for theranostics of our health"

Strahinja Došen

Department of Health Science and Technology, Aalborg University, Denmark

„A new generation of smart connected bionic limbs"

Tuesday, June 9th, 2026, 17:30 (Hall 1)

GENERAL ASSEMBLY of ETRAN SOCIETY

Prof. dr Slobodan Vukosavić

In Memoriam: Prof. dr Bratislav Milovanović
In Memoriam: Prof. dr Milić Stojić
In Memoriam: Prof. dr Vladimir Katić
In Memoriam: Prof. dr Veljko Potkonjak

Tuesday, June 9th, 2026, 20:00, Ceremonial Hall „BELVEDERE"

AWARDS FOR BEST PAPERS ETRAN/ICETRAN 2026

GALA DINNER

Wednesday, June 10th, 2026, 11:15 - 16:00

Excursion - boat ride to Golubac fortress

ЗБОРНИК АПСТРАКАТА

/

BOOK OF ABSTRACTS

ОТВАРАЊЕ / OPENING SESSION

Понедељак, 8. јун / Monday, June 8th Сала 1 / Hall 1 17.30-18.00

Председавајући/Chair:
Слободан Вукосавић, Универзитет у Београду, Електротехнички факултет, Београд, Србија

УВОДНА ПРЕДАВАЊА / KEYNOTE LECTURES

Понедељак, 8. јун / Monday, June 8th Сала 1 / Hall 1 18.00-19.30

KEYNOTE (#7436)
ПРЕГЛЕД ИСТОРИЈАТА ДРУШТВА ЗА ЕТРАН

Душан Драјић

Развој Друштва за ЕТРАН од оснивања до данас и његових 70 конференција.

Кључне речи: ЕТАН/ЕТРАН конференције, 70 година, ЕТРАН/ИцЕТРАН конференције, Друштво за ЕТРАН

KEYNOTE (#0564)
DIFFERENTIABLE DIGITAL TWINS AND AI: TOWARDS THE REALIZATION OF 6G AND SMART RAILWAY SYSTEMS

Phillip Svoboda

The transition towards 6G networks necessitates a fundamental paradigm shift from reactive network management towards proactive and autonomous optimization strategies. At the center of this evolution lies the "Digital Twin" (DT), which serves as a high-fidelity virtual representation of the physical radio environment. In this talk, we present recent research findings on the construction of differentiable network twins, supported by extensive empirical measurements from real-world datasets in Vienna. In contrast to conventional "black-box" approaches, we propose a framework where network abstractions are rendered fully differentiable. This allows for the direct and scalable optimization of critical network parameters, such as transmit power and load-balancing, utilizing gradient-based Artificial Intelligence.

Furthermore, we discuss the integration of uncertainty-aware Bayesian learning to enhance the prediction reliability of signal parameters (RSRP), particularly within complex urban environments and railway corridors. In the context of 6G, these digital twins evolve beyond simple monitoring tools to become the core engine for Integrated Sensing and Communication (ISAC), facilitating high-precision localization and context-aware connectivity. By addressing the "sim-to-real" gap as a structured AI challenge, this work outlines a practical roadmap for sustainable, zero-touch network management. These insights are intended to provide a solid basis for future communication and collaboration with researchers working on digital-twin-based network evolution and intelligent infrastructure.

Keywords: 6G networks, Digital Twin, Bayesian learning, zero-touch network management

KEYNOTE (#8136)
GRADED LOGIC FOR EXPLAINABLE DECISION MAKING IN HEALTHCARE

Jozo Dujmović

Graded Logic (GL) is a propositional logic of human commonsense reasoning and decision making. GL is fully continuum-valued, i.e., everything is a matter of degree. It is based on continuum-valued logic variables (graded truth), continuum-valued simultaneity (graded conjunction), continuum-valued substitutability (graded disjunction), and continuum-valued importance of logic variables. The graded conjunction and the graded disjunction are dualized, complementary, and unified in a single continuum-valued, andness-directed, importance-weighted, idempotence-selectable, and annihilator-selectable fundamental logic function called Graded Conjunction/Disjunction (GCD). Graded Logic is the mathematical infrastructure of the Logic Scoring of Preference (LSP) decision method which has applicability in solving a variety of complex evaluations and decision problems Our goal is to present the following typical applications in healthcare:

- Machine learning methods for development of the LSP medical diagnostic models
- Explainability of graded logic models for disease diagnosis (explainability of diagnostic models and explainability of diagnostic results)
- Evaluation of disease severity, patient disability, and effects of a therapy
- Vaccination priority evaluation (COVID-19)
- Organ transplantation priority evaluation (liver transplantations)
- Optimum timing of risky therapy
- Evaluation and selection of medical equipment and medical software tools
- Suitability maps for optimum location of medical services

Keywords: Graded Logic, Graded Conjunction/Disjunction, Logic Scoring of Preference

Уторак, 9. јун / Tuesday, June 9th Сала 1 / Hall 1 16.45-17.30

KEYNOTE (#0057)
ТЕКСТИЛНА ЕЛЕКТРОНИКА “ОД ГЛАВЕ ДО ПЕТЕ” ЗА ТЕРАНОСТИКУ НАШЕГ ЗДРАВЉА

Горан Стојановић

У оквиру овог предавања, биће представљени сензори реализовани на текстилу који мере различите параметре нашег здравља, од померања мишића током жвакања, до мерења pH вредности из зноја, и сензора притиска током седења, до мерења параметара женског здравља и патерна нашег хода.

Сви резултати који ће бити представљени су настали у лабораторији за неконвенционалну електронику Факултета техничких наука, Универзитета у Новом Саду, под лидерством проф. др Горана Стојановића, од којих су неки патентирани као што је на пример капацитивни сензор мерења профила нашег дисања реализован у заштитној маски за лице, коју смо користили током пандемије корона вируса.

Такође, биће представљене дугорочне визије да наше читаво тело буде покривено дискретним сензорима у текстилу који ће имати континуалну дијагностичку сврху, али уз помоћ микрофлуидних чипова на текстилу имати и терапеутску улогу.

Кључне речи: сензори, текстил, мерење, микрофлуидни чип

KEYNOTE (#4910)

A NEW GENERATION OF SMART CONNECTED BIONIC LIMBS

Strahinja Došen

The lecture will start by describing the conventional state-of-the-art methods for the control of robotic prostheses based on the processing of myoelectric signals, including the use of machine learning (pattern recognition and regression). We will then address the drawbacks of these methods and related challenges for clinical translation and wider use. We will then discuss an alternative approach to controlling bionic limbs, where the main idea is to enhance these systems with additional sensors and cognitive-like processing so that they can perform some functions autonomously (semi-automatic control). Semi-autonomous prosthesis prototypes will be described, and it will be shown how they can improve prosthesis performance while decreasing the cognitive and physical effort of controlling these devices. Finally, we will discuss the new generation of bionic limbs that are enhanced with connectivity allowing them to access the virtually unlimited computational resources of the Cloud and Edge. The radically new functions enabled by the Cloud/Edge will be discussed, including computational offloading, continuous data logging, adaptation and learning as well as remote intervention. The lecture will end by summarizing the pros and cons of the three approaches to prosthesis control (namely, conventional, semi-autonomous, and connected bionics) and perspectives for future developments.

Keywords: Myoelectric control, Semi-autonomous prostheses, Cloud/Edge computing in bionics

ЕЛЕКТРОНИКА / ELECTRONICS

СЕСИЈА / SESSION (ЕЛ1+ELI1)

Понедељак, 8. јун / Monday, June 8th Сала 2 / Hall 2 9.00-11.00

Председавајући / Chair:
Marko Dimitrijević, Univerzitet u Nišu - Elektronski fakultet, Niš, Srbija

EL1.1 (#6116)
REALIZACIJA DC/AC KONVERTORA ZASNOVANOG NA POJAČAVAČU TPA3111D1 U KLASI D

Vladimir Lapčević, Ivan Kokić, Veljko Janić, David Marinović

U ovom radu je predstavljena realizacija DC/AC konvertora pomoću pojačavača u klasi D. DC/AC konvertori se prave u širokom opsegu snaga, a ovde će biti prikazan DC/AC konvertor snage 10 W. U ovom radu je predstavljena elektronika za realizaciju DC/AC konvertora uz sva detaljna objašnjenja i matematičke formule.

Ključne reči: pojačavač u klasi D, efikasnost, filtar, transformator

ELI1.1 (#5214)
A FRAMEWORK FOR AUTOMATED SYNTHESIS OF ULTRA-LOW POWER APPLICATION-SPECIFIC EMBEDDED PROCESSORS

Xuan Ji, Tom Kazmierski

The design of Application-Specific Embedded Processors (ASEPs) traditionally relies on manual, expert-driven efforts, while automated exploration often employs High-Level Synthesis (HLS) to generate data for Design Space Exploration. However, HLS is constrained by its high level of abstraction, limited model fidelity, and a relatively small number of design variants that it can effectively explore. To tackle the challenge of automated Application-Specific Embedded Processor (ASEP) generation, this paper proposes a novel four-tier optimization framework that automates generation of designs from the assembly level to RTL, systematically exploring the application algorithm, instruction sets, hardware architecture, and code generation. The proposed framework keeps functional correctness for all generated designs and demonstrates exceptional scalability. Two simple case studies are investigated here to illustrate the validity of the proposed framework, a 2D affine transformation, and Gaussian filtering of images. Based on the same hardware constraints, the framework has automatically generated and optimized 192 and 1,728 extremely small RTL designs for the 2D affine transformation and Gaussian filter algorithms, respectively, revealing a large theoretical design space. ASEPs are traditionally designed manually, which is a costly process requiring highly skilled expertise. To reduce design cost, larger general-purpose processors are frequently used instead of ASEPs. The automation framework proposed here reduces the need for expert design skills and can quickly generate and optimize application-specific processors that have superior performance to their general-purpose counterparts and are more than an order of magnitude smaller. The small size is key to ultra-low power implementations. In summary, this work provides a systematic automated solution for constructing high-quality ASEP by exploring large design spaces.

Keywords: Embedded processors, ultra-low power, application-specific processors, automated synthesis, design space exploration, optimization

ELI1.2 (#0795)
DIGITAL PREDISTORTION USING NEURAL NETWORKS AND MEMORY POLINOMINALS

Borisav Jovanovic

Digital predistortion (DPD) is widely recognized as an effective technique for power amplifier (PA) linearization. By compensating for nonlinearities in the PA transfer characteristic, DPD ensures compliance of wireless infrastructure with telecommunication standard requirements, including bit error rate (BER), transmit spectrum mask (TSM), and error vector magnitude (EVM). In addition to improving linearity, DPD contributes to reduced operational costs by enhancing PA energy efficiency. We employed different algorithms to implement DPD. Proposed DPD methods rely on complex valued memory polynomials and neural networks. The methods are described in the paper from mathematical standpoint. Simulation results are also presented in the paper.

Keywords: Memory polynomial, Multilayer Perceptron, Digital predistortion, Power amplifier

ELI1.3 (#8500)
MAHALANOBIS DISTANCE-BASED KNN IMPUTATION OF MISSING POWER OUTPUT DATA IN SOLAR POWER PLANTS

Novak Radivojević, Marko Jović, Uroš Ilić, Andrija Petrušić, Miona Andrejević Stošović

Power output measurements at solar plants are routinely affected by gaps caused by faults such as communication failures and data logging issues. When such gaps are present, the usual practice of discarding the corresponding samples reduces the amount of training data available for machine learning models and can introduce bias if gaps are not randomly distributed. This paper proposes a method for imputing missing power output values using k-nearest-neighbor (kNN) search based on Mahalanobis distance computed over co-located meteorological measurements. The method was applied to data from a prosumer-regime solar plant with a 60 kW installed capacity and validated through a hold-out experiment for a range of values of k, in which 5% of complete samples were artificially left-out, then recovered by the proposed method and the left-out values are compared to corresponding imputed values. Results show that the mean absolute error of imputed values on the validation set is below 5 kW for all tested values of k, with the lowest MAE of 4.41 kW and RMSE of 7.53 kW achieved for k = 10.

Keywords: solar power plant, missing data, imputation, k-nearest neighbors, Mahalanobis distance

ELI1.4 (#9789)
ULTRASONIC COLLISION DETECTOR USING HC-SR04 AND ARDUINO UNO R3

Mihajlo Stojanović, Miljana Milić, Jelena Milojković

This paper presents the design and implementation of a proximity-based collision detection system using an HC-SR04 ultrasonic sensor and an Arduino Uno R3 microcontroller. The system provides audible feedback through a passive buzzer whose beeping frequency is dynamically adjusted according to measured distance. Three distinct operational zones are defined: continuous slow beeping for distances above 15 cm, progressively increasing beep rate in the 5–15 cm range using the Arduino map() function, and a constant tone for distances below 5 cm. The ultrasonic ranging function

is implemented manually without any external library. Experimental results confirm consistent distance readings within ±1 cm over the rated 2–400 cm range, and audible zone transitions proved intuitive during user testing. The design is compact, low-cost, and directly extensible to multi-sensor or visual-feedback configurations.

Keywords: Arduino Uno R3, audible proximity alert, buzzer driver, collision avoidance, HC-SR04, proximity sensing, ultrasonic sensor

ELI1.5 (#6567)

XGBOOST-BASED SOLAR POWER FORECASTING: LAG FEATURES, K-MEANS CLUSTERING, AND SEASONAL SPLITTING

Matija Špeletić, Novak Radivojević, Uroš Ilić, Andrija Petrušić, Miona Andrejević Stošović, Zlatica Marinković

This paper investigates XGBoost-based approaches for predicting photovoltaic power output at a 156 kW installation in southeastern Serbia. Building on prior LSTM- and MARS-based research, we introduce lag features—derived from the plant's own production history—and cyclical time encodings as novel feature engineering steps. Three model configurations are compared: a global plain model, a K-means clustered model routing predictions by weather regime, and a calendar-season model. A persistence baseline is established as a reference. Lag features yield a 13% reduction in daytime root mean square error (RMSE) relative to persistence. K-means clustering (k=3) discovers irradiance and time-of-day regimes rather than seasonal patterns, and per-cluster models provide no measurable accuracy improvement over the global model. Calendar-season splitting, tested to assess whether dedicated seasonal models capture season-specific effects, does not outperform the global model due to the reduced training data available per season. The plain XGBoost model with lag features is recommended as the optimal configuration.

Keywords: solar power forecasting, XGBoost, lag features, K-means clustering, feature engineering, gradient boosting

ELI1.6 (#6033)

APPLICATION OF REAL-TIME SIMULATION FOR VERIFICATION OF INDUSTRIAL CONTROLLER OPERATION

Ognjen Petrović, Simiša Simić, Zoran Stojanović, Marko Dimitrijević, Milutin Petronijević, Pamela Njemčević

This manuscript presents the development of a real-time simulation environment and the application of Hardware-In-the-Loop (HIL) technology for testing an industrial controller. The research includes implementing a power system model in the Typhoon HIL Control Center software, using its built-in SCADA interface for management and monitoring. Special attention is paid to implementing communication between the simulator and the industrial controller using the Modbus TCP protocol, and to enabling two-way system management. Finally, the conducted tests verify the functionality of the developed system and assess the applicability of the HIL approach for testing control solutions in the power industry.

Keywords: real-time simulation, hardware-in-the-loop, control algorithm testing, MODBUS

ELI1.7 (#8036)
DESIGN AND IMPLEMENTATION OF INTEGRATED MAGNETICS FOR LLC RESONANT CONVERTER BASED ON MAGNETIC DECOUPLING

Vojin Vešković, Igor Jovanović, Luka Stanić, Miodrag Skender, Dragan Mančić

Increasing power density represents one of the key development trends in modern power electronic converters. This trend has encouraged the adoption of planar transformers and integrated magnetic structures. However, integrated magnetics are still often avoided in practical designs, while many solutions reported in the literature rely on custom-designed ferrite cores that are typically either not commercially available or overly complex to implement in compact enclosure. This paper presents a practical method for magnetic integration in an LLC resonant converter using commercially available cores. The proposed approach combines simplicity and ease of implementation with effective magnetic decoupling, achieved through analytical design method. As a result, flux in the shared leg is reduced and a nearly uniform flux distribution within the ferrite core is ensured. The proposed solution is validated through analytical approach, simulations, and experimental results obtained from a 300 W LLC converter implementing an integrated planar transformer. Experimental results confirm the feasibility of the proposed approach and show approximately 1% efficiency improvement and reduced magnetic volume compared to a conventional discrete magnetic implementation.

Keywords: Integrated magnetics, Planar ferrite cores, Resonant LLC converter

ELI1.8 (#4190)
CHARACTERIZATION OF CYLINDRICAL ULTRASONIC SONOTRODES USING ANALYTICAL AND FEM METHODS

Aleksandar Panić, Igor Jovanović, Dragan Mančić

This paper presents an analysis of the oscillations of disk-shaped metal endings (sonotrodes) designed for use in ultrasonic transducers. The research aims to study and predict resonant frequencies and vibration modes, with a particular focus on the coupling of thickness and radial oscillations. For modeling and displacement distribution analysis, an analytical 3D approximate matrix method was used, enabling the efficient prediction of thickness and radial oscillations, as well as their mutual coupling. In addition to the analytical model, a numerical model using the finite element analysis software package was applied, allowing for the prediction of the system's dynamic behavior. Experimental measurements were carried out using an industrial ultrasonic resonant analyzer in the frequency range from 15 kHz to 50 kHz. The results show high agreement between the analytical model, numerical simulations, and experimental measurements. The research is specifically focused on the identification and characterization of axisymmetric flexural (bending) modes that occur within the measurement range for steel and duralumin sonotrodes, with dimensions most commonly used in ultrasonic transducers. The proposed approach provides reliable guidelines for optimizing sonotrodes geometry and avoiding coupling with unwanted parasitic modes.

Keywords: ultrasonic transducers, sonotrodes, 3D analytical method, FEM method, resonant frequency

ТЕЛЕКОМУНИКАЦИЈЕ / TELECOMMUNICATIONS

СЕСИЈА / SESSION (TE1 + TEI1)

Понедељак, 8. јун / Monday, June 8th Сала 2 / Hall 2 15.00-17.15

Председавајући / Chair:
Дејан Драјић, Универзитет у Београду - Електротехнички факултет, Београд, Србија

TEI1.1 (#1760)
GENAI AGENT FOR NETWORK DESIGN AND MAINTENANCE: N-RELAY COOPERATIVE SYSTEMS OVER RAYLEIGH FADING WITH SELECTION COMBINING CASE STUDY

Vuk Vujovic, Suad Suljović, Dejan N. Milic, Nenad Petrović, Milan Jović, Goran Đorđević

This paper analyzes a relay communication system with a single source, N relays, and a direct source–destination link under Rayleigh fading conditions. Amplify-and-Forward (AF) relaying and Selection Combining (SC) at the receiver are employed, while the system outage probability (Pout) is evaluated via statistical analysis of the instantaneous signal-to-noise ratio (SNR). The results indicate that the receiver sensitivity threshold (γth) has a dominant effect on system performance, whereas the relay transmit power has a smaller impact. Additionally, the study explores the use of locally deployable Generative Artificial Intelligence (GenAI) for agentic, automated network design and management, showing reduced execution time and effort while maintaining accuracy, highlighting its potential for efficient 5G/6G network optimization. On the other side, adoption of agentic memory and Model Context Protocol (MCP) with locally deployable model results with outcomes comparable to commercial, externally managed GenAI services.

Keywords: agentic, AI, Outage probability, Rayleigh fading, GenAI

TEI1.2 (#2537)
LLM-DRIVEN NETWORK MANAGEMENT RELIABILITY: LCR ANALYSIS OF SC RECEIVERS UNDER WEIBULL FADING AND CO-CHANNEL INTERFERENCE CASE STUDY

Nenad Petrović, Milos Popovic, Suad Suljović, Sinisa Minic, Jovan Vujic, Radisa Stefanovic

This paper investigates a wireless communication system employing an L-branch selection combiner (SC), where the input signals are subject to Weibull fading, and co-channel interference (CCI) is also considered, modeled using the Weibull distribution. To mitigate the effects of fading and interference, SC is applied as a simple yet effective diversity technique. In the first part of the paper, a closed-form expression for the level crossing rate (LCR) of the signal-to-interference ratio (SIR) is derived, providing analytical insight into the system dynamics. Numerical results demonstrate how the fading and interference parameters influence the LCR. In the second part, we show how the obtained values can be further utilized in an LLM-driven approach for network management, enabling evaluation of functional safety aspects and performance optimization of the network configuration.

Keywords: LCR, SC, diversity, Weibull fading, Large Language Model (LLM)

TEI1.3 (#2919)
STATISTICAL ANALYSIS OF OPTIMAL FACTORIZATION IN MULTISTAGE DECIMATION STRUCTURE

Vukasin Babic, Djordje Babic

In this paper, we examine the behavior of the optimal factorization framework for multistage decimation introduced in our earlier work. The objective is not to modify the optimization procedure, but to clarify how the optimal realizations are distributed across the decimation-ratio range and how sensitive the achieved gains are to the filter specifications. Using a computation rate model based on multiplications per second, we compare globally optimal realizations based on the transposed modified Farrow structure (TMFS) followed by FIR stages with the corresponding FIR-only cascades. The results show a clear separation between prime and composite ratios and confirm that the optimal structures remain shallow across the considered range. A sensitivity analysis further indicates that the passband edge has the strongest influence on the achievable gain. These results complement the earlier algorithmic contribution and provide practical guidance on when the generalized TMFS–FIR architecture is the most beneficial.

Keywords: Digital filters, Multirate filtering, FIR filter design, Farrow filter

TEI1.4 (#3497)
A MESSAGE-ORIENTED INTRA-NODE CONTROL ARCHITECTURE FOR MODULAR OTN NODES

Stefan Šuka, Miloš Stojadinović, Dejan Drajić, Mladen Sokić, Luka Mladenović, Zoran Čiča

This paper presents the design and implementation of an intra-node control communication framework for modular Optical Transport Network (OTN) systems. The proposed architecture coordinates a Central Management Unit (CMU) and distributed line card applications within an industrial OTN platform. Communication is realized through a lightweight message-oriented layer based on ZeroMQ, combining Request–Reply transactions for deterministic configuration handling and Publisher–Subscriber signaling for asynchronous status exchange. JSON is used for structured and extensible message representation, while systemd provides supervised service lifecycle management and fault isolation. The framework has been implemented and validated on an OTN node platform developed by Iritel.

Keywords: Optical Transport Network (OTN), intra-node, control-plane communication, Central Management Unit (CMU), ZeroMQ-based messaging, modular OTN architecture, industrial implementation

TEI1.5 (#9694)
SECURE COMMUNICATION ARCHITECTURE OF IOT SYSTEMS INTEGRATED WITH BLOCKCHAIN TECHNOLOGY

Aleksa Stoimenov, Aleksandar Katić, Zoran Čiča, Dejan Drajić

With rapid expansion of IoT applications, ensuring adequate security for IoT systems has become increasingly challenging. Blockchain technology has proven to be very effective at protecting data integrity and has been researched as a promising addition to network security, across various industries. It is characterized by a transparent and immutable nature, while relying on decentralized and distributed networks, as well as cryptographic mechanisms to achieve a high level of security. This paper proposes a network architecture that utilizes Blockchain technology, along with a voting system and

a consensus model based on random role assignment, to establish a secure environment for a typical IoT topology. By leveraging decentralized storage of security records, the proposed approach eliminates single points of failure, while enabling faster and more seamless device authentication.

Keywords: Blockchain, IoT, wireless sensor networks, security, distributed communication, decentralization

TEI1.6 (#2878)

DEVELOPMENT PLATFORM FOR PROGRAMMING ETHERNET CHIP ON THE OPTICAL TRANSPORT NETWORK UNIT

Miloš Stojadinović, Zoran Čiča, Dejan Drajić, Stefan Šuka, Mladen Sokić, Luka Mladenović

In modern optical transport networks, new requirements arise that need to be met with appropriate equipment. The paper presents new solutions in the architecture of Optical Transport Network units with a focus on the central control system and communication with the Ethernet chip. In order to implement the aforementioned communication, it is necessary to perform a successful hardware connection, adapt the configurable logic and ensure the entire communication chain between the user space of the operating system and the hardware. In addition to demonstrating the verification of the functionality of the implemented interface, technical details about the development platform and the applied technologies are also presented.

Keywords: Optical Transport Networks, Ethernet, System on Chip

TEI1.7 (#7186)

APB TO MDIO BRIDGE IMPLEMENTED ON MICROCHIP POLARFIRE SOC

Mladen Sokic, Stefan Suka, Jelena Popovic Bozovic, Lazar Saranovac, Milos Stojadinovic, Luka Mladenovic

This paper presents the design of an MDIO controller implemented on Microchip Polarfire SoC platform. The proposed controller is integrated in Icicle open source project that contains RISC-V processor with different types of peripherals. The proposed peripheral is APB slave to the processosor and uses MDIO 45 clause interface to communicate with CFP2 optical transciever. Operating system that is used in Linux Ubuntu and there is a driver that is written in Iritel that drives the peripheral. The implementation and the results of the custom solution will be presented in the following text with the comparison to the Microchip core component from the catalog (MDIO_APB), also integrated in Icicle project.

Keywords: FPGA, APB, MDIO, RISC-V, Optical transciever

TE1.1 (#1130)

PRAĆENJE KVALITETA VAZDUHA U ZATVORENOM PROSTORU PRIMENOM NISKOBUDŽETNIH SENZORA I INTERNETA STVARI

Katarina Garić, Dejan Drajić, Zoran Čiča, Ivan Vajs

Kvalitet vazduha u zatvorenom prostoru predstavlja značajan faktor rizika po zdravlje, jer ljudi provode najveći deo svog vremena u zatvorenim prostorima poput stanova, škola, radnih mesta i kancelarija. U ovom radu prikazan je praktičan pristup za kontinuirano praćenje parametara kvaliteta vazduha u zatvorenom, koristeći prenosivi uređaj sa niskobudžetnim senzorima i IoT tehnologijom za prikupljanje i analizu podataka. Merenja obuhvataju koncentracije suspendovanih čestica (PM1, PM2.5,

PM10), isparljiva organska jedinjenja (VOC), temperaturu, pritisak i relativnu vlažnost vazduha. Podaci su prikupljani u različitim tipičnim okruženjima (stambeni prostori, sala za trening, kupatilo) kako bi se uočile promene usled uobičajenih aktivnosti. Rezultati pokazuju da izlaganje duvanskom dimu, upotreba aerosola i nedovoljna ventilacija dovode do osetnog porasta PM i VOC indikatora, dok provetravanje uglavnom smanjuje VOC i stabilizuje PM vrednosti. Ostvareni rezultati postavljaju okvire za buduća istraživanja sa ciljem da se pravovremeno prepozna nepovoljan kvalitet vazduha u zatvorenom prostoru, razviju smernice za frekventnost i trajanje provetravanja i edukaciju korisnika o uticaju svakodnevnih aktivnosti na kvalitet vazduha.

Keywords: kvalitet vazduha u zatvorenom, IoT, niskobudžetni senzori, PM monitoring, VOC monitoring

TE1.2 (#9118)
ADAPTIVNI EKF ZA PROCENU VAZDUŠNIH PARAMETARA PRI DEGRADACIJI KVALITETA MERENJA PITO-STATIČNOG SISTEMA

Vlada Sokolovic, Goran Markovic

U radu je predstavljeno modelovanje i simulacija MEMS (Micro-Electro-Mechanical Systems) pito-statičkog sistema za estimaciju vazdušnih parametara u uslovima degradiranih merenja. Analiziran je uticaj šuma, bias drifta, dinamičkih efekata i zaleđivanja Pito cevi. Za estimaciju stanja primenjen je prošireni Kalmanov filter (EKF, Extended Kalman filter), uz adaptivni pristup zasnovan naNormalized Innovation Squared (NIS) kriterijumu za detekciju anomalija i za prilagođavanje matrice šuma merenja. Rezultati simulacije pokazuju da primena EKF daje dobre rezultate u nominalnim uslovima, dok primenu adaptivnog EKF odlikuje značajno smanjivanje greške procene u prisustvu poremećaja, posebno za merenje brzine. Predloženi pristup unapređuje pouzdanost sistema za obradu vazdušnih podataka u realnim uslovima eksploatacije.

Keywords: Adaptivni prošireni Kalmanov filter, vazdušni parametri, pito-statički sistem, pouzdana procena stanja.

РАЧУНАРСТВО / COMPUTING AND INFORMATION ENGINEERING

СЕСИЈА / SESSION (RTI1)
SOFTVERSKO INŽENJERSTVO I VEŠTAČKA INTELIGENCIJA / SOFTWARE ENGINEERING AND ARTIFICIAL INTELIGENCE – SEAI

Понедељак, 8. јун / Monday, June 8th Сала 4 / Hall 4 9.00-11.00

Председавајући / Chair:
Pavle Vuletić, Univerzitet u Beogradu - Elektrotehnički fakultet, Beograd, Srbija

RTI1.1 (#4038)
APPLICATION OF AN ONLINE EDUCATIONAL TOOL FOR ACQUIRING COMPETENCIES IN OPERATIONS MANAGEMENT AND INDUSTRIAL ENGINEERING
INVITED LECTURE

Miloš Danilović

The modern dynamic production environment requires continuous improvement of tools for managerial decision-making. Although decision-making is increasingly directed

toward artificial intelligence, the most important managerial decisions are still related to solving combinatorial optimization problems. Numerous papers presenting improvements to existing procedures are published daily; however, the implementation of the proposed algorithms in practice is often unclear and complicated. In addition, experimental evaluations of these algorithms, even in the most reputable journals, often contain bias, which makes it difficult for potential users to select and apply an appropriate algorithm. This lecture aims to present a new, publicly accessible environment—the web application OPR-MAN (Angular, .NET 8, SQL Server)—which enables users to compare, apply, and visually present the results of the best algorithms for the most important problems in operations management: sequencing and allocation problems, clustering problems, routing and packing problems, as well as material requirements planning problems. For each module, users can upload benchmark problems from the literature or create their own instances, solve them, and compare the obtained solutions with those generated by other algorithms for the same problem. The visualization of solutions is graphically rich; for example, routes are displayed on real maps, packing solutions are graphically illustrated, and similar visual representations are provided for other problems. The application has already found practical use in many companies within supply chains. A particularly important application of this system is in education, as it allows students to follow every step of the algorithmic solution process. The application is used in the training of students at the Faculty of Organizational Sciences, where it has been evaluated as a significant contribution to the development of competencies of future operations managers.

Keywords: combinatorial optimization, web application, educational software, OPR-MAN, algorithm evaluation

RTI1.2 (#1705)
WEBRTC AS A TRANSPORT SUBSTRATE FOR LOW-LATENCY MOBILE AI OFFLOADING

Tamara Milovanović, Bratislav Predić

While deploying models on device is still the ideal approach for mobile edge AI, resource limitations often prevent large neural networks from running locally. In these cases, streaming multimodal sensor inputs to a remote inference service provides a practical path to deliver interactive AI functionality. In this context, low-latency, bidirectional media transport becomes a first-order requirement for real-time human with machine interaction. This paper examines WebRTC (Web Real-Time Communication) as a communication substrate for such AI offloading, enabling sub-second streaming of multimodal inputs (audio/video) and synchronous responses without the overhead of polling-based architectures. We describe the protocol stack end-to-end, including application-level signaling (SDP offer/answer and trickle ICE), NAT traversal via ICE with STUN/TURN, and mandatory security through DTLS-SRTP. We further discuss multi-party topologies and analyze Selective Forwarding Unit (SFU) architectures as a practical scaling strategy for interactive, AI-assisted conferencing. Overall, WebRTC emerges as a key enabler for the next generation of intelligent mobile systems where real-time perception and response are achieved through remote inference rather than on device.

Keywords: WebRTC, Mobile Applications, Edge AI, Real-time Communication, Distributed Systems

RTI1.3 (#5443)
AI-BASED BINARY CODE ANALYSIS FOR AUTOMATED TARGET RESOURCE IDENTIFICATION

Vahagn Gishyan, Vazgen Melikyan, Armenak Babayan

Interlanguage full-fledged compatibility with C++ is still one of the open tasks of modern programming. Its complexity lies in assembling the necessary data to use the functionality. Traditional methods use wrappers to assemble this data, but this method is limited in use. Since most of the necessary data in different versions is in a binary file, and recent research has shown that AI is effectively reduced with binary code analysis, a new AI model has been developed to solve the problem. However, it is known that AI may not give accurate answers and/or generate them. This article discusses the process of learning a model for binary analysis with an emphasis on rigorous search. The tests show that, as a result of training, the model provides a high fineness of answers compared to known solutions, even with incorrect answers.

Keywords: AI models, binary analysis, target identification, C++ interoperability

RTI1.4 (#4695)
REALIZATION OF AXON II CHESS ENGINE

Vladan Vuckovic

This paper will present the details of the construction of the author's new chess program Axon II (version 2026). The combinatorial explosion problem, which is fundamental to all applications for intensive decision tree processing, is addressed in the new engine by a combination of modern tree processing techniques and intensive use of X86 machine code for programming the basic functions of the engine, primarily the position generator and evaluator. Empirical tests on various platforms show very high raw engine speed factor (NPS factor) in comparison with referent chess engine - Stockfish 18.

Keywords: Theory of Logic Games Computer Chess Chess Engines Machine Programming

RTI1.5 (#3718)
A TWO-STAGE FEW-SHOT FRAMEWORK FOR HATE SPEECH DETECTION AND CATEGORIZATION IN EMOJI-CONTAINING TEXT

Janko Tufegdžić, Matija Dodović, Dražen Drašković

This paper proposes a two-stage framework for hate speech detection and categorization in emoji-containing text. The framework first performs binary hate speech detection and then assigns a fine-grained hate category only to texts predicted as hateful. To examine the effect of emojis, the study uses paired texts in two forms: an emoji-containing version and a corresponding emoji-free version. The experiments were conducted on a dataset with paired samples and evaluated across several locally hosted large language models. The results show that binary detection is generally more stable and more accurate than fine-grained categorization. They also indicate that emoji removal has a relatively limited effect on hate speech detection, but a stronger effect on category assignment, suggesting that emojis influence the semantic interpretation of hateful content more than its initial recognition. Among the evaluated models, qwen3 achieved the best overall performance, while phi4 provided the most balanced trade-off between effectiveness and efficiency. The findings highlight the importance of emoji-aware analysis and show that a two-stage approach offers a useful framework for studying both the presence and the type of hate speech in social media text.

Keywords: Hate Speech Detection, Hate Speech Categorization, Large Language Models, Emojis, Few-Shot, Artificial Intelligence, Natural Language Processing

RTI1.6 (#2741)

A PROTOCOL FOR DERIVING DOMAIN-SPECIFIC UNITS OF ANALYSIS FOR THE EVALUATION OF END-USER DEVELOPMENT TOOLS: A DEMONSTRATION IN SMART CONTRACT AUTHORING

Helena Anišić, Dinu Dragan, Sara Bogdanović, Dušan Gajić and Veljko Petrovic

Evaluating End-User Development (EUD) authoring tools requires empirical studies in which participants complete representative tasks. In many domains, such tasks necessarily involve producing a complete artifact composed of multiple distinct elements. Measuring only whether the final artifact is correct offers limited insight into where and why users fail, and does not support meaningful comparison across tools that differ in how they approach the authoring process. To address this limitation, we propose a protocol for deriving domain-specific units of analysis, which are artifact elements that correspond to relevant domain concerns and can be assessed for correctness independently of any specific tool's notation or authoring technique. The protocol consists of four phases: Artifact Corpus Construction, Individual Identification, Consolidation and Refinement, and Coverage Validation, with domain experts involved in the latter three. We demonstrate the execution of the protocol through its application to the domain of smart contract authoring tools, where a representative task cannot be smaller than creating a complete contract and existing tools differ considerably in how they support that process. The absence of a systematically derived set of such units in prior literature provided additional motivation for this choice of domain. This paper focuses on the protocol and reports its implementation in the smart contract authoring domain, while a detailed analysis of the resulting units is reserved for a subsequent study.

Keywords: end-user development, usability evaluation, smart contracts, domain-specific units

СЕСИЈА / SESSION (PT1 + RTI2)
RAČUNARSKE MREŽE I SIGURNOST / COMPUTER NETWORKS AND SECURITY – CNS

Понедељак, 8. јун / Monday, June 8th Сала 4 / Hall 4 11.15-14.00

Председавајући / Chair:
Aleksandar Stanimirović, Univerzitet u Nišu - Elektronski fakultet, Niš, Srbija

RTI2.1 (#9162)

DESIGN AND IMPLEMENTATION OF A PLATFORM FOR AUTOMATED INFRASTRUCTURE PROVISIONING AND DEPLOYMENT OF CONTAINERIZED APPLICATIONS

Vukadin Draskovic, Vladimir Ćirić

Modern software system development requires a high degree of automation in the infrastructure management and application delivery process. Traditional approaches based on manual configuration are becoming increasingly inefficient in environments characterized by frequent changes, scalability requirements, and the growing complexity of contemporary systems. As a response to these challenges, this paper presents a platform that integrates the concepts of Infrastructure as Code, configuration automation, and container orchestration into a unified, fully automated workflow for infrastructure provisioning and deployment of containerized applications. In this paper, we proposed a platform that combines the Infrastructure as Code tool Terraform for definition and

creation of virtual resources, the automation tool Ansible for automated configuration of the operating environment and provisioning of a Kubernetes cluster, as well as for managing Kubernetes applications through Helm charts. This integration enables the user to initiate the entire process, from initial infrastructure creation to application deployment, using only a minimal set of configuration parameters. The proposed solution was tested on the private cloud infrastructure of the Laboratory for Advanced Security Systems at the Faculty of Electronic Engineering in Nis. As a practical demonstration, the platform was used to automatically deploy a containerized application for real-time security data classification. The results indicate that the integrated approach significantly accelerates and simplifies the initial system setup, reduces the tendency to configuration errors, and provides a standardized and repeatable delivery workflow.

Keywords: cloud computing, Infrastructure as Code, automation tools, orchestration

RTI2.2 (#8656)
DESIGN AND IMPLEMENTATION OF A WEB APPLICATION FOR COMPARISON OF STEGANOGRAPHIC TECHNIQUES

Anja Meštrović, Danko Miladinovic, Žarko Stanisavljević

This paper presents design and implementation of a web application for image steganography usage and comparative analysis of four techniques: Edge Least Significant Bit (EdgeLSB), Pixel Value Differencing (PVD), Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). To address the lack of standardized evaluation platforms, a unified steganography tool was developed to perform embedding and extraction, as well as to enable evaluation under identical conditions. The study examines trade-offs among payload capacity, visual quality and resistance to hidden data detection, using objective metrics and steganalysis techniques. The results indicate that PVD and DWT achieve the most effective balance between high embedding capacity and image fidelity. EdgeLSB maintains high visual quality but exhibits lower capacity, while the proposed DCT implementation is sensitive to coefficient manipulation, leading to reduced efficiency and challenges in preserving robustness against detection. Ultimately, this comparative analysis provides a benchmark for selecting optimal steganographic methods within the implemented tool based on specific requirements.

Keywords: Image Steganography, Data Hiding, Security, LSB, PVD, DCT, DWT, Comparative Analysis, Steganalysis

RTI2.3 (#4215)
PRIVACY-PRESERVING MEDICAL DIAGNOSIS USING HOMOMORPHIC ENCRYPTION

Ana Vitkovic, Pavle Vuletic

The use of machine learning (ML) in medical diagnostics brings significant advances in assistance to early disease detection, but also raises concerns related to the protection of private medical data. One of the strategies for privacy-preserving medical diagnostics is processing encrypted diagnostics data using fully homomorphic encryption (FHE). This paper presents a systematic comparison of multiple combinations of ML models and FHE schemes including: logistic regression, neural networks, and random forest models across two FHE frameworks, OpenFHE and Concrete-ML. Choice of FHE scheme fundamentally constrains which ML operations are practical, with inference time differences spanning up to four orders of magnitude. Based on these findings, we implement HeartGuard AI, a web application performing logistic regression inference on encrypted patient data using client-side browser encryption via WebAssembly,

achieving 86.13% accuracy with predictions identical to those obtained when the same model is evaluated on unencrypted data and 15ms server-side inference time.

Keywords: fully homomorphic encryption, machine learning, privacy-preserving inference, medical diagnostics, CKKS, TFHE

RTI2.4 (#3506)
SECURE MULTI-PARTY COMPUTATION WITH CONFIDENTIAL VIRTUAL MACHINES AND FULL DISK ENCRYPTION

Slavica Mitrović, Danko Miladinovic, Pavle Vuletić

secure multi-party computation requires mechanisms that protect sensitive data during collaborative processing while preventing unauthorized access by participants or infrastructure providers. Trusted execution environments offer strong protection for data in use, but technologies such as AMD SEV-SNP primarily secure memory contents and do not inherently protect data stored on disk. To address this limitation, a system architecture is proposed that combines remote attestation, LUKS disk encryption, and a modified SNPGuard framework to extend confidentiality guarantees to persistent storage. In the proposed design, a disk manager running inside a confidential virtual machine without local persistent storage generates and maintains disk encryption keys exclusively in protected memory, while an agent running in a separate confidential virtual machine is granted access to the decryption key only after successful mutual attestation. This approach enables secure provisioning of disk decryption keys and protects data both at rest and during processing, without exposing key material to computation participants. The work also examines existing confidential computing solutions and supporting technologies, including QEMU, OVMF, initramfs, and Buildroot, and evaluates the security properties of the proposed system. The results indicate that the approach provides a practical foundation for secure multi-party computation, while also highlighting open challenges related to centralized trust, disk integrity verification, and resilience against advanced attacks.

Keywords: AMD SEV-SNP, confidential computing, LUKS, multi-party computation, trusted execution environment, full disk encryption

RTI2.5 (#9822)
SERVER-RELATED SECURITY BOTTLENECKS AND DATA AVAILABILITY IN WEARABLES: A CASE STUDY

Miloš Milošević, Nadica Miljković

This study analyzes the security and feasibility of redirecting data within the Fitbit Charge~6 ecosystem. The communication architecture and data flow are examined to identify practical redirection points while evaluating privacy and security constraints. Static analysis of the Android application shows that complete bypassing the official cloud infrastructure is infeasible due to the hardcoded endpoints and server-side controls. Access to fine-grained physiological and activity metrics is possible only via the official Fitbit Web Application Programming Interface (API). An experimental Raspberry Pi setup incorporating free and open-source software demonstrates secure local retrieval and storage of user-authorized data through the Web API, enabling enhanced analysis and research applications while preserving privacy and security.

Keywords: Fitbit Charge 6, wearable devices, data security, user privacy, local data storage, communication architecture

RTI2.6 (#2110)
PERFORMANCE COMPARISON OF ROUTING DESIGNS IN HIERARCHICAL INTRUSION DETECTION PIPELINES

Aleksandar Stojković, Evgenija Krajchevska, Aleksandar Stanimirović, Dragan Stojanović, Leonid Stoimenov

This paper presents a hierarchical, multi-model Network Intrusion Detection System pipeline architecture implemented using Numaflow on Kubernetes, with Apache Kafka as a data source. The system builds on prior work with a two- layer detection architecture in which a fast, lightweight Layer 1 model filters confidently classified traffic, escalating only suspicious records to a set of heavier, specialized Layer 2 models. Outputs from both Layer 1 and Layer 2 are combined by an Arbiter vertex. Main challenge addressed is conditional routing. Layer 1's escalation decision must affect the flow of data through topologically separate preprocessing branches, which is not natively supported by Numaflow. Three routing solutions are designed and evaluated: reduce vertex join, map vertex join leveraging Redis, and in-model preprocessing. Results show that the reduce vertex approach has the best performance at low escalation rates, while the map-based approach is better at higher escalation rates.

Keywords: Network intrusion detection, Numaflow, Kubernetes, Hierarchical model, Conditional routing.

RT1.1 (#5399)
UPOREDNA ANALIZA MEHANIZAMA ZAŠTITE PODATAKA U MIROVANJU VODEĆIH CLOUD PROVAJDERA

Marija Popović, Žarko Stanisavljević, Pavle Vuletić

Sa masovnom migracijom poslovnih sistema na cloud platforme, bezbednost podataka u mirovanju (eng. data at rest) postaje primarni izazov. Ovaj rad pruža uporednu analizu kriptografskih mehanizama pet vodećih cloud provajdera: Google Cloud Platform (GCP), Amazon Web Services (AWS), Microsoft Azure, IBM Cloud i OVHcloud. Poseban fokus stavljen je na strategije upravljanja ključevima gde korisnik zadržava kontrolu (eng. Customer-Supplied Encryption Keys – CSEK). Rad uključuje pregled srodnih istraživanja, tehničku analizu arhitekture enkripcije, tabelarno poređenje bezbednosnih standarda, kao i praktičnu demonstraciju implementacije CSEK mehanizma. Rezultati pokazuju da, iako svi provajderi koriste AES-256 standard, postoje značajne tehničke razlike u nivoima sertifikacije hardverske zaštite (eng. Hardware Security Module – HSM), stepenu digitalnog suvereniteta i modelima upravljanja poverenjem.

Keywords: Cloud security, Data at Rest, CSEK, Envelope Encryption, HSM, KMS

СЕСИЈА / SESSION (PT2 + RTI3)
RAČUNARSKA TEHNIKA I PRIMENE / COMPUTER ENGINEERING AND APPLICATIONS – CEA

Понедељак, 8. јун / Monday, June 8th Сала 4 / Hall 4 15.00-17.15

Председавајући / Chair:
Miloš Cvetanović, Univerzitet u Beogradu - Elektrotehnički fakultet, Beograd, Srbija

RTI3.1 (#0009)
MULTI-OBJECTIVE OPTIMIZATION OF BLOCKCHAIN SHARDING CONFIGURATION USING NSGA-II GENETIC ALGORITHM

Dejan Vujičić, Nikola Zogović

Blockchain sharding networks partition the network into parallel processing units to overcome the throughput limitations of monolithic chains. Configuring such a network requires balancing two conflicting objectives – transaction throughput and latency, that cannot be optimized independently. This paper applies the Non-dominated Sorting Genetic Algorithm II (NSGA-II) to approximate the Pareto front of sharding configurations defined by three decision variables: number of shards, committee size, and cross-shard transaction ratio. The performance model is calibrated against measurements from RapidChain and OmniLedger. Ten independent runs yield a stable Pareto front approximation of 100 solutions covering 30–1,500 Transactions per Seconds (TPS) at 96–390 ms latency. NSGA-II achieves Inverted Generational Distance (IGD) of 0.0048 ± 0.0003 and hypervolume convergence above 90% within 40 generations, with near-zero inter-run variance (Coefficient of Variation, CV < 0.1%) across ten independent runs, confirming robust convergence to a well-distributed approximation of the Pareto front.

Keywords: blockchain, latency, multi-objective optimization, NSGA-II, Pareto front, sharding, throughput

RTI3.2 (#0178)
COMPARISON OF NSGA-II WITH RANDOM SEARCH AND GRID SEARCH FOR MULTI-OBJECTIVE BLOCKCHAIN SHARDING CONFIGURATION

Dejan Vujičić, Nikola Zogović

Choosing an appropriate search algorithm for multi-objective optimization problems requires understanding both the structural properties of the problem and the mechanisms through which different algorithms exploit them. This paper compares Non-dominated Sorting Genetic Algorithm II (NSGA-II) against two baseline methods – Random Search and Grid Search, on the problem of configuring a blockchain sharding network with respect to throughput and latency. The comparison is conducted over ten independent runs per stochastic algorithm and evaluated using Inverted Generational Distance (IGD) and a coverage density analysis. NSGA-II achieves IGD = 0.0048 ± 0.0003, an 8-fold improvement over Random Search (IGD = 0.040, Wilcoxon $p < 0.001$) and a comparable improvement over Grid Search (IGD = 0.038). The results show that the advantage of NSGA-II stems from directed, population-based search that concentrates effort near the Pareto front, rather than from a larger evaluation budget alone.

Keywords: blockchain, Grid Search, IGD, multi-objective optimization, NSGA-II, Pareto front, Random Search, sharding, statistical comparison

RTI3.3 (#1675)
ADAPTIVE CHARGING ALGORITHM FOR WIRELESS SENSOR NETWORKS

Ziqi Xu

In this study, we investigate the recharging of nodes in wireless rechargeable sensor networks(WRSNs). We first formulate a novel node recharging scheduling problem to maximize the number of surviving nodes, and further propose an adaptive recharging scheduling algorithm for WRSNs. In this scheme, wireless charger(WC) calculates calculate the charging priority of nodes based on their lifetime, importance, and distance from itself, and select the node with the highest priority to replenish energy. When its energy is insufficient, it can switch to partial charging mode. The simulation results show that the proposed algorithm performs better than the other algorithms in terms of the proportion of dead nodes, network lifetime, and charging delay. The proposed algorithm can effectively reduce the mortality rate of the nodes.

Keywords: wireless rechargeable sensor network, adaptive charging, lifetime, wireless charger

RTI3.4 (#4907)
DIRECT MUTABLE SHARED MEMORY ARCHITECTURE FOR INTERLINGUA SYSTEM COMMUNICATION

Vahagn Gishyan, Martin Mirzoyan

The typical approach to cross-language data exchange between programming languages consists of serialization or using immutable shared buffers, which do not allow in-place modification, and impose copying overhead for each mutation. We present Mutable Shared Memory (MSM), a memory architecture that allows any C-compatible language (C++, Python, Rust, and etc.) to directly read and write the same data without serialization or duplication of buffers. MSM uses a deterministic 8-byte aligned object layout, a centralized native allocator exposed via foreign function interface (FFI), and a (conditionally) lock-free singlewriter/multiple-reader protocol on x86-64. Experimental evaluation shows that MSM achieves 5.6× speedup over Apache Arrow on in-place array mutation, 2.0× faster end-to-end throughput on cross-language graph pipelines, and 6.1× improvement over MsgPack on iterative exchange workloads. The findings indicate that it is not necessary for shared memory to be immutable in order to achieve safe cross-language communication. Direct mutable shared memory access under a clearly defined concurrency protocol delivers substantial performance gains.

Keywords: Shared memory, Mutable memory, Interlingual System Communication, Interoperability

RTI3.5 (#7412)
ANALYSIS OF MURMURHASH3 HASH FUNCTION USAGE IN BDD PACKAGES

Miloš Radmanović

The use of BDD (Binary Decision Diagram) packages have become essential in implementation of many CAD (Computer Aided Design) algorithms, especially in the field of logic synthesis. There are currently many different BDD packages available, but all of them are built according to the basic principles and recommendations for implementing these packages. These packages usually have unique and computed hash-based tables to provide a way to efficiently access BDD nodes and the results of partial operations on them. Selection of a hash function can have impact on the performance of

these tables. MurmurHash3 hash function is a non-cryptographic hash function known for its excellent performance and distribution characteristics. Therefore, this paper presents an analysis of the impact of using the MurmurHash3 hash function in BDD packages. Experiments on the BDD benchmarks show slight improvement in performance of BDD packages.

Keywords: Boolean functions, circuit synthesis, binary decision diagram, optimization methods

RTI3.6 (#8519)
IMPLEMENTATION OF THE ISO/IEC 42001 STANDARD IN ORGANIZATIONAL ENVIRONMENT AND MODERN INFORMATION SYSTEMS

Aleksandra Panović, Vesna Ružičić

The implementation of the ISO/IEC 42001 standard in organizational environments enables the effective integration and use of modern information systems (IS), contributing to improved personalized learning and operational efficiency. By aligning standardized processes with advanced digital platforms, organizations can systematically collect and analyze data, monitor performance, and adapt resources to meet specific user and organizational needs. This study examines the impact of ISO/IEC 42001-compliant IS on learning outcomes and organizational processes. The results indicate that such systems support more informed decision-making, enhance overall efficiency, and improve alignment between technological solutions and strategic objectives. The application of ISO/IEC 42001 in modern IS represents an important step toward optimizing organizational performance and enabling sustainable digital transformation.

Keywords: ISO/IEC 42001, Standard, Information Systems, Organizational Environment, Digital Transformation

RT2.1 (#1800)
UTICAJ AMD SEV-SNP POVERLJIVOG RAČUNARSTVA NA PERFORMANSE MICROSOFT SQL SERVER SISTEMA ZA UPRAVLJANJE BAZAMA PODATAKA

Teodora Radaljac, Aleksa Srbljanović, Miloš Cvetanović

Poverljivo računarstvo (eng. Confidential Computing) omogućava hardversku zaštitu podataka tokom aktivne obrade u memoriji virtuelne mašine, čime se zaokružuje zaštita podataka u tri stanja: u mirovanju, u tranzitu i u upotrebi. Ovaj rad kvantifikuje uticaj na performanse AMD SEV-SNP (eng. Secure Encrypted Virtualization – Secure Nested Paging) mehanizma na Microsoft SQL Server, koristeći HammerDB sa TPROC-C (transakcionim) i TPROC-H (analitičkim) radnim profilima. Merenja su sprovedena na identično konfigurisanim Google Cloud instancama sa AMD EPYC procesorima, pri čemu se jedina razlika odnosila na aktivaciju SEV-SNP mehanizma, dok su transparentno šifrovanje podataka u mirovanju (eng. Transparent Data Encryption, TDE) i šifrovanje transportnog sloja (eng. Transport Layer Security, TLS) bili aktivni u oba scenarija. Rezultati ukazuju da stepen performansnog opterećenja u značajnoj meri zavisi od tipa radnog profila i nivoa konkurentnosti. Za transakcioni profil opterećenje je izraženo pri niskoj konkurentnosti, ali se značajno smanjuje pri većem broju korisnika, dok je za analitički profil razlika između platformi zanemarljiva.

Keywords: AMD SEV-SNP, poverljivo računarstvo, performanse baza podataka, HammerDB, TPROC-C, TPROC-H, TDE, TLS, Google Cloud Platform

АУТОМАТИКА / AUTOMATION

СЕСИЈА / SESSION (АУ1+AUI1)
AUTOMATIC CONTROL IN THEORY AND PRACTICE

Понедељак, 8. јун / Monday, June 8th Сала 3 / Hall 3 11.15-14.00

Председавајући / Chair:
Željko Đurović, Univerzitet u Beogradu - Elektrotehnički fakultet, Beograd, Srbija

AUI1.1 (#0372)
DEVELOPMENT AND IMPLEMENTATION OF A POSITION CONTROL SYSTEM FOR A SERVO MOTOR USING A PI CONTROLLER AND A LAG COMPENSATOR

Adrijana Jovanović, Miloš Pavić, Lazar Saranovac

This paper presents the design and implementation of a control system for a servo motor used for position control of aerodynamic control surfaces. The system is based on the microcontroller STM32F411, which performs real-time control and monitoring of the actuator. The servo motor is equipped with a lead screw reducer and drives a control surface characterized by a hinge moment acting as a load disturbance. The control algorithm is implemented using proportional integral (PI) and lag compensators in order to achieve stable and accurate tracking of the reference signal. Feedback information about the motor position is obtained from an incremental encoder. In addition, a display connected to the microcontroller provides real-time visualization of the encoder position and the reference value, enabling monitoring of the system during operation. The proposed control structure is implemented and tested on an embedded platform. Experimental results demonstrate that the designed controller achieves satisfactory tracking performance and stable system behavior despite the presence of mechanical load and lead screw dynamics.

Keywords: servo system, real-time, automatic, embedded, DC motor

AUI1.2 (#6945)
IMPLEMENTATION OF CURRENT REGULATION OF BLDC MOTOR WITH TRAPEZOIDAL COMMUTATION SCHEME

Milan Ignjatovic, Emil Veg, Predrag Petronijevic, Nikola Lepojevic, Luka Savanovic

The most used commutation scheme for electronic commutation of BLDC motors is trapezoidal (six-step) commutation. It is simple to implement, and is mostly used for application that require speed control. However, trapezoidal commutation can still be used with application that require other types of control such as position or current. This paper will address one method of current control of BLDC motor.

Keywords: motor control, BLDC, PI controller, current regulation

AUI1.3 (#1349)
DEVELOPMENT OF A MOBILE PLATFORM FOR MAZE-SOLVING

Katarina Antanasijević, Vladimir Sibinović, Vladimir Mitić, Anđela Jovanović, Boban Veselić

This paper presents the development and experimental validation of an autonomous navigation system for the Arduino Alvik mobile robot, designed to find an exit in a maze

without prior knowledge of its structure. The system integrates additional sensors, odometry-based localization, and a proportional-derivative controller for stable corridor tracking. Maze solving is achieved using a left-hand wall-following algorithm. Experimental results demonstrate reliable obstacle detection and stable motion, confirming the effectiveness of the proposed approach for autonomous mobile robotics applications.

Keywords: mobile robot, maze-solving algorithm, motion control, Arduino,

AUI1.4 (#6010)
CURRENT CONTROL DESIGN AND VALIDATION IN LOW-INERTIA PMSM DRIVES

Emilija Mrđen, Marko Jelić, Petar Matić

In this paper, modified PI current controller structures and a method for tuning the parameters of an adaptive controller in a drive system with a Surface Permanent Magnet Synchronous Motor with low moment of inertia are proposed, taking into account both electrical and mechanical dynamics. The proposed controller structures enable the cancellation of cross-coupling between the axes and do not rely on the calculated speed obtained from encoder outputs, which may slow down the operation of the current control loop. The controller performance is evaluated through computer simulations in both continuous and discrete domains, as well as through experimental validation.

Keywords: Permanent Magnet Synchronous Motor, Controller Parameters, Transfer Function, System Response Characteristics

AUI1.5 (#7275)
EXPLICIT MPC FOR CLEANROOM PRESSURE CASCADES: FROM OPTIMAL CONTROL TO INDUSTRIAL IMPLEMENTATION

Branislav Jeremić, Aleksandar Rakić

This paper presents a deployment-oriented transformation of Model Predictive Control (MPC) into its explicit form for cleanroom pressure cascade systems. Starting from an experimentally validated multivariable MPC controller, an equivalent explicit MPC (eMPC) formulation is obtained through offline multi-parametric optimization. In addition to the explicit-controller derivation, the paper investigates the relationship between controller complexity, execution time, and closed-loop performance through systematic simplification of the explicit solution. Runtime measurements and performance-degradation analysis are used to evaluate different explicit-controller complexities. The results show that the number of regions can be significantly reduced without measurable degradation of closed-loop performance according to the proposed performance degradation index (PDI). At the same time, measured execution times demonstrate approximately two orders-of-magnitude runtime speedup compared to conventional MPC. The paper also discusses architectural aspects of integrating eMPC into industrial DCS/PLC and Industrial IoT (IIoT) control environments. The obtained results indicate that eMPC enables deterministic and computationally efficient execution suitable for industrial control environments.

Keywords: MPC, Model Predictive Control, Explicit MPC, Clean Rooms Cascade, PLC, IIoT, HVAC

AUI1.6 (#8870)
CONTAMINATION PROBABILITY ESTIMATION USING HUBER-BASED WEIGHTING

Aleksandra Krstić, Željko Đurović

The presence of outliers in measurements can significantly degrade the performance of standard estimation methods. Classical approaches, such as Maximum Likelihood (ML), which rely on the assumption of a correctly specified noise distribution, become highly sensitive when the actual distribution deviates from the assumed one. In such situations, M-estimators exhibit improved performance due to their robustness to outliers. Although the Huber contamination model has long been established as a benchmark in robust estimation, determining the contamination probability remains a challenging problem. This paper considers a robust adaptive approach to estimating the contamination probability based on weighting coefficients and compares it with classical methods in scenarios with Gaussian and non-Gaussian noise distribution.

Keywords: robust estimation, outliers, contamination probability estimation, Huber loss

AUI1.7 (#9750)
MODELING THE CALORIFIC VALUE OF COAL FROM PROCESS MEASUREMENTS: FEATURE SELECTION AND TEMPORAL ALIGNMENT

Marko Vučković, Aleksa Stojić, Goran Kvaščev

The calorific value of coal is a key parameter in assessing the production capacity of a thermal power unit. Its reliable estimation enables optimal tuning of the combustion process control system. Variations in fuel quality significantly affect combustion stability, load distribution among mills, as well as the overall system efficiency, with their impact reflected through changes in thermodynamic and electrical quantities. This paper considers the problem of feature selection and model design for the estimation of coal calorific value, based on available process measurements and laboratory-analyzed samples. Particular focus is placed on the identification of appropriate physical variables, as well as on determining the time interval in which they become representative of the observed sample.

Keywords: coal calorific value, process measurements, feature selection, modeling, temporal context

AU1.1 (#9005)
DETEKCIJA I UTICAJ NAPOUZDANIH MERENJA PRI MODELIRANJU KALORIJSKE VREDNOSTI UGLJA

Đorđe Urošević, Aleksa Stojić, Željko Đurović

Procena kalorijske vrednosti uglja je važan zadatak u postrojenjima kao što su termoelektrane. Tačnu vrednost je moguće dobiti jedino u laboratorijskim uslovima, dok se u realnom vremenu ona može proceniti korišćenjem odgovarajućih matematičkih modela. Međutim, prisustvo nepouzdanih merenja može značajno uticati na procenu parametara modela i tako uticati na smanjenje sposobnosti generalizacije samog modela. Cilj ovog rada je detekcija takvih merenja a zatim i ispitivanje njihovog uticaja na regresioni model za procenu kalorijske vrednosti uglja. Dobijeni rezultati pokazuju da pristupi iterativne korekcije modela i usrednjavanja modela predstavljaju dobar kompromis između tačnosti i stabilnosti parametara čime se smanjuje osetljivost konačnog modela na izbor i obradu nepouzdanih merenja.

Keywords: kalorijska vrednost uglja, detekcija nepouzdanih merenja, regresioni modeli, robusna regresija

AUI1.8 (#4131)
A COMPARISON OF 3D GAUSSIAN SPLATTING AND INSTANT-NGP UNDER DEGRADED INPUTS

Natalija Đorđević, Sanja Vujnović

Novel view synthesis has advanced significantly in recent years, with two main approaches: NeRF-based methods and 3D Gaussian Splatting. Although both achieve high-quality results, their performance is yet to be studied and improved under conditions of degraded inputs. In this paper, we compare representative methods from both groups. We degrade inputs by introducing motion blur, a common effect in real-world image capture, and analyze how it impacts reconstruction quality. We also analyze how introducing camera pose errors affects the performance. The results show how robust each method is and highlight their strengths and weaknesses when dealing with mentioned input degradations.

Keywords: novel view synthesis, 3D reconstruction, radiance fields, Gaussians, motion blur, camera pose

AUI1.9 (#7810)
THE PREDICTION OF MISSILE-TARGET INTERCEPTION USING C-BAND RADAR

Zvonko Radosavljevic, Dejan Ivkovic, Branko Kovacevic

The calculation of the encounter of a projectile and a target in the air is a common topic in the modern defense industry. Many methods are used for this purpose, and the most common are methods related to differential equations of motion known from the theory of external ballistics, taking into account the influence of wind, atmosphere, and thrust from the fuel used to propel the projectile. The paper presents an example of the calculation of the prediction of the encounter of a projectile and a target in the cannon firing zone in an automatic fire control system based on the integration of differential equations of motion Ode 45, by the Runge-Kuta method. The obtained predicted flight time to the target is used to determine the moment of firing the projectile from the cannon as well as the azimuth and elevation angles used to direct the cannon towards the target. Targets at a distance of 3000 m moving at a uniform speed as well as targets with acceleration and movement in maneuver were tested. The simulation results showed good results and a small error in the projectile passing the target.

Keywords: exterior ballistics, equations of projectile motion, target tracking

НУКЛЕАРНА ТЕХНИКА / NUCLEAR ENGINEERING AND TECHNOLOGY

СЕСИЈА / SESSION (NTI1)

Понедељак, 8. јун / Monday, June 8th Сала 1 / Hall 1 15.00-17.15

Председавајући / Chair:
Koviljka Stanković, Univerzitet u Beogradu - Elektrotehnički fakultet, Beograd, Srbija

NTI1.1 (#9026)
DEVELOPMENT OF NUCLEAR ENERGY WITHIN THE ENERGY SYSTEM OF THE REPUBLIC OF SERBIA
INVITED PAPER

Predrag Škobalj, Slavko Dimović, Milica Ilić, Marija Jankovic, Predrag Stefanović

The Republic of Serbia largely meets its electricity needs through production in thermal power plants that use coal as fuel. As the coal-lignite deposits in the Kolubara and Kostolac basins are limited, and the reserves in Kosovo and Metohija are not under the control of the Government of the Republic of Serbia, it is necessary to find a solution to ensure the country's energy security and stability. At the end of 2024, amendments to the Law on Energy lifted the moratorium on the use of nuclear energy for peacetime purposes. With this change, the Republic of Serbia gained the opportunity to start a nuclear programme and, with the potential construction of a nuclear power plant, meet its basic energy needs. In this paper, we will analyse the current energy capacities of our country, the possibilities for replacing coal-fired thermal power plants with nuclear power plants, the advantages and disadvantages of nuclear power plants, the experiences of countries in the region, and the obstacles and challenges to building a nuclear power plant.

Keywords: nuclear energy, nuclear programme, power plant

NTI1.2 (#9013)
NUCLEAR LAW - LEGISLATIVE SCOPE, SOURCES, AND KEY ACTORS

Sanja Baranac Stojičić, Katarina Žarković, Milica Ćurčić and Milan Ljušić

Nuclear law is a complex and highly specialised branch of law that regulates all activities involving fissile materials, ionising radiation, and exposure to natural sources of radiation. Its primary purpose is to establish a rigorous legal framework that ensures comprehensive protection of individuals, society, and the environment from the potentially harmful effects of radiation, while also creating the necessary legal prerequisites for the peaceful use of nuclear energy. Due to the specific and far-reaching risks inherent in nuclear activities, this field requires continuous harmonisation of national legislation with international standards. This paper critically analyses the definition and legislative scope of nuclear law, examining its sources and the hierarchy of legal instruments in detail. Special attention is given to the role of key actors in this field, as well as the historical evolution of legal norms directly prompted by major nuclear accidents at Chernobyl and Fukushima. Through the analysis of these events, the paper demonstrates the shift from strictly national regulations to a transnational approach

to safety, emphasising the importance of international cooperation and constant oversight to maintain global nuclear security.

Keywords: Nuclear law, ionising radiation, nuclear safety, international conventions, environmental protection

NTI1.3 (#1566)
MEDIA NARRATIVES AND THE SECURITIZATION OF NUCLEAR THREATS: COMMUNICATING SECURITY RISKS AND BUILDING PUBLIC TRUST

Milica Ćurčić, Sanja Baranac Stojičić, Slavko Dimović

In the contemporary security environment, the perception of nuclear energy is increasingly shaped not only by historical experiences but also by current media reporting on crises and conflict situations. In particular, reporting on military operations in countries with developed nuclear infrastructure, such as Ukraine and Iran, often contributes to the spread of fear and public panic, whereby the risks of nuclear incidents are frequently presented without adequate fact-checking or sufficient expert context. In this regard, the securitization of the nuclear threat can be observed, through which potential risks are framed as immediate and existential dangers. Such narratives may lead to a distortion of risk perception and further undermine public trust in nuclear energy as a safe and controlled energy source. At the same time, historical events such as the Chernobyl disaster and the Fukushima nuclear disaster have left a strong imprint on collective memory, with media reporting significantly contributing to the formation of long-lasting narratives of nuclear energy as a high-risk technology. This paper analyzes the role of the media as a key actor in the process of shaping risk perception, drawing on theoretical approaches such as Framing Theory and the Social Amplification of Risk framework. Particular attention is given to the ways in which media frames, source selection, and reporting tone influence the level of public trust in institutions and nuclear projects. Through a comparative analysis of communication practices in different countries, the paper identifies key challenges, including sensationalism, lack of expert interpretation, and the dominance of crisis-driven narratives. Based on the conducted analysis, concrete strategies are proposed for improving communication on nuclear energy in Serbia, with a particular emphasis on transparency, a proactive relationship with the media, and the development of a dialogical communication model, in order to build an informed and trust-based public opinion.

Keywords: media, nuclear threats, nuclear security, public trust

NTI1.4 (#7786)
TESTING PREPAREDNESS AND RESPONSE IN EMERGENCY SITUATIONS - CONVEX-3, 2025

Milica Rajacic, Jelena Krneta Nikolic, Nataša Sarap and Marija Janković

In order for radiation protection experts to be as well trained as possible to respond to emergency situations, in addition to studying literature and attending courses, participation in nuclear accident exercises is a significant factor affecting the readiness of personnel. This paper presents the course of one such exercise (ConvEx-3), available data, target values, and the procedure in which the values were determined by the Radiation and Environmental Protection Department, Institute "Vinča". The task of the exercise was to detect the emitted radionuclides and determine their activities within 24 hours, based on the obtained gamma radiation spectrum and relevant sampling and measurement data. The radionuclides identified were: I-131, I-132, Cs-134, Cs-136, Cs-

137, Te-129m, Te-129, Te-132 and all reported results were in good agreement with the target values.

Keywords: emergency exercise, gamma spectrometry, air filter spectrum

NTI1.5 (#3399)
RADIOLOGICAL ASSESSMENT OF INTERNATIONAL RIVER SYSTEMS POTENTIALLY INFLUENCED BY NUCLEAR POWER PLANTS

Marija Jankovic, Nataša Sarap, Slavko Dimović, Predrag Škobalj, Milan Ljusić, Ivan Lazović, Milica Ćurčić, Sanja Baranac Stojičić

Environmental radioactivity monitoring represents one of the key components of public health protection and environmental safety, particularly in areas potentially influenced by nuclear facilities. Continuous monitoring of surface waters, soil, and air enables the timely detection of artificial radionuclides, as well as the assessment of possible radiological impacts on the environment. Special attention is given to river systems that may be exposed to transboundary influences originating from nuclear power plants located along major watercourses. Due to the geographical position of the Republic of Serbia downstream from Nuclear Power Plant Krško and Nuclear Power Plant Paks, surface water radioactivity monitoring constitutes an important part of the national radiological surveillance system. Within the framework of bilateral cooperation between Serbia and Hungary, radioactivity monitoring of the Danube River has been established in the transboundary region at monitoring stations located in Bezdan and Mohacs, with the aim of assessing potential radiological impacts and preserving the quality of this international watercourse.

Keywords: nuclear power plants, radioactivity, surface water

NTI1.6 (#7403)
DOSE EXPOSURE TO COAL ASH

Marija Jankovic, Jelena Krneta Nikolić, Milica Rajačić, Nataša Sarap, Ivana Jelić, Marija Šljivić-Ivanović, Bojan Janković

Coal remains one of the dominant global energy sources, accounting for approximately 35% of global electricity generation. According to recent reports by the International Energy Agency global coal demand reached a record high of approximately 8.79 billion tones in 2024, while coal-fired electricity generation exceeded 10,700 TWh worldwide. As a fine powder by-product generated during coal combustion, coal fly ash constitutes approximately 65–95% of the total ash produced and is recognized as one of the largest industrial solid wastes worldwide. The annual generation of coal fly ash is estimated to be around one billion tons. In this study, measurements of the ambient gamma dose equivalent rate were conducted in the near-ground atmospheric layer at a height of 1 m above the surface. The investigation focused on active and passive ash and slag disposal sites in the coal fired power plants TENT A and Kolubara, with the aim of assessing the radiological impact of coal combustion by-products on the surrounding environment.

Keywords: coal, ash, ambient dose equivalent rate,

NTI1.7 (#0820)

COAL AND BURNING COAL WASTE PRODUCTS RADIOLOGICAL ANALYSIS USING SEMICONDUCTOR HPGE SPECTROMETRY BY MEANS OF INTERNAL QUALITY CONTROL

Aleksandra Samolov, Aleksandar Kandić, Mirjana Đurašević, Igor Čeliković, Tamara Milanović, Milić Erić, Ivana Vukanac

Coal while burning , as well as slag and ash as coal combustion byproducts, can affect the state of the radioactivity in the environment since those combustion byproducts contain natural radionucledes. Therefore, the importance of monitoring radionuclides in those samples are of a great significance. To ensure the accuracy and precision (reliability) of the obtained measurement results, quality control (QC) and quality assurance (QA) program were established, which include checking of the HPGe spectrometer characteristics. Two point sources (60Co and 137Cs) were used for checking detectors characteristics recommended by ISO and IAEA documents. The paper presents the results of the QA/QC program of the HPGe spectrometer used for measurements of coal, ash and slag samples obtained from the "Nikola Tesla" and "Kolubara" thermal power plants. These results confirm both accuracy and precision of measurement results, as well as the long-term stability of the spectrometer.

Keywords: Coal, slag, fly-ash, gamma spectrometry, quality control

NTI1.8 (#1223)

EVALUATION OF THE NON-INVASIVE X-RAY SPECTROMETRY EXTRAPOLATION METHOD FOR TUBE VOLTAGE ESTIMATION

Dunja Stojanović, Nikola Kržanović, Miloš Živanović, Luka Bakrač, Luka Lotina, Luka Pavelić

Calibration of radiation protection dosimeters is performed in reference fields (radiation qualities) realized in accordance with ISO 4037-1:2019. This standard specifies the requirements for parameters influencing these radiation qualities, including the X-ray tube voltage, which defines the maximum photon energy of the beam. The recommended method for determining the X-ray tube voltage is invasive, using a voltage divider. However, alternative approaches are being explored, such as X-ray spectrometry methods, where the tube voltage is derived from the recorded X-ray spectrum. One such approach, the linear extrapolation method, determines the spectral end-point by applying a linear fit to the high-energy region of the spectrum. In this study, the linear extrapolation spectrometry method for X-ray tube voltage determination was evaluated and compared with the invasive method using a voltage divider. Deviations of less than 0.5% were observed in the tube voltage range of 60–120 kV, while at lower and higher energies, larger deviations were observed, reaching up to 1.2%. The spectrometry-based linear extrapolation method is an appropriate alternative to invasive voltage divider measurements; however, further improvements are needed to enhance its accuracy.

Keywords: ISO 4037-1, X-ray tube voltage, X-ray spectrometry, Voltage Divider, Radiation Protection

NTI1.9 (#6333)
FLEET METROLOGICAL CHARACTERIZATION OF AMBIENT DIGITAL DOSIMETERS AND CALIBRATION DATA-MANAGEMENT SOFTWARE

Miona Tomić, Jelena Krneta Nikolić, Koviljka Stanković

This paper presents a fleet-level metrological characterization of the DMRZ-M15 ambient digital dosimeter with probe S1 and a dedicated software tool for calibration-data management and quality-control (QC) support. Ten instruments were analyzed using accredited calibration certificates obtained in the reference gamma fields S-Cs (662 keV, 137Cs) and S-Co (60Co), together with ISO 4037 narrow-spectrum X-ray qualities N-100, N-120, N-150, and N-200. For each beam quality, the calibration coefficient NH for the ambient dose equivalent rate was extracted, and a practical instrument correction factor Kcorr was defined as the average of the two lowest S-Cs points. Fleet statistics yield Kcorr = 1.002 ± 0.011 and NH,S-Cs = 0.996 ± 0.012 (mean ± SD), while mean energy-response deviations relative to S-Cs are -22.5% for S-Co, -27.2% for N-100, -27.2% for N-120, -20.2% for N-150, and +2.9% for N-200. These results quantify both between-instrument variability and systematic energy dependence relevant to routine operation and QC interpretation. In parallel, a Windows Presentation Foundation (WPF) application based on the Model-View-ViewModel (MVVM) pattern was developed to support structured import of certificate-derived data, record validation, automatic computation of Kcorr, fleet-level summaries, LaTeX/CSV export, and QC charting based on z-score criteria. The combined metrological dataset and software workflow reduce manual processing errors and provide a practical basis for traceable long-term monitoring of DMRZ-M15 instruments.

Keywords: DMRZ--M15, ambient dose equivalent, calibration coefficient, ISO 4037, energy response, quality control, WPF, MVVM, traceability

NTI1.10 (#0901)
RADIOLOGICAL CHARACTERIZATION OF A 226RA-BE NEUTRON SOURCE

Nikola Petreski, Miodrag Milošević

This paper presents a non-destructive methodology for a radiological characterization of a legacy neutron source in the case of legacy neutron source containing 226Ra-Be, enclosed in a container of unknown material composition. Since there was no initial information on source activity, neutron emission rate or shielding properties, observed methodology combined experimental data from dosimetry measurements with Monte Carlo MCNP6.3 simulations. Gamma-ray spectrometry was performed to confirm the presence of 226Ra through its progeny 214Pb and 214Bi. Neutron ambient dose equivalent rate measurement combined with observation of prompt gamma radiation at an energy of 853.6 keV, from neutron capture reactions on beryllium, demonstrated that source was of the 226Ra-Be neutron source type. An iterative procedure which includes variation of assumed composition material of the container was conducted, until measurement activity of 214Pb and 214Bi showed identical or very closely matching values and the neutron emission rate fell within the expected range. Information about material composition of the container, combined with Monte Carlo MCNP6.3 simulations of initial neutron spectrum and detailed model for Monte Carlo MCNP6.3 simulations of neutron source with measurements of neutron flux density by irradiation

of golden foils, enable the determine the 226Ra-Be activity and neutron emission rate without any prior information.

Keywords: 226Ra-Be neutron source, radiological characterization, Monte Carlo MCNP6.3 radiation transport simulation

NTI1.11 (#2459)
TEXTURAL PROPERTIES VS. ACTUAL SORPTION: CHALLENGES IN RADIONUCLIDE IMMOBILIZATION PREDICTION

Kristina Pavićević, Danica Jovašević, Maja Rajković, Ivana Jelić, Marija Janković, Nataša Sarap, Aleksandar Savić, Dragi Antonijević, Marija Šljivić-Ivanović

The removal of radionuclides from liquid radioactive waste (RW) represents an important environmental and technological challenge. In recent years, increasing attention has been focused on the utilization of inexpensive sorbents derived from waste and by-products. In this study, a comparison of the textural properties and sorption efficiency of waste construction and demolition components towards radionuclide ions was performed. Textural characterization of the materials was performed using BET, BJH, and t-plot analyses in order to determine the specific surface area, pore volume, and pore size distribution. The results revealed significant differences in the textural properties of the investigated materials, with specific surface areas of approximately 48 m2/g for waste concrete (WC), 9 m2/g for waste brick (WB), and 1 m2/g for waste asphalt (WA). Correspondingly, WC exhibited the highest sorption capacities, reaching up to ≈0.55 mmol/g for Ni2+ in previous research. The comparison between the textural parameters and the sorption performance of the investigated ions confirmed that sorption behaviour is influenced by a complex interplay of multiple factors. These include the surface chemistry of the sorbent, the speciation of the ions, and the experimental conditions, all of which collectively govern the efficiency of radionuclide sorption.

Keywords: specific surface area, sorption capacity, BET, BJH analysis, t-plot

АКУСТИКА / ACOUSTICS

СЕСИЈА / SESSION (AKI1)

Уторак, 9. јун / Tuesday, June 9th Сала 2 / Hall 2 9.00-11.00

Председавајући / Chair:
Miomir Mijić, Univerzitet u Beogradu - Elektrotehnički fakultet, Beograd, Srbija,
Dejan Ćirić, Univerzitet u Nišu - Elektronski fakultet, Niš, Srbija

AKI1.1 (#4436)
ADVANCING ASSISTIVE SPEECH TECHNOLOGIES FOR INCLUSION WITHOUT LINGUISTIC BARRIERS
INVITED PAPER

Branislav Gerazov

Advancements in assistive speech technologies have revolutionized communication for people with disabilities worldwide, advancing their inclusion in society. Their application for less-resourced languages remains a challenge due to the limited amount of data available for training speech synthesis models. This makes it difficult to ensure adequate representation and inclusion for speakers of these languages. The problem is

more pronounced for children who require age-appropriate text-to-speech (TTS) voices to serve as their personal identity in augmentative and alternative communication (AAC) devices. To bridge this gap, the Speech Group at FEEIT, UKIM is spearheading the development of speech synthesis voices. Key achievements include the creation of "Suze," a free, high-quality TTS voice targeting on-device off-line use, specifically for the Cboard AAC app, but also for screen readers for mobile and PC. Expanding on this success, the team recently developed child voices for Macedonian and other European languages for AAC within the VoiceKids project. Through ongoing research and long-standing partnerships with the assistive technology organizations, we drive regional innovation, ensuring that linguistic barriers do not hinder accessibility or social inclusion in the digital age.

Keywords: speech technologies, assistive technologies, text-to-speech (TTS) systems, screen readers, augmentative and alternative communication (AAC)

AKI1.2 (#1497)
DIRECT LOCALIZATION OF ACOUSTIC IMPULSE SOURCES IN OUTDOOR ENVIRONMENTS: EXPERIMENTAL VALIDATION

Milan Mišković, Nenad Vukmirović, Miljko Eric, Miomir Mijić, Miloš Bjelić

Results of experimental validation of method for direct localization of acoustic impulse sources in outdoor environment, proposed previously by the authors are presented. Based on the ambiguity function formulated for the collocated and distributed antenna arrays, the ambiguity function of the microphone array was formulated as a tool for characterization of the non-uniform geometry of the microphone array in terms of ambiguous grating lobes and side lobe levels.

Keywords: Direct localization, TDOA method, microphone arrays, ambiguity function, association problem

AKI1.3 (#9435)
AUTOREGRESSIVE MODELING OF DRONE NOISE SIGNALS

Vasilije Kovacevic, Jelena Certic, Miloš Bjelić

Drone noise is a growing acoustic issue as unmanned aerial vehicles become more common in urban and suburban areas, prompting methods for analysis, modeling, and synthesis. This paper presents a parametric approach to modeling and synthesizing drone noise signals using autoregressive (AR) techniques. It examines two methods: short-time AR modeling and subband AR modeling through filter-bank decomposition. The short-time method captures temporal changes by adapting parameters for each frame, while the subband method models frequency-specific structures by applying separate AR models to each spectral band. Both approaches produce synthetic signals by exciting the estimated models with white Gaussian noise. The results demonstrate that these techniques effectively replicate the broadband characteristics and overall spectral envelope of drone noise. The subband method more accurately captures frequency-localized details, whereas the short-time method efficiently models temporal variations. Although small smoothing occurs in fine spectral features, both methods closely resemble the original signals. Overall, AR-based modeling offers a computationally efficient and physically meaningful means for drone noise analysis and synthesis, with practical applications in acoustic simulation and signal processing.

Keywords: autoregressive modeling, drone noise, noise synthesis, stochastic signal modeling, spectral analysis, time-frequency analysis

AKI1.4 (#6266)
A CNN-BASED BIMODAL SPEECH RECOGNITION FRAMEWORK WITH MFFCC AND TEMFCC FEATURES

Branko Marković, Jovan Galić

This paper presents the results of bimodal speech recognition (normal and whispered speech) under specific conditions. The front end of the Automatic Speech Recognition (ASR) system is based on both Mel Frequency Cepstral Coefficients (MFCC) and Teager Energy Mel Frequency Cepstral Coefficients (TEMFCC). The back end employs Convolutional Neural Networks (CNNs) for classification. Speech samples are taken from the Whi-Spe database, and Cepstral Mean Subtraction (CMS) is applied as a standard normalization technique. The results are presented through tables and histograms, enabling a comparison of recognition performance between MFCC and TEMFCC features under both matched and mismatched conditions.

Keywords: Speech recognition, Whisper, Convolutional neural networks, Mel scale, Teager energy operator, Cepstral means subtraction

AKI1.5 (#6082)
MEASUREMENT OF SOUND ABSORPTION COEFFICIENT UNDER ANECHOIC CONDITIONS BY TRANSFER FUNCTION METHOD

Dejan Ćirić, Maro Puljizević, Aleksandar Pantić, Marko Janković, Toplica Jakimov

The sound absorption coefficient is a fundamental parameter for characterizing acoustic materials, widely used in building acoustics, noise control engineering, and material design. Its accurate determination, however, remains a challenging task due to the strong dependence on measurement conditions, sound field characteristics, and experimental assumptions. Traditional methods, such as reverberation room and impedance tube techniques, provide standardized but often limited information, particularly with respect to angle-dependent behavior and intrinsic material properties. This paper provides an overview of existing approaches for measuring the sound absorption coefficient, with particular emphasis on free-field and anechoic conditions. Key challenges, including low-frequency limitations, finite sample effects, and sensitivity to measurement geometry, are discussed. A measurement methodology based on a semi-arc configuration is then introduced. The proposed system employs a swept-sine excitation and a transfer function approach using three microphones to estimate the reflection properties of the material. Two realizations of the semi-arc measurement setup are presented, enabling flexible control of incidence angles and improved characterization capabilities. The paper aims to contribute to the ongoing development of reliable and versatile measurement techniques for sound absorption under controlled acoustic conditions.

Keywords: Sound absorption coefficient, Anechoic measurements, Acoustic material characterization

AKI1.6 (#7958)
BEE SOUND ACQUISITION IN A NATURAL ENVIRONMENT

Toplica Jakimov, Dejan Ćirić, Jelena Pejić, Petar Pejić, Mihajlo Milovanović

The preservation of bee populations is essential for maintaining global ecological balance and agricultural productivity. Given that traditional hive monitoring techniques are invasive and labor-intensive, acoustic monitoring has emerged as a superior non-invasive alternative. This paper presents the development and field implementation of an

autonomous system for bee sound acquisition and advanced signal characterization. The hardware architecture is based on a Raspberry Pi 4 platform integrated with high-precision MEMS microphones, specifically designed for continuous operation in natural, outdoor environments. The study details a robust digital signal processing pipeline, including multi-stage filtering, signal stabilization, and the extraction of critical acoustic features such as Zero-Crossing Rate (ZCR), Root Mean Square (RMS) energy, and MelFrequency Cepstral Coefficients (MFCC). By utilizing Melspectrograms and spectral analysis, the system provides a detailed time-frequency representation of the colony's acoustic signatures. The results demonstrate the effectiveness of the proposed acquisition protocol in isolating biological signals from environmental noise, establishing a reliable foundation for longterm acoustic surveillance and biodiversity monitoring in apiculture.

Keywords: Bee sound acquisition, MEMS microphones, Raspberry Pi, Signal processing, Acoustic feature extraction, Melspectrogram,

AKI1.7 (#0430)
DESIGN AND DEVELOPMENT OF A SERBIAN VOICE-CONTROLLED CALCULATOR

Mihailo Marković

This paper presents the design and development of a Serbian voice-controlled calculator. The system is implemented through several stages, including parsing the input sentence to identify operands and operators, speech recognition using neural networks, conversion of recognized speech into numerical values, and synthesis of the final spoken result. The developed models include digits (zero to nine) and the tree basic arithmetic operations (addition, subtraction, multiplication) and one relation (equal) in Serbian. All speech signals are represented as feature vectors composed of 12 Mel-frequency cepstral coefficients (MFCCs). The neural network architecture consists of two layers. Each word is represented by 20 frames. The performance of the system is evaluated in terms of word recognition rate, with results presented in tables and histograms.

Keywords: Voice calculator, Arithmetical operation, Mel scale, cepstral coefficients, speech recognition, Neural networks,

СЕСИЈА / SESSION (AK1)

Уторак, 9. јун / Tuesday, June 9th Сала 2 / Hall 2 14.30-16.30

Председавајући / Chair:
Dragana Šumarac Pavlović, School of Electrical Engineering, University of Belgrade, Serbia
Miloš Bjelić, School of Electrical Engineering, University of Belgrade, Serbia

AK1.1 (#8125)
UTICAJ FANTOMSKIH PARCIJALA NA PERCEPCIJU TONOVA HARFE

Tatjana Miljković, Miloš Bjelić, Jelena Ćertić, Dragana Šumarac Pavlović

Izraženo prisustvo fantomskih parcijala u spektrima tonova harfe otvara pitanje njihovog uticaja na percepciju zvuka. Iako su fizički mehanizmi njihovog nastanka već razmatrani, perceptivna istraživanja do sada su uglavnom bila ograničena na klavir i na ukupni doprinos longitudinalnih komponenti, a ne na izdvojeni uticaj fantomskih parcijala. U ovom radu predstavljen je subjektivni AB test za ispitivanje uticaja fantomskih parcijala

na percepciju tonova harfe. Test signali sintetisani su na osnovu realnih tonova harfe primenom aditivne sinteze, pri čemu su fantomski parcijali uključeni na frekvencijskim pozicijama na kojima se očekuju u realnim signalima. Amplitude fantomskih parcijala određene su na osnovu amplituda odgovarajućih roditeljskih parcijala, a zatim dodatno skalirane radi ispitivanja efekta njihove izraženosti. Predloženi eksperimentalni okvir predstavlja osnovu za buduća istraživanja uticaja fantomskih parcijala na opažaj boje tona, kao i njihovog združenog dejstva sa inharmoničnošću na konsonantnost i disonantnost intervala žičanih muzičkih instrumenata.

Ključne reči: Fantomski parcijali, Percepcija, Harfa, Subjektivni test,

AK1.2 (#3438)
UTICAJ EKVALIZACIJE AMPLITUDSKIH KARAKTERISTIKA ZVUČNIKA NA DIJAGRAM USMERENOSTI ZVUČNIČKOG NIZA

Marija Ratković, Miloš Bjelić

U ovom radu je predložena metoda za ekvalizaciju amplitudskih karakteristika zvučnika u zvučničkom nizu, korišćenjem LMS (Least Mean Square) algoritma za projektovanje ekvalizacionih filtara. Cilj rada je ispitati uticaj ovih promena na prostornu raspodelu zvučne energije zvučničkog niza. Pokazano je da ekvalizacija neznatno utiče na dijagrame usmerenosti, ali da značajno utuče na promenu frekvencijskog odziva reprodukovanog signala. Pored toga, primenom ekvalizacije postiže se povećanje nivoa zvučnog pritiska u opsegu od 5 dB do 20 dB na različitim frekvencijskim opsezima u odnosu na stanje bez ekvalizacije. Ovi rezultati doprinose većoj energetskoj efikasnosti zvučničkog niza i poboljšanju kvaliteta reprodukovanog zvuka. Ovakav vid obrade signala predstavlja predobradu za preciznu implementaciju algoritama za kontrolu usmerenosti ovakvog sistema.

Ključne reči: amplitudska karakteristika, dijagram usmerenosti, ekvalizacija, LMS, zvučnički niz

AK1.3 (#6424)
KOMBINOVANA EKVALIZACIJA HIDROFONA I ZVUČNIKA U ODSUSTVU REFERENTNOG SENZORA

Lara Kašca, Stefan Ćirković, Miloš Bjelić

U ovom radu razmatra se mogućnost ekvalizacije signala dobijenog pomoću niskobudžetnog senzora u uslovima kada ni izvor zvuka tj. zvučnik, ni prijemni hidrofon nisu precizno karakterisani. Ovo predstavlja čestu situaciju u eksperimentalnoj podvodnoj akustici iz čega proističe motivacija rada, da se omogući pouzdana obrada akustičkih signala i u takvim ograničenim uslovima. Eksperimentalni sistem sastoji se od ručno izrađenog podvodnog zvučnika, čije frekvencijske karakteristike nisu unapred poznate i seta niskobudžetnih hidrofona, postavljanih sukcesivno na malom rastojanju od zvučnika u vodi. Primenjen je NLMS adaptivni algoritam filtriranja, pri čemu je, u odsustvu visokokvalitetnog hidrofona, kao referentni signal korišćen direktno pobudni MLS signal emitovan sa zvučnika. Istraživanje je sprovedeno kao preliminarna faza u iščekivanju upotrebe referentnog hidrofona, koji bi omogućio standardni pristup ekvalizaciji, poređenjem odziva dva senzora. Dobijeni rezultati pokazuju stabilnu konvergenciju i konzistentnost procenjenih koeficijenata adaptivnog filtra na više merenja i na svim hidrofonima, čime se demonstrira da je moguće uspešno kompenzovati kombinovani uticaj nepoznatih karakteristika zvučnika i hidrofona, i bez referentnog hidrofona, te se potvrđuje izvodljivost predloženog pristupa.

Ključne reči: podvodna akustika, hidrofoni, ekvalizacija, LMS algoritam

AK1.4 (#2561)
REALIZACIJA PODVODNOG INERCIJALNOG ZVUČNIKA SA RIGIDNIM KUĆIŠTEM I DML ELEKTROAKUSTIČKIM PRETVARAČEM

Stefan Ćirković, Lara Kašca, Miloš Bjelić

Za potrebe hidrofonskih nizova neophodan je podvodni izvor zvuka za umeravanje i kalibraciju hidrofona. U ovom radu predstavljen je razvoj i eksperimentalna evaluacija podvodnog zvučnika zasnovanog na inercijalnom pobuđivanju rigidnog, hermetički zatvorenog kućišta primenom DML (Distributed Mode Loudspeaker) elektroakustičkog pretvarača. Aktuator je mehanički spregnut sa unutrašnjošću kućišta, pri čemu njegovo kretanje dovodi do oscilovanja cele strukture i generisanja dipolnog akustičkog zračenja u vodi. Rezultati merenja na prvom prototipu potvrđuju ispravnost predloženog koncepta i ukazuju na mogućnost njegove primene u sistemima za karakterizaciju i kalibraciju hidrofonskih nizova.

Ključne reči: Podvodna akustika, Podvodni zvučnici, DML aktuator, Hidrofonski nizovi, Inercijalni dipol

AK1.5 (#0439)
NEKA ISKUSTVA MERENJA IZOLACIJE OD ZVUKA UDARA S POBUDOM GUMENOM LOPTOM

Filip Batić, Nikola Jokić, Miomir Mijić

Standard ISO 16283-2 definiše postupak terenskog merenja zvučne izolacije od zvuka udara. U jednom aneksu tog standarda opisana je varijanta mernog postupka u kome se umesto standardnog izvora zvuka udara („tapkalica“) za pobudu koristi precizno definisana gumena lopta koja sa određene visine pada na pod. Prema parametrima iz standarda organizovana je izrada takve lopte i sa njom su isprobana merenja izolacije od zvuka udara. Pokazalo se da rezultati dobijeni na taj način prikazuju neke dimenzije izolacije od udarnog zvuka u zgradama koje uobičajeni postupak merenja „tapkalicom“ ne vidi. Lopta kao izvor zvuka udara omogućava uvid u izolaciju na niskim frekvencijama, gde „tapkalica“ ne stvara adekvatnu pobudu. Na primer, rezultati merenja loptom bolje ukazuju na potencijalno uznemiravanje koje u zgradama višeporodičnog stanovanja može nastati u stanu kada se bosim nogama trči po podu na spratu iznad. U radu su opisani bitni aspekti standardne gumene lopte kao izvor zvuka udara i prikazani su neki rezultati merenja dobijeni s njom u raznim stambenim objektima.

Ključne reči: Zvuk udara, zvučna izolacija, gumena lopta, ISO 16283-2

АНТЕНЕ И ПРОСТИРАЊЕ / ANTENNAS AND PROPAGATION

СЕСИЈА / SESSION (АП1+API1)

Уторак, 9. јун / Tuesday, June 9th Сала 4 / Hall 4 9.00-10.30

Председавајући / Chair:
Miodrag Tasić, Univerzitet u Beogradu - Elektrotehnički fakultet, Beograd, Srbija,
Branko Kolundžija, Univerzitet u Beogradu - Elektrotehnički fakultet, Beograd, Srbija

API1.1 (#0825)
RECENT ADVANCEMENTS IN CONTRAST-ENHANCED MICROWAVE IMAGING FOR MEDICAL DIAGNOSTICS
INVITED PAPER

Lorenzo Crocco, Rosa Scapaticci, Gennaro Bellizzi, Roberta Palmeri, Agostino Gervasio

Microwave imaging is an emerging diagnostic technique that uses electromagnetic fields in the microwave frequency range to extract clinically relevant information, while relying on safe and cost-effective instrumentation. A key challenge is the extraction of useful signals from measurements, due to the intrinsic complexity of wave–matter interactions. To address this limitation and improve the sensitivity and specificity of microwave imaging for diagnosing and monitoring pathological conditions, magnetic nanoparticles have been proposed as contrast agents. These nanocomposites are particularly suitable because they can induce variations in the magnetic properties of otherwise non-magnetic media. In addition, their microwave response can be remotely controlled by applying a low-frequency magnetic field of appropriate strength. To date, two main applications have been explored: early breast cancer detection and bone regeneration monitoring. In the former, nanoparticles are dispersed in water-based solutions and selectively accumulate in tumor tissue. In the latter, nanoparticles are embedded within magnetic scaffolds, serving both as therapeutic mediators and as tools for monitoring tissue regeneration. This work reviews the key aspects of contrast-enhanced microwave imaging, along with the specific requirements of these two applications. Then, the design and implementation of a dual-purpose microwave tomographic system capable of supporting both use cases is presented.

Keywords: Microwave imaging, wave–matter interactions, magnetic nanoparticles, therapeutic mediators, monitoring tissue, regeneration

API1.2 (#2356)
DESIGN OF WELL-MATCHED MAXIMUM-GAIN UDA-YAGI ANTENNA

Nemanja Grbić, Branko Kolundzija

Innovative optimization strategy is applied to design a well-matched maximum-gain Yagi-Uda antenna. Optimal parameters of the antenna, as well as the resulting gain in forward direction are shown for n = 2k directors, where k goes from 0 to 10. Optimization strategy and reason for its development are described.

Yagi-Uda antenna, matched, maximum gain, optimization, multi-minima, antenna dimensions,

API1.3 (#6881)
ESTIMATION OF HEAD TISSUE BOUNDARIES IN MICROWAVE IMAGING

Marija Nikolic Stevanovic, Darko Ninkovic, Anja Kovacevic, Branko Kolundzija

In this paper, we present a framework for estimating the human head geometry using microwave imaging. To evaluate the proposed approach, a realistic NEVA head phantom comprising eight tissue types was considered. The single-step microwave imaging results, obtained using limited prior knowledge of the outer head shape, demonstrate that the brain boundary, outer skull boundary, and skin boundary can be successfully detected using the considered antenna array.

Keywords: inverse scattering, medical imaging, microwave imaging,

API1.4 (#7196)
AN EXTENDED MLP-BASED MODEL FOR S11 PARAMETER PREDICTION OF BIFILAR HELIX ANTENNAS

Nemanja Perić, Nebojša Dončov, Olivera Pronić-Rančić, Zoran Stanković, Ksenija Mladenović

In this paper, an extended neural model based on the Multilayer Perceptron (MLP) architecture is proposed for predicting the S11 parameter of a bifilar helix antenna. This work builds on previous artificial neural network (ANN) models by extending the operating frequency range to 1–2 GHz, thereby covering both GPS and GLONASS navigation bands, and by introducing a more robust multi-parameter approach. The proposed model uses the following input parameters: the radius of the helix, the thickness of the helix wire, the spacing between turns, the number of turns, the coaxial cable characteristic impedance, and the operating frequency. The training and testing datasets were generated through rigorous electromagnetic (EM) simulations. The results demonstrate excellent accuracy and a significant reduction in computational time.

Keywords: bifilar helix antenna, S11 parameter, EM model, neural model, MLP

API1.5 (#7815)
DESIGN AND OPTIMIZAION OF TUNING AND PHASING NETWORKS FOR TRANSMISSION-LINE RF COILS IN MAGNETIC RESONANCE IMAGING

Pavle Popović, Branislav Notaroš, Milan Ilić

We demonstrate an optimization procedure of a typical capacitor-based tuning network for transmission-line RF coils in magnetic resonance imaging (MRI) using real-time tuning performed within a circuit-based solver. Rapid solver response is facilitated by employing closed-form models and the results are verified by a full-wave electromagnetic analysis in a single run. In addition, we propose, design, and manufacture an 8-way lumped-element power-splitting and phasing network for an 8-channel transmission-line coil. The design is validated by measurements on a manufactured prototype.

Keywords: Magnetic resonance imaging (MRI), matching networks, phasing networks, RF coil

API1.6 (#9472)
CIRCULARLY POLARIZED SLOT ANTENNA FOR DOPPLER BIOSENSING RADAR

Luka Lazović

A compact uniplanar circularly polarized slot antenna intended for short-range Doppler biosensing radar applications operating at 2.4 GHz, is presented in this paper. The proposed antenna is based on open-ring slot resonators excited by a microstrip feeding structure. The antenna is implemented on an FR4 substrate and designed to provide compact dimensions, satisfactory impedance matching, low axial ratio, and reduced mutual coupling between adjacent antennas. Simulated results, performed in CST, show that the proposed antenna achieves good impedance matching at the operating frequency, an axial ratio below 1 dB, and a realized gain of approximately 4 dBi. Mutual isolation between closely positioned antennas is analyzed for different antenna configurations and separation distances. The obtained results demonstrate that the proposed antenna structure provides satisfactory isolation performance, making it suitable for compact Doppler biosensing radar systems.

Keywords: Doppler radar, circular polarization, slot antenna, biosensing

AP1.1 (#6905)
REKONSTRUKCIJA HDMI SIGNALA ANALIZOM EMISIJE MAGNETSKOG POLJA

Borko Đaković, Milena Grdović, Nenad Stefanović, Nenad Stojanović, Dragan Olćan

Prikazana je mogućnost rekonstrukcije bitova protokola HDMI signala analizom radijacione emisije magnetskog polja, što otvara mogućnost beskontaktne rekonstrukcije slike monitora računara. U radu je objašnjen HDMI protokol, kao i na koji način se vrši prenos signala. Prikazana je eksperimentalna postavka koja se sastoji od PCB HDMI test pločice za merenje signala, osciloskopa, pasivnih sondi i magnetske sonde. Takođe, prikazani su rezultati merenja, koji se sastoje od vremenskog prikaza protokola HDMI signala na osciloskopu, kao i vremenskog prikaza signala snimljenog sondom bliskog polja. Izvršena je obrada signala sa magnetkse sonde, u cilju detekcije emisije magnetskog polja, određivanjem trenutka tranzicije stanja bitova na liniji i rekonstrukcije HDMI protokola. Na samom kraju izvedeni su zaključci eksperimenta.

Keywords: HDMI, Emisija magnetskog polja, hardverska bezbednost,

AP1.2 (#7518)
ELEKTROMAGNETSKO MODELOVANJE PRELOMA TIBIJALNE KOSTI I PRATEĆEG HEMATOMA

Miodrag Tasic, Branislav Ninković, Dragan Olćan

Pored tradicionalnih metoda za dijagnostikovanje preloma kostiju, u koje spadaju kompjuterska tomografija i magnetska rezonansa, istraživanje odgovarajućih dijagnostičkih metoda primenom mikrotalasnog formiranja slike privlači sve više pažnje poslednjih godina. Ova tehnika zasniva se na merenju refleksije od antena i transmisije između antena postavljenih u okolini organa od interesa. U ovom radu prikazano je elektromagnetsko modelovanje preloma tibijalne kosti (lat. tibia) i pratećeg hematoma. Pokazano je kako pojednostavljivanje detaljnog modela potkolenice utiče na s-parametre antena, postavljenih u vazduhu oko modela, u frekvencijskom opsegu od 0,7 GHz do 1 GHz.

Keywords: prelom tibije, hematom, elektromagnetsko modelovanje, refleksija, transmisija, Metoda momenata,

БИОМЕДИЦИНСКА ТЕХНИКА / BIOMEDICAL ENGINEERING

СЕСИЈА / SESSION (БТ1 + BTI1)

Уторак, 9. јун / Tuesday, June 9th Сала 5 / Hall 5 14.30-16.30

Председавајући / Chair:
Milica Janković, Univerzitet u Beogradu - Elektrotehnički fakultet, Beograd, Srbija

BTI1.1 (#1020)
MULTIMODAL SENSING FOR AI-ASSISTED DIAGNOSIS OF HEART FAILURE
INVITED LECTURE

Mirjana Stojanović, Aleksandar Lazović, Maša Tiosavljević, Predrag Tadić, Vladimir Atanasoski, Marija Ivanović, Aleksandra Maluckov, Ljupčo Hadžievski, Arsen Ristić, Vladan Vukčević, Jovana Petrović

Heart failure (HF) is a complex clinical syndrome characterized by the inability of the heart to maintain adequate circulation to meet metabolic demands. Despite advances in therapy, HF remains associated with high morbidity, mortality, and healthcare costs, largely due to delayed diagnosis and limited accessibility of definitive imaging methods. Early identification, particularly in primary care settings, remains a major unmet clinical need. To address this challenge, we revisited the concept of polycardiography using modern sensing technologies. Polycardiography enables synchronous acquisition of electrical and mechanical cardiovascular activity, providing access to electromechanical coupling parameters. We developed a prototype multimodal system capable of simultaneous recording of electrocardiogram (ECG), phonocardiogram (PCG), seismocardiogram (SCG), and photoplethysmogram (PPG) signals. From these signals, established HF-related biomarkers can be extracted, including systolic time intervals (STIs) such as left ventricular ejection time (LVET) and pre-ejection period (PEP). Prior to clinical deployment, the SensSmartTech validation study was conducted on healthy volunteers to verify device performance and characterize the dependence of key cardiovascular features on heart rate. This effort resulted in the SensSmartTech database, publicly available via PhysioNet, comprising multimodal cardiovascular recordings across a wide heart rate range. The database provides insight into physiological variability and supports algorithm development and benchmarking.The central focus of this work is the SensSmart clinical study, conducted at the University Clinical Centre of Serbia. The study has been completed and comprehensive data analysis is underway. Its primary objective is to evaluate the non-inferiority of HF detection based on multimodal polycardiography relative to echocardiography. Preliminary results obtained using AI-based classification demonstrate promising performance in discriminating HF patients from controls, while also indicating the complementary diagnostic value of combining multiple sensing modalities. At the conference, we will present interim outcomes of the clinical analysis, including classification performance and an assessment of the relative contribution of individual multimodal features to HF detection.

Keywords: Heart failure, Polycardiography, Multimodal biosignal analysis

BTI1.2 (#3688)
IMPACT OF WAVELET SELECTION ON DEEP-LEARNING-BASED ECG DENOISING

Vladimir Atanasoski, Jovana Petrović, Goran Gligorić

Electrocardiographic (ECG) signals are often corrupted by noise such as baseline wander, electromyographic noise, and power-line interference, which can degrade clinical interpretation. Therefore, effective filtering methods are essential to extract clinically relevant information from noise-contaminated signals, and wavelet-based methods are among the most commonly used approaches for denoising. However, the denoising performance of traditional threshold-based wavelet methods heavily depends on the choice of the mother wavelet. In this study, we compare several common wavelet types (db3–db5, sym4–sym5, coif3, Haar, bior1.5 and rbio2.4) used within a deep learning framework based on autoencoder. The wavelet denoising performance is evaluated under different noise conditions using the SNR improvement and Person coefficient as metrics. The comparison across different wavelet types shows that all evaluated wavelets achieve similar performance, with differences within 5% for both metrics. This indicates that the variation between wavelet types is relatively small and not statistically significant. These results suggest that learning the denoising function directly from data using deep learning can reduce the dependence on the specific choice of wavelet.

Keywords: ECG denoising, Stationary Wavelet Transform, Autoencoder

BTI1.3 (#8854)
AUTOMATED DETECTION OF EPILEPTIC SEIZURES FROM EEG: FROM MODEL PREDICTIONS TO REAL-WORLD APPLICATIONS

Aneta Kartali, Octavian Mihai Machidon, Alina Luminita Machidon, Veljko Pejović

Reliable automated seizure detection from EEG recordings is essential for continuous, out-of-clinic monitoring and patient care. Despite the availability of standardized guidelines for evaluation, many developed approaches do not follow the recommended practices, making direct comparison difficult. Reproducibility presents another major concern due to the lack of complete documentation of preprocessing and training pipelines. Furthermore, subject-independent models frequently exhibit significant performance drops when applied to unseen subjects, implying the lack of robustness and generalizability in existing approaches. All these shortcomings hinder the development of seizure detection systems suitable for real-world applications. In this work, we analyze reported results and evaluate multiple seizure detection techniques under standardized, subject-independent settings. We introduce a subject-independent lightweight temporal convolutional model trained on continuous multichannel EEG recordings from the CHB-MIT dataset. The proposed approach yields 78.00% sensitivity and a false alarm rate of 1.59 per hour for subject-wise 10-fold cross-validation analysis. Our results further emphasize the impact of evaluation methodology on reported performance as well as the need for transparent reporting to support reproducibility and the development of reliable seizure detection systems for real-world deployment.

Keywords: seizure detection, electroencephalogram (EEG), deep learning, temporal convolution

BTI1.4 (#9027)

A PROTOCOL FOR EDA SIGNAL STABILIZATION AND VALIDATION USING DRY TEXTILE ELECTRODES ON THE UPPER ARM

Tanja Vuković, Jovana Malešević, Matija Štrbac

Electrodermal activity (EDA) is widely used for assessing autonomic nervous system activity and stress. However, when using dry textile electrodes, signal stabilization remains a critical challenge, particularly in wearable applications. This work investigates the stabilization dynamics of EDA signals acquired from the upper arm using dry electrodes and proposes a practical protocol for determining signal validity. Three pilot studies were conducted to analyze stabilization time, define validation criteria, and develop a decision logic for determining signal readiness. The results show that stabilization time varies across subjects and conditions, with an average of 26.1 ± 15.2 minutes. Phasic responses were observed even before tonic stabilization, suggesting their potential role in early signal validation; however, reliable signal validation requires the combined evaluation of both components. Based on these findings, a 5.5-minute validation protocol was defined and successfully tested on nine subjects. The proposed approach provides a practical framework for ensuring reliable EDA acquisition in wearable systems.

Keywords: EDA, dry electrode, stabilization time, upper arm,

BTI1.5 (#8447)

MULTIMODAL BIOMARKER ANALYSIS OF READING DIFFICULTIES: EYE-TRACKING, HRV, AND EDA STRESS DYNAMICS

Tamara Papić, Katarina Stekić, Ivan Vajs, Marija Novičić, Vanja Ković, Milica M. Jankovic

This study investigates stress dynamics during reading in children with reading difficulties using a multimodal approach combining eye-tracking (ET), ultra-short-term pulse rate variability (PRV), and electrodermal activity (EDA). The goal is to evaluate differences in ET, PRV, and EDA profiles between struggling and control readers, while also exploring the potential modulating effects of gender. Forty-eight elementary school students of the second grade (24 struggling readers, 24 control readers, gender-balanced) read two stories. Story 1 was divided into 13 consecutive slides, and Story 2 was on one slide, while physiological and oculomotor activity was recorded. Linear mixed-effects models (Story 1) and standard linear models (Story 2) with false discovery rate (FDR) corrections showed that the three eye-tracking features (mean fixation duration, fixation frequency, and saccade frequency) were significantly different between groups with different reading skills. EDA metrics indicated a group effect for the number of EDA peaks; the struggling readers exhibited a higher peak frequency than the control group. Boys showed higher tonic variability and larger mean EDA peak amplitudes than girls in Story 1, while the Interquartile Range (IQR) of saccade duration and Multifractal Detrended Fluctuation Analysis (MFDFA) derived short-term scaling increment were also higher in boys. No significant Group × Gender interaction effects were observed across any domain or story. The results suggest that struggling readers demonstrate dysregulated visual attention deployment and heightened sympathetic autonomic arousal during reading, with ET and EDA features being the most sensitive biomarkers.

Keywords: reading difficulties, mixed-effects models, eye tracking, heart rate variability, electrodermal activity

BTI1.6 (#4347)

EVALUATION OF TIME DOMAIN FEATURE COMBINATIONS FOR LDA AND KNN IN EMG-BASED HAND MOVEMENT CLASSIFICATION

Andrea Vaštag, Nikola Jorgovanović, Filip Gašparić, Strahinja Došen, Milovan Medojević

Myoelectric control is a widely used approach in modern prosthetic hands, where movements are driven by electromyographic (EMG) signals. However, achieving reliable control remains a challenge due to the inconsistency between device capabilities and control quality. This study evaluated various time domain feature sets with Linear Discriminant Analysis (LDA) and k-Nearest Neighbors (KNN) classification algorithms for pattern recognition. Datasets included EMG recordings from three participants performing four wrist motions. Results show that Waveform length is the most discriminative individual feature (F1-score up to 0.99), while Slope Sign Changes shows high variability (accuracy 58.28–98.15%). With two combined features, KNN had 87.36–99.54% accuracy compared to LDA's 86.25–96.89%. Using all features, accuracies reached up to 98.75% for LDA and 99.09% for KNN. It is also demonstrated that using only two features leads to satisfactory performance. However, performance strongly relies on individual anatomical characteristics, indicating the need for user-specific calibration.

Keywords: Electromyography, feature extraction, K-Nearest Neighbors, Linear Discriminant Analysis, myoelectric prosthesis control, pattern recognition

BTI1.7 (#4247)

ANALYSIS OF STANDING LONG JUMP STABILITY VIA GRADCAM AND 1D CONVOLUTIONAL NEURAL NETWORKS

Selena Bogojevic, Ivan Vajs, Jelena Ćertić, Olivera Knežević, Vladislava Krsmanović

The standing long jump (SLJ) is a complex task requiring explosive power and relying on effective force absorption through the kinematic chain during landing. Movement of the lower extremities in SLJ can be described in terms of the rotational positions of segments and joints. This study aims to investigate how information provided by joint and segment sagittal plane angles relate to jump stability. Twenty participants (aged: 18-30) performed multiple SLJ, which were recorded using inertial measurement units (IMU) affixed to the participants' lower extremities, arms, and trunk. The angle signals derived from IMU data were utilized to classify SLJ stability with a 1D convolutional neural network (1DCNN). Leave-one-subject-out cross-validation showed that segment signals achieved 87.5% accuracy and an F1 score of 86.4%, outperforming joint-based model which achieved only 77.67% accuracy with 76.17% F1 score. Grad-CAM analysis was used do determine relevant SLJ sections, and highlighted the landing phase as most important for stability. The study concludes that sagittal-plane angles, especially during landing, provide valuable information for SLJ stability detection.

Keywords: standing long jump, CNN, Grad-CAM, stability, inertial measurement unit, joint kinematics, segment kinematics

BT1.1 (#2449)
PRISTUPI AUTOMATSKOM PREPOZNAVANJU EMOCIJA NA OSNOVU POKRETA TELA

Sonja Dimitrijević, Đorđe Urukalo, Jelena Ilić, Marija Radmilović, Miloš Jevtić, Vanja Nenadović, Nikola Zogović

Automatsko prepoznavanje emocija na osnovu pokreta tela ima potencijal da unapredi interakciju čovek–računar i čovek–robot, uz širok spektar primena. Ipak, istraživanja u ovoj oblasti i dalje su u relativno ranim fazama. Ovaj rad predstavlja preliminarni sistematski pregled automatskog prepoznavanja emocija na osnovu pokreta tela. Analizirani su modaliteti i metode prikupljanja podataka, obuhvaćena emocionalna stanja, primenjene tehnike prepoznavanja, ostvareni učinak, kao i kontekst i karakteristike učesnika studija. Rezultati pokazuju da se većina istraživanja zasniva na upotrebi skupih sistema za snimanje pokreta i analizi različitih tipova pokreta, uključujući gestove, hod i plesne sekvence. Studije su obuhvatile prepoznavanje do osam emocionalnih stanja, primenom metoda mašinskog i dubokog učenja. Većina radova upoređivala je više pristupa radi identifikacije metoda sa najboljim performansama, pri čemu su pojedine studije ostvarile tačnost veću od 95%. Skupovi podataka uključivali su od 2 do 59 učesnika različitih profila. Iako postoje brojni izazovi, dalji razvoj oblasti zavisiće pre svega od unapređenja tehnologija za prikupljanje podataka, tehnika prepoznavanja i njihove validacije u realnim uslovima.

Keywords: automatsko prepoznavanje emocija, mašinsko učenje, duboko učenje, interakcija čovek-računar, interakcija čovek-robot

СЕСИЈА / SESSION (BTI2)

Среда, 10. јун / Wednesday, June 10th Сала 5 / Hall 5 9.00-11.15

Председавајући / Chair:
Jovana Petrović, Univerzitet u Beogradu – Institut za nuklearne nauke „Vinča“, Beograd, Srbija

BTI2.1 (#0581)
ADVERSARIAL ROBUSTNESS OF DEEP LEARNING MODELS FOR CHEST X-RAY PNEUMONIA CLASSIFICATION

Anđela Blagojević, Milan Čabarkapa, Tijana Geroski, Lazar Dašić, Ognjen Pavić, Nenad Filipović

Deep learning models have shown strong performance in chest X-ray pneumonia classification, but their robustness to adversarial perturbations remains a major concern for clinical deployment. In this paper, we investigate the adversarial robustness of a Convnet model for chest X-ray pneumonia classification under multiple attack settings and evaluate the effectiveness of adversarial training as a defense mechanism. The model was trained on a chest X-ray dataset and evaluated on both an internal test set and an external RSNA dataset to assess cross-dataset generalization. We considered several adversarial attacks across multiple perturbation strengths. In addition, feature squeezing was analyzed as a lightweight defense strategy. On the internal test set, the standard model achieved an accuracy of 0.8686 and recall for the pneumonia class of 0.997, but its performance dropped sharply under adversarial perturbations, reaching near-zero accuracy for stronger iterative attacks. In contrast, the adversarially trained model preserved strong clean performance, achieving an accuracy of 0.8958, while improving

robustness across all evaluated attacks. For example, under PGD with perturbation budget 0.003922, the standard model achieved only 0.0385 accuracy, but the adversarially trained model achieved accuracy of 0.8285. These results indicate that adversarial training provides a substantial robustness without sacrificing baseline predictive performance. Overall, our findings highlight the importance of robustness-aware evaluation in medical imaging and support adversarial training as a practical strategy for improving the reliability of chest X-ray classification systems.

Keywords: deep learning, chest X-ray pneumonia classification, adversarial attacks, adversarial training

BTI2.2 (#3782)
AUTOMATED SEGMENTATION OF TOOTH-DENTAL FILLING INTERFACES IN SEM IMAGES USING DEEP LEARNING

Nikola Brenesel Brenesel, Lazar Milić, Igor Putnik, Vukašin Košutić, Tamara Perić, Goran M. Stojanović

Analyzing the interface between tooth tissue and restorative materials in scanning electron microscopy (SEM) images is important and innovative approach for evaluating the quality of dental restorations. However, this is typically done only descriptively, which is inconsistent between different examiners. This paper presents an automated pipeline for segmenting the filling region in annotated SEM micrographs of teeth restored with glass-ionomer cement. The pipeline uses color markers placed along the filling boundary before imaging. Since SEM images are grayscale, these markers are the only colored elements present. The saturation channel in HSV color space is extracted and binarized using Otsu's thresholding to detect the boundary line. The filling region is then removed using directional edge scanning and binary masking. The resulting masks are used for training a deep learning model based on the U-Net architecture with a ResNet50 encoder. The model was trained and evaluated using 5-fold cross-validation on a dataset of 36 images, achieving an average Dice coefficient of 0.87 and an intersection over union (IoU) score of 0.79. The trained model was then tested on 25 previously unseen images and evaluated by a dental specialist. The results show that automated segmentation of filling regions in SEM images is sufficient and could be employed in the reduction of time spent for manual analysis.

Keywords: scanning electron microscopy, convolutional neural network, U-Net, dental restoration, automated segmentation

BTI2.3 (#9178)
A MULTI-HEAD HEATMAP ARCHITECTURE FOR FULL-MOUTH 3D DENTAL LANDMARK DETECTION

Marko Lazarevski, Ali Shadman, Giuseppe Baselli

Accurate 3D dental landmark detection is a foundational step in automated orthodontic planning, aligner design, and occlusal analysis. We present a comparison of three lightweight point-cloud encoders, hierarchical PointNet, PointNeXt, and PointViG, equipped with a unified multi-head architecture for joint full-mouth tooth presence prediction, fixed-count landmark localization, and variable-count cusp tip detection. Both arches are merged into a single full-mouth point cloud that preserves interarch geometry. The landmark head uses learned cross-attention queries indexed by tooth slot and landmark category, decoded via a differentiable soft-argmax. Variable-count cusp tips are handled by a dedicated heatmap channel decoded by k-means clustering, where the number of clusters is provided by an auxiliary count regression head. Evaluated under

5-fold cross-validation on the 3DTeethLand benchmark, PointViG achieves a mean radial error of 1.78 mm and both mean average precision and mean average recall of 0.548, reaching competitive leaderboard performance without ensembling or per-tooth spatial conditioning. Among the three backbones, PointViG's dynamic graph convolution in feature space proves decisive: its ability to aggregate information from semantically related but spatially distant points yields consistent gains across all landmark categories, particularly on geometrically complex posterior teeth.

Keywords: Dental Landmark Detection, Point Cloud Processing, Multi-Task Learning, PointViG, Heatmap Regression, Full-Mouth Detection, Cusp Detection

BTI2.4 (#2396)
A COMPARATIVE STUDY OF SIMPLE RNN AND LSTM ARCHITECTURES FOR DATA-DRIVEN MODELING OF NONLINEAR SYSTEMS IN BIOMEDICAL ENGINEERING

Bojan Jorgovanović, Ksenija Baraković, Anja Vranješević, Olivera Tomašević, Vojin Ilić, Slobodan Tabaković

This work presents a comparative evaluation of simple recurrent neural networks (RNNs) and Long Short-Term Memory (LSTM) networks for data-driven modeling of dynamic nonlinear systems in biomedical engineering. The benchmark system used in this work is a two-compartment pharmacokinetic system with Michaelis-Menten elimination. Both architectures are trained using an identical data set and training procedure and are evaluated on an unseen test set to ensure a fair comparison. Model performance is assessed using multiple error-based metrics and the coefficient of determination to evaluate both prediction accuracy and dynamic fidelity, alongside a detailed analysis of computational performance. The results indicate that the LSTM outperforms the RNN in terms of predictive accuracy. In contrast, the RNN consistently achieves lower inference times and reduced execution-time variability. These findings highlight a clear trade-off between modeling accuracy and computational cost.

Keywords: Recurrent neural networks, Long short-term memory, Nonlinear system identification, Data-driven modeling, Pharmacokinetics, Model comparison

BTI2.5 (#8123)
HEALTHOCR-RAG: A MODULAR, PRIVACY-FIRST FRAMEWORK FOR THE AUTOMATED SIMPLIFICATION OF SCANNED INTERNAL MEDICINE REPORTS

Aleksandar Joksimović, Miloš Jolović, Petar Lukovac, Milica Simić, Marijana Despotović-Zrakić

The interpretation of complex internal medicine reports remains a significant challenge for patients, frequently leading to 'semantic reversals' and diminished treatment adherence. The primary objective of this research is to bridge the communication gap between technical clinical documentation and patient health literacy through an automated simplification pipeline. HealthOCR-RAG was developed as a modular framework that integrates Optical Character Recognition (OCR) for digitizing physical reports with a privacy-first processing layer for mandatory anonymization. The system utilizes Retrieval-Augmented Generation (RAG) to ground large language model (LLM) explanations in verified medical knowledge bases. The implementation suggests that combining temporary in-memory processing with schema-controlled generation can reduce the risks of unsupported medical content and unnecessary privacy exposure. The principal contribution of this work is a safety-aware architecture that transforms noisy

scanned documents into structured, patient-centric explanations without providing diagnostic advice.

Keywords: Optical Character Recognition. Retrieval-Augmented Generation. data privacy. patient health literacy

BTI2.6 (#8156)

MULTI-DOMAIN APPROACH TO FEATURE SELECTION FOR FNIRS-BASED STROOP TASK RECOGNITION

Tamara Parojčić, Milica Janković, Sanja Vujnović, Marija Novičić

This paper presents a multi-domain feature selection framework for functional Near Infrared Spectroscopy (fNIRS) signals to identify the most informative features for distinguishing neutral and incongruent states during the Stroop task. A total of 280 features were extracted from both oxygenated hemoglobin (HbO) and deoxygenated hemoglobin (HbR) signals. The extracted features were extracted from three domains: time, frequency, and wavelet. Feature selection was done by using the Fisher score method. Results indicate that mean amplitude (time domain) and wavelet coefficients are the most informative features. The most relevant channels for classification were in frontal and frontal-central region. Selected features and channels have potential for application in distinguishing cognitive states using fNIRS.

Keywords: fNIRS, Stroop task, Fisher score, time domain, frequency domain, wavelet domain, feature selection

BTI2.7 (#9207)

A NEW DIAGNOSTIC METHOD FOR THE DETECTION OF HUMAN KIDNEY CANCER BASED ON OPTOMAGNETIC LIGHT-MATTER INTERACTION

Aleksandra Dinić, Lidija Matija, Gorana Nikolić, Branislava Jeftić, Ivana Stanković, Đuro Koruga

Over the past decades, the global incidence of renal cell carcinoma (RCC) has been steadily increasing, while early detection remains challenging due to the asymptomatic nature of the disease and limitations of current diagnostic methods. Standard imaging techniques are often insufficient for accurate tissue characterization at the cellular level, and definitive diagnosis typically relies on invasive biopsy procedures. This study proposes a novel, non-destructive diagnostic approach based on opto-magnetic imaging spectroscopy (OMIS) combined with machine learning (ML) algorithms for the classification of human kidney tissue. Unlike the conventional OMIS setup that uses white light, this work introduces ultraviolet (UV) illumination to enhance sensitivity to superficial tissue structures and endogenous fluorophores. A total of 40 ex vivo human kidney tissue samples (20 healthy and 20 cancerous) were analyzed. Characteristic OMIS spectra were extracted and used as input features for multiple ML models, including K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Random Forest (RF), and Naive Bayes (NB) classifiers. Model performance was evaluated using stratified k-fold cross-validation and standard metrics. The best performance was achieved using the SVM classifier, with an accuracy of 80% and a Cohen's kappa of 0.60. Although this performance does not yet meet clinical standards, the results demonstrate the feasibility of distinguishing between healthy and cancerous kidney tissue. The findings suggest that UV-enhanced OMIS combined with machine learning represents a promising step toward an objective diagnostic tool for kidney cancer.

Keywords: Kidney cancer, Renal Cell Carcinoma (RCC), Opto-magnetic Imaging Spectroscopy (OMIS), Machine learning (ML)

BTI2.8 (#8240)
REFRACTIVE INDEX MEASUREMENT OF BIOMEDICAL FLUIDS AND NOVEL PHOTOPOLYMERS USING LOW-COHERENCE INTERFEROMETRY

Blanka Kuzmanović, Magdalena Atanasovska, Ana Joža, Nastasija Malivuk, Jovan Bajić

In this paper, a low-coherence interferometric method for non-contact refractive index measurement is experimentally investigated with emphasis on biomedical samples. The experimental setup is based on a fiber-optic configuration, where the optical path difference (OPD) is obtained from the recorded interference spectrum using Fast Fourier Transform (FFT). The method was first tested on several representative biomedical liquids, including buffer solutions, artificial sweat, artificial saliva, phosphate-buffered saline (PBS), and sodium chloride solutions, to assess the measurement procedure and performance. The method was then applied to characterize stereolithography (SLA) photopolymers (NextDent Ortho IBT and Ortho Flex), which are relevant for biomedical and microfluidic applications but lack refractive index data in the near-infrared range. The results demonstrate the potential application of the proposed method for optical characterization of biomedical fluids and novel photopolymers, while also indicating limitations related to sample geometry and measurement uncertainty.

Keywords: low-coherence interferometry, fiber-optic sensor, refractive index measurement, biomedical fluids, SLA photopolymers

BTI2.9 (#8566)
TOWARDS ROBUST OPEN MICROFLUIDICS: A THREE-DIMENSIONAL MICROFLUIDIC DEPLOYMENT SYSTEM

Igor Putnik, Lazar Milić, Dejan Movrin, Filip Mrkić, Sanja Kojić, Goran M. Stojanović

This work presents a novel 3D-printed stabilization platform designed to enhance the reliability and repeatability of open microfluidic systems. The platform introduces mechanical confinement and controlled sealing through an adjustable enclosure, enabling improved control of fluid media while preserving the accessibility and ease of fabrication of open systems. A cross-junction droplet generator fabricated via SLA 3D printing in combination with the fabricated enclosure was used as a proof-of-concept to evaluate system performance. Experimental results demonstrate stable droplet generation across a range of flow values, with droplet size increasing from approximately 100 μm to 450 μm and generation frequency rising from 1.72 Hz to 17.73 Hz with the increase in flow rate. Additionally, a hysteresis effect in droplet formation was observed, most likely due to residual fluid remaining within the channels. Despite these effects, the system achieved repeatable operation and consistent droplet generation under controlled conditions. The proposed system effectively bridges the gap between open and closed microfluidics by introducing structural stabilization without compromising on modularity, ease and cost of fabrication, offering a practical pathway toward more reliable open microfluidic platforms for biomedical applications.

Keywords: microfluidics, droplet generation, 3D printing, microfluidic system, open microfluidics

ЕЛЕКТРОЕНЕРГЕТИКА / POWER ENGINEERING

СЕСИЈА / SESSION (EEI1)

Понедељак, 8. јун / Monday, June 8th Сала 1 / Hall 1 9.00-11.00

Председавајући / Chair:
Marko Rosić, University of Kragujevac - Faculty of Technical Sciences, Čačak, Serbia
Mladen Banjanin, University of East Sarajevo - Faculty of Electrical Engineering, BiH

EEI1.1 (#9966)
A NONLINEAR PROGRAMMING APPROACH FOR DECOUPLED HARMONIC LOAD FLOW IN FUTURE MICROGRIDS

Stevan Rakočević, Dražen Jovanović, Martin Ćalasan, Mihailo Micev, Amer Smajkić, Nikola Krstić

The design of secure and reliable microgrids (MGs) increasingly relies on the extensive deployment of power electronic converter–based technologies. As these converters introduce harmonic distortion, accurate harmonic assessment is essential to ensure compliance with power-quality standards in future MGs. This paper advances previous work by extending a nonlinear programming (NLP)–based decoupled harmonic load flow (DHLF) method for accurate harmonic analysis in MG environments. The proposed approach eliminates the need for explicit inversion of harmonic admittance matrices while maintaining high computational accuracy. Its performance is evaluated on the Enhanced IEEE 33-bus test system under varying nonlinear loads and time-dependent DER outputs. Comparative analysis with the DHLF implementation in DIgSILENT demonstrates strong accuracy and improved numerical efficiency.

Keywords: decoupled harmonic load flow, microgrids, nonlinear programming, power converters

EEI1.2 (#2268)
EVALUATION OF THE MODIFIED COVARIANCE METHOD PERFORMANCE WITH CLEANING CHARACTERISTIC HARMONIC DIGITAL FILTER IN PROTECTION RELAY

Natheer Alwan, Veljko Papic

Under harsh transient situations, contemporary protection relays necessitate the accurate and swift estimation of phasors. The prior CCHDF filter was limited by DFT techniques and utilized the Biunivocal Frequency Relationship of Phasors (BFRP). The Modified Covariance Method (MCM) is a sophisticated autoregressive spectral estimator offered as a substitute for spectral estimation in this study. This method improves the estimation of frequency, magnitude, and phase in challenging conditions. The initial algorithm's structure is preserved by the resulting MC-CCHDF (Modified Covariance CCHDF) filter, which provides enhanced accuracy and a faster convergence rate with harmonics and noise that are closely spaced.

Keywords: Cleaned Characteristic Harmonic Digital Filter, Modified Covariance, Modified Covariance CCHDF

EEI1.3 (#8413)
GROUNDING OF A 110 KV OVERHEAD–CABLE LINE TRANSITION TOWER LOCATED IN AN URBAN AREA

Mladen Banjanin, Miloš Milovanović, Bojan Perović

This paper presents the design of the grounding system for a transition tower connecting two overhead transmission lines (OHLs) and two underground cable lines (UCLs). The tower is in an urban area, and space constraints significantly constrain the layout of the grounding system. At the same time, the strict safety requirements must be satisfied. Ground potential rise (GPR), as well as touch and step voltages, are calculated, and their surface distributions around the tower are analyzed. Calculations are performed using the single-phase short-circuit current reduction factor for OHLs and UCLs. The grounding system of the transition tower is dimensioned in accordance with IEEE Std. 80 to ensure compliance with the prescribed safety criteria.

Keywords: cable line, grounding system, overhead line, transition tower, urban area

EEI1.4 (#5700)
INFLUENCE OF GAMMA AND NEUTRON RADIATION AND LIGHT SPECTRUM ON THE DEGRADATION OF SOLAR CELLS

Alija Jusić, Adnan Mujezinović, Uroš Kovačević, Aleksandra Vasić-Milovanović, Ajdin Alihodzic, Irfan Turković

Silicon solar cells are subject to degradation over time due to imperfections formed in the crystal structure by high-energy photon interactions. These imperfections lead to macroscopic aging effects such as reduced efficiency, open-circuit voltage, and short-circuit current. Since real-time aging tests are impractical due to time and cost constraints, as well as rapid technological advancements, this paper proposes an accelerated aging method based on artificial degradation using high-energy electromagnetic (gamma) and particle (neutron) radiation. Key cell parameters, including series resistance, open-circuit voltage, short-circuit current, and efficiency, were monitored and compared to known real-time aging data. To analyze performance degradation over the time, pairs time - current density at the maximum power point, are formed based on the data collected through experiments. The results enabled the definition of conditions for correlating accelerated tests with actual long-term aging, offering a valuable tool for reliability assessment and design optimization of photovoltaic technologies.

Keywords: Accelerated aging test, Gamma radiation, Light spectrum, Neutron radiation, Solar cell, Weibull distribution.

EEI1.5 (#3797)
IMPACT OF ELECTRIC VEHICLE CHARGING STATIONS ON POWER QUALITY IN MEDIUM AND LOW VOLTAGE NETWORK

Adin Memić, Merima Kopčić, Haris Čapelj, Nedis Dautbašić, Maja Muftić Dedović

The increasing penetration of electric vehicles (EVs) poses new challenges for distribution and low voltage networks, particularly regarding power quality. This paper presents a comprehensive analysis of the impact of EV charging on distribution and low voltage system performance, focusing on a 50 kW DC fast charger. Real-world measurements were conducted, and a detailed simulation model of the charger was developed in Simulink to evaluate the effects of EV charging on voltage stability,

harmonic distortion, and overall power quality in low- and medium-voltage networks. The research within this paper was conducted for the purpose of future development of optimization models for the analyzed field. This paper highlights the significant influence of power electronic converters used in EV chargers and emphasizes the need for strategic planning and mitigation techniques to ensure reliable and high-quality power supply during large-scale EV integration.

Keywords: Power Quality, Medium Voltage, Low Voltage, Electric Vehicle Charging, Harmonics, Flicker, Optimisation

EEI1.6 (#8472)

A MODULAR-HYBRID SYSTEM FOR POWER MANAGEMENT AND AUTONOMOUS POWER OPTIMIZATION IN SMART AGRICULTURE

Vladimir Pejanović, Boris Dumnić, Marjan Urekar, Selena Samardžić Cvijanović

The paper presents a design of a modular device for power control of smart agricultural systems, with special attention to the issue of power stabilization for agricultural devices (sprayers, pumps and sensors). The designed modular hybrid device is intended for power management in smart agriculture systems. The key problems that the paper solves are unstable power supply due to poor access to the electric grid in rural areas; Volatilities in power provided by solar panels due to meteorological factors; Potential implementation of a hybrid power supply that combines electric grid and solar energy power sources with optimization and better energy efficiency. The system serves not only for power supply, but also for smart management of fertilization and irrigation, which potentially achieves energy autonomy and increases the efficiency of agricultural production. The paper complements existing contemporary literature by focusing on infrastructural specifics and offers a practical engineering response to the challenges of smart agriculture in the area of power and digitalization.

Keywords: Hybrid power supply, Quasi-MPPT, Smart agriculture, ESP32, Fertilization, Irrigation, Robust electronics, Cost efficiency

EEI1.7 (#7802)

CONTROL OF THE FLYING CAPACITOR MULTILEVEL CONVERTER FOR ACTIVE POWER DECOUPLING IN SINGLE-PHASE PV SYSTEMS UNDER VARYING SHADING CONDITIONS

Todor Aleksandrović, Luka Božić, Aleksandar Milić

This paper presents an active power decoupling (APD) method for single-phase photovoltaic (PV) transformerless converters utilizing a front-end multilevel flying capacitor (FCML) converter. While conventional APD techniques often rely on less efficient auxiliary circuits, the implemented multilevel topology inherently improves overall system efficiency. The multivariable control strategy is systematically designed by first deriving a dynamic Thevenin equivalent model of the PV panel at the Maximum Power Point (MPP) across varying solar irradiances to define parameters across the operating range. The control plant model is then established via Small-Signal Analysis, alongside a dynamic flying capacitor voltage reference, derived from energy balance equations. A limitation of conventional approaches is addressed where standard PI controllers fail to maintain wide range stability and ensure error-free tracking of sinusoidal voltage references. Consequently, an upgraded control scheme is introduced using a proportional-resonant (PR) controller for the voltage loop and employing a lead compensator for the current loop, complete with a dedicated parameter tuning methodology. The output stage inverter control is also outlined to ensure stable grid

connection and robust common DC link disturbance handling. Simulations in MATLAB/Simulink validate the proposed algorithm's stability and dynamic response throughout the defined PV operating range. Finally, an analytical figure of merit demonstrates that the proposed control implementation achieves a reduction in passive component volume compared to conventional strategies without APD.

Keywords: Flying Capacitor Multilevel Converter, Active Power Decoupling, Thevenin equivalent model, PI controller, Lead compensator, PR controller

СЕСИЈА / SESSION (EE1 + EEI2)

Понедељак, 8. јун / Monday, June 8th Сала 1 / Hall 1 11.15-14.00

Председавајући / Chair:
Slobodan Vukosavić, University of Belgrade – School of Electrical Engineering, Belgrade, Srbija
Marko Rosić, University of Kragujevac - Faculty of Technical Sciences, Čačak, Serbia

EEI2.1 (#1098)
ANALYTICAL AND NUMERICAL BASED EVALUATION OF POWER LOSSES IN LOW-VOLTAGE GAN TRANSISTORS

Miroslav Popović, Aleksandar Milić, Željko Despotović

Gallium-Nitride (GaN) transistors are increasingly used in the design of low voltage high power density power converters. To use this technology to its full potential it is necessary to understand and minimize power losses. In this paper, two models for estimating power losses in GaN transistors are analysed and compared against circuit-level simulations. The total losses are separated into individual components, which are evaluated independently, since some loss mechanisms are inherently more difficult to estimate. The analysis is performed on several commercially available 100 V rated GaN transistors and their performance is assessed across a wide range of operating conditions. Reverse conduction losses are explained in detail, as they can be comparable to other loss components in GaN transistors. Final results provide comparison between the two estimation models and guidelines for optimal device selection depending on the application.

Keywords: Gallium nitride (GaN), power losses, loss mechanism, loss analysis, reverse conduction, dead time

EEI2.2 (#3492)
EVALUATION OF INDUCTOR COUPLING FOR LOSS REDUCTION IN A SEPIC POWER CONVERTER

Marko Lazarević, Aleksandar Milić, Željko Despotović

This paper analyzes the impact of inductor coupling on total magnetic-component losses in a SEPIC converter. Since the benefits of magnetic coupling depend on the specific converter parameters and operating conditions, a numerical evaluation is required in order to quantify its actual impact on loss reduction. The proposed approach combines coupled inductor modelling, analytical inductance calculation, core and copper loss calculations, and a sweep of Ferroxcube E-core geometries. Additionally, Ansys Maxwell simulations are used to confirm the trends observed in the obtained analytical results. For the analyzed volume-matched cases, the coupled inductor solution achieved lower total loss with mean total loss reduction for all analyzed sets close to 24%. It was also shown that the main benefit of coupling comes from copper loss reduction, with the

average copper volume reduced by almost 17% in the considered application. These results show that properly designed magnetic coupled circuits can represent an effective approach for improving efficiency by reducing magnetic losses and improving copper utilization in SEPIC converters.

Keywords: SEPIC converter, coupled inductors, copper losses, core losses, loss reduction, finite element analysis (FEA)

EEI2.3 (#1409)
ROBUST DIGITAL CONTROL OF A DCM SEPIC FOR ELECTROMAGNETIC VIBRATORY ACTUATORS

Dušan Bižić, Aleksandar Milić, Željko Despotović

The objective of this paper is to present a digital signal processor-based control system for a SEPIC operating in discontinuous conduction mode. By deriving an analytical full-order model of the converter under current programmed control, the application of an H∞ loop-shaping design procedure is facilitated. The resulting output voltage controller robustly compensates for the accurately modelled converter dynamics that appear within the desired closed-loop bandwidth. Furthermore, practical implementation guidelines are provided for a Texas Instruments digital signal processor, leveraging its on-chip comparators and digital-to-analog converter modules with integrated compensating ramp generation. Hardware-in-the-loop simulations are performed utilizing a Typhoon HIL 404 real-time simulator to validate the control system design for powering Electromagnetic Vibratory Actuators.

Keywords: discontinuous conduction mode, electromagnetic vibratory actuator,s digital signal processor, optimal voltage control, current programmed control

EEI2.4 (#5239)
COMPARISON OF DC-LINK VOLTAGE CONTROL METHODS IN BRAKING REGIME FOR HIGH INERTIA ELECTRICAL DRIVES

Luka Savanović, Željko Despotović, Aleksandar Milić

High-inertia electrical drives generate substantial amounts of excess energy during the braking regime. This energy must be managed by the power converters either by dissipation or by returning generated energy back to the power source. The braking chopper and active rectifier DC-link voltage control methods are compared in terms of DC-link voltage overshoot during the motor braking regime for an electrical drive system with a wide range of inertia. This paper investigates the performance of the topologies that illustrate these two principles. Practical implementation advantages and drawbacks for both methods are listed and discussed.

Keywords: braking, inertia, rectifier, overshoot, dissipation, implementation, chopper

EEI2.5 (#0425)
LABORATORY TEST BENCH FOR EXPERIMENTAL VERIFICATION OF RPMFS MOTOR PROTOTYPE

Đorđe Lekić, Slobodan Vukosavic

A test bench is developed for experimental verification of a manufactured RPMFS (Rotor Permanent Magnet Flux Switching) motor prototype, previously designed by the authors. In the test bench, the RPMFS motor prototype is mechanically coupled to an induction machine via a torque sensor. Both machines are supplied by two three-phase voltage source inverters (VSIs) with shared DC buses and a braking resistor, powered from the mains supply by a single-phase diode rectifier. Real-time speed and torque control of the

tested prototype is implemented using the TMS320F28335 digital signal processor (DSP), connected to all sensors and one of the VSIs by an interface PCB designed by the authors. The DSP is connected to a PC through USB/JTAG interface, which enables recording and monitoring of waveforms and responses of all measured and controlled quantities during experiments. The paper provides a detailed description of the developed test bench with schematics of measuring and control circuits and explanations of the DSP program, which is implemented using the C2000TM Microcontroller Blockset library in MATLAB® Simulink® environment. Results of conducted experiments confirm the applicability of the test bench and the validity of models used to design the RPMFS prototype.

Keywords: Test bench, Experiment, RPMFS Motor, VSI, DSP

EEI2.6 (#7359)
SYNCHRONOUS TURBO-GENERATOR WINDING INDUCTANCE CALCULATION

Gojko Joksimovic, Aldin Kajević, Yan Wenju, Pavol Rafajdus, Yassen Gorbounov, Xing Wang

This paper summarises the method of calculating the inductance of all windings in a synchronous machine using the concept of the winding function. The obtained results are then compared with those obtained using the classical method, i.e. by employing analytical expressions where such expressions exist. Conversely, the actual winding with parallel-connected groups is modelled by a fictitious winding with series-connected turns. The application of the winding function concept allows for the accounting for all higher harmonics in the MMF wave, in contrast to classical calculations that are based on the fundamental harmonic only. The presented method of calculation is general and can be applied to both conventional synchronous machines and to reluctance machines with or without permanent magnets in their structure, with previous knowledge of the air-gap permeance function.

Keywords: Inductances, Synchronous machines, Winding functions

EEI2.7 (#1631)
ROTOR POSITION ESTIMATION IN SHAFT-SENSORLESS PMSM DRIVES USING PLL WITH PWM DELAY COMPENSATION

Saša Vukosavljev, Darko Marčetić

This paper investigates rotor position estimation in shaft-sensorless permanent magnet synchronous motor (PMSM) drives with emphasis on the impact of system delays at high speeds. Existing voltage-based rotor position estimators often neglect the cumulative delays from sampling, computation, PWM, and filtering, which leads to degraded accuracy. The hypothesis is that proper delay handling—either through explicit compensation can significantly improve estimation performance. The aim is to experimentally compare estimation methods based on reference voltages, delay-compensated reference voltages, and measured motor voltages, and to evaluate PLL-based position estimation using a flux estimator under different delay configurations. Results show that uncompensated estimation produces significant position error, while delay compensation greatly improves accuracy. Estimation based on measured voltages achieves comparable performance by inherently including delay effects. Additionally, PLL performance is optimal when delay compensation matches the actual system delay. These findings highlight the importance of delay-aware design in sensor-less PMSM control.

Keywords: Sensorless motor control, PMSM, rotor position estimation, delay compensation, PLL, flux estimator, FOC

EE1.1 (#5060)
PRIMENA PROŠIRENOG KALMANOVOG FILTERA U ESTIMACIJI OSNOVNIH VELIČINA ASINHRONOG MOTORA

Saša Skoko, Marko Rosić, Dragan Ćetenović

U ovom radu prikazana primena algoritma proširenog Kalmanovog filtera (Extended Kalman Filter - EKF) u estimaciji stanja asinhronog motora, sa mogućnošću estimacije električne brzine obrtanja i mehaničkog momenta opterećenja na vratilu. Radom je obuhvaćen postupak sinteze osnovnih jednačina EKF algoritma i prikazani su rezultati testiranja za slučaj direktnog puštanja u rad asinhronog motora u neoptrećenom i opterećenom stanju. U radu je uočena ostljivost algoritma na nagle promene momenta opterećenja pa je predloženo uvođenje posebne funkcije po kojoj se menja koeficijent matrice kovarijansi Q koji definiše poverenje EKF algoritma u procenu mehaničkog momenta opterećenja. Rezultati testiranja pokazuju da se na ovaj način postižu dobri rezultati u estimaciji električne brzine obrtanja i mehaničkog momenta opterećenja na vratilu motora.

Ključne reči: Kalmanov filter, asinhroni motor, estimacija brzine i mehaničkog momenta

EE1.2 (#8007)
PRORAČUN KARAKTERISTIKA STRUJNOG MERNOG TRANSFORMATORA SA TORUSNIM FEROMAGNETSKIM JEZGROM

Srđan Divac, Rijald Mašović, Marko Rosić, Branko Koprivica

Cilj ovog rada je da se prikaže proračun karakteristika strujnog mernog transformatora (ST) sa torusnim jezgrom od feromagnetskog lima. Proračun uzima u obzir magnetski histerezis jezgra primenom metoda interpolacije harmonika na jačinu magnetskog polja i magnetsku indukciju. Na osnovu unapred zadatih karakteristika ST, parametara jezgra i poznate familije histerezisnih petlji vrši se proračun greške prenosnog odnosa i fazne greške za različite vrednosti primarne struje. U radu su prikazane i analizirane vrednosti proračunatih grešaka u opsegu od 5% do 120% naznačene primarne struje ST za 500 A. Dodatno, analizirana je promena grešaka kada se isto jezgro koristi za izradu ST sa naznačenom primarnom strujom u opsegu od 200 A do 1000 A.

Ključne reči: strujni merni transformator, feromagnetsko jezgro, metod interpolacije harmonike, greška prenosnog odnosa, fazna greška

ЕЛЕКТРИЧНА КОЛА, ЕЛЕКТРИЧНИ СИСТЕМИ И ОБРАДА СИГНАЛА / ELECTRIC CIRCUITS AND SYSTEMS AND SIGNAL PROCESSING

СЕСИЈА / SESSION (ЕК1+ЕКІ1)

Уторак, 9. јун / Tuesday, June 9th Сала 3 / Hall 3 9.00-11.00

Председавајући / Chair:
Milka Potrebić Ivaniš, University of Belgrade – School of Electrical Engineering, Belgrade, Srbija
Ana Tatović, University of Kragujevac, Faculty of Technical Sciences

EKI1.1 (#3366)
CAPACITIVE PLANAR INSERT LOADED WAVEGUIDE BANDPASS FILTER WITH MULTIPLE TZS

Amit Bage, Milka Potrebić Ivaniš

This article presents a novel rectangular waveguide bandpass filter with multiple TZs using capacitive planar insert technology. A three-symmetrical rectangular shape single split complementary split ring resonators (CSRRs) is designed on a Roger RO4350 dielectric substrate and placed in the transverse plane of a standard WR-90 rectangular waveguide. The distance between these planar inserts is optimized and placed at 9.654 mm to form a wideband tri-pole bandpass filter. To introduce TZs below passband, CSRRs with capacitive effects are introduced into the planar insert. The numerical analysis is carried out using CST Studio Suite. The numerical analysis shows the filter operates at 10.35 GHz with a 3-dB bandwidth of 1.0037 GHz and TZs at 9.42, 9.28 and 8.98GHz.

Keywords: WR-90, X-Band, Bandpass, TZs

EKI1.2 (#4777)
DUAL-BAND ANTENNA DESIGN FOR 5G MIMO SYSTEMS USING FOUR ELEMENTS

Ishani Rao, Surendra Kumar Gupta, Lakhindar Murmu, Milka Potrebić Ivaniš, Amit Bage

This article presents a miniaturized four-element MIMO antenna for 5G mm-Wave communication. For optimum performance, the antenna is designed on Rogers RT5880, having a dielectric constant of 2.2, a loss tangent of 0.0009, and a substrate thickness of 0.508 mm. The antenna element consists of a pentagon patch with double-ring slots and a ground plane. The single antenna element is further extended to design a two-element MIMO antenna and a four-element MIMO antenna. In a four-element MIMO antenna system, four symmetrical antennas are placed orthogonally, and the inter-element separation is maintained at 0.2λ0 to achieve an isolation of <-19dB at 28 and 38 GHz, respectively. The proposed MIMO antenna covers 28/38GHz bands with a gain of 3.92 dBi and 4.57 dBi at the resonant frequencies, the diversity performance, such as envelope correlation coefficient (ECC) are lower than 0.015, a diversity gain (DG) exceeding 9.97 dB in both operating bands. Additionally, the Mean Effective Gain (MEG) and Total Active Reflection Coefficient (TARC) results further confirm the suitability of the antenna for high-performance MIMO applications. The numerical analysis is carried out

using CST Microwave Studio. These qualities highlight the system's applicability for 5G mm-Wave communication.

Keywords:5G, 28/38 GHz, DG, ECC, MEG, MIMO antenna, mm-Wave Communication, TARC

EKI1.3 (#3880)
DESIGN AND ANALYSIS OF WEARABLE ANTENNA WITH HIGH IMPEDANCE SURFACE (HIS) FOR 5G SYSTEMS

Amit Bage, Ritik Bhatia, Milka Potrebić Ivaniš, Ana Tatović

The design and analysis of a wearable antenna with a high impedance surface (HIS) are presented in this study. On denim fabric, a radiating patch is created by combining a ring and a U-shaped resonator. The high impedance surface (HIS) semifabric antenna uses a 3.5 GHz operating frequency. When an antenna is placed on a human body, the HIS is employed to shield it from back radiation. The suggested antenna with HIS has dimensions of 66.8 x 66.8 x 4.84 mm. In addition to significantly lowering SAR value and back radiation, HIS raises the standard wearable antenna's gain from 2.06 dBi to 8.76 dBi. CST Studio is used for the numerical analysis.

Keywords: Wearable Antenna, HIS, AMC, 5G, Jeans

EKI1.4 (#0083)
ON CYCLOSTATIONARY SPECTRUM ANALYSIS OF FMCW RADAR FOR VITAL SIGNS DETECTION

Dejan Rakic, Lazar Saranovac, Vladimir Milovanovic

Abstract—We consider FMCW radar for vital sign detection and monitoring using the spectral correlation function (cyclostationary signal processing) for creating time sliding 2D alpha-frequency map. The FMCW radar first detects the peaks in the Range-Doppler (R-D) map, selects detected targets and takes samples from the one of them from the point in R-D. The extracted signal is nonlinear frequency modulated with body movement, breath and hearth rate. In general, the time domain signal taken from the target in R-D map can be modeled as AM-FM modulated. The body movement interferes with modulated components generated by breathing and heart pulses. Cyclostationary Features Detection (CFD) can separate useful signals form the interference, because signal components modulated by respiration and heart rate exhibit cyclostationarity. The Spectral Correlation (SC) is applied for forming 2D alpha-frequency maps that are sliding in time. The single map can be processed by some of the AI methods or standard classification. The results are presented for the ideal baseband model represented by FM signal modulated by breath and hearth rates. These results are compared with real measurements taken from the mechanical device which emulates breathing and heart biting. Finally, the processing of the real measurements taken from the deflected RF signal from humans is presented and analyzed.

Keywords: FMCW, SCD, vital sign detection

EKI1.5 (#3153)
INFLUENCE OF GAP GEOMETRY OF RECTANGULAR RESONATORS IN H-PLANE WAVEGUIDE BAND-STOP FILTERS

Bojana Vrljanac, Anđela Ninković, Milka Potrebić Ivaniš

This paper presents an analysis of H-plane waveguide band-stop filters with resonators implemented on a dielectric carrier inserted into the waveguide, focusing on the influence of gap position and orientation of the resonant elements on the scattering

parameters. The resonant elements are realized as rectangular metallic structures with a capacitive gap. The frequency range of interest is the X-band. Individual resonators are designed and analyzed using full-wave electromagnetic simulations in WIPL-D Pro CAD, while configurations with three resonators inside the waveguide are evaluated using circuit-level analysis in WIPL-D Microwave Pro. The main result of interest is the influence of gap orientation on the scattering parameters, complemented by a comparative analysis of RLC equivalent circuit models and CAD-based simulations.

Keywords: H-plane waveguide band-stop filters, Capacitive-gap resonators, Gap orientation effects, Scattering parameters, X-band, Equivalent circuit modelling

EKI1.6 (#4196)
FEASIBILITY OF A LOW COST OFF-THE-SHELF 60 GHZ FMCW MMWAVE RADAR FOR ENVIRONMENTAL SENSING

Ivo Marković, Amit Bage

Climate change is an ongoing and unavoidable process that demands continuous monitoring and analysis. Anticipating future environmental changes and mitigating associated risks requires extensive observations and measurements across diverse geographic locations. This growing need for ubiquitous environmental monitoring is driving a shift from expensive, specialized instrumentation toward low-cost, integrated sensing solutions. In this context, this paper evaluates the feasibility of using a commercially available 60 GHz Frequency-Modulated Continuous-Wave (FMCW) millimeter-wave (mmWave) radar for environmental characterization. This study focuses on analyzing the radar's capabilities and performance, as well as its applicability in real-world scenarios that introduce challenges not typically encountered in controlled laboratory environments. The outcome of this work is the identification of key limitations that require further solutions, along with existing toolsets that are already mature and can be directly leveraged for practical deployment.

Keywords: Climate change, Environmental sensing, FMCW radar, mmWave, Precipitation, Snowpack

EK1.1 (#9772)
NAMENSKI SISTEM ZA ANALIZU ZAUZETOSTI PROSTORA U MARKETIMA SA REALNIM VREMENOM ODZIVA

Kristina Mitrović, Lazar Saranovac

U ovom radu je prikazan sistem za analizu zauzetosti prostora u marketima, realizovan na Rasbperry Pi uređaju. Predloženi sistem koristi YOLO algoritam za detekciju prisutnosti osobe i kameru postavljenu na Raspberry Pi koja sistemu u realnom vremenu prenosi stanje svake zone marketa. Sistem prati dnevnu zauzetost svake zone i na kraju dana eksportuje prikupljene podatke. Podaci koje projektovani sistem prikupi mogu poslužiti za dalju analizu popularnosti i posećenosti određenih delova maloprodajnog objekta u cilju poboljšanja poslovanja.

Keywords: real-time, Raspberry Pi, YOLO, detekcija prisustva osobe

СЕСИЈА / SESSION (ЕК2+ЕКІ2)

Уторак, 9 јун / Tuesday, June 9th Сала 3 / Hall 3 14.30-16.30

Председавајући / Chair:
Ana Tatović, University of Kragujevac, Faculty of Technical Sciences
Milka Potrebić Ivaniš, University of Belgrade – School of Electrical Engineering, Belgrade, Srbija

ЕКІ2.1 (#1121)
COOPERATIVE MODEL PREDICTIVE CONTROL FOR ADAPTIVE BITRATE CLIENTS

Nebojša Simić, Zoran Čiča, Ana Gavrovska

Adaptive Bitrate (ABR) streaming optimizes for individual Quality of Experience (QoE) under variable network conditions. Nevertheless, this isolated approach often leads to systematic unfairness and resource contention when multiple clients share a bottleneck link. To address this, we propose Cooperative MPC (Model Predictive Control), a modified model predictive control formulation that applies an epidemic gossip protocol to share throughput observations among clients. By limiting communication to a small, constant number of random peers per gossip round, the protocol aims to achieve swarm-wide state convergence with overhead that scales independently of the total client population. In this paper we evaluate this approach through a proof-of-concept simulation across varying swarm sizes up to 128 concurrent clients. Initial results indicate that cooperative throughput-sharing can effectively mitigate the aggressive spike exploitation inherent in standalone MPC algorithms, thereby stabilizing bitrate selection and reducing rebuffering events. Furthermore, the protocol demonstrates resilience to realistic message delays and extended gossip periods, suggesting potential viability for deployment at CDN (Content Delivery Network) edges or dense local networks.

Keywords: Model Predictive Control (MPC), Adaptive Bitrate (ABR), Content Delivery Network (CDN), video streaming, Quality of Experience (QoE), cooperative approach

ЕКІ2.2 (#2145)
OPTIMAL OPERATING POINT DETECTION IN VERSATILE VIDEO CODING-BASED LOSSY COMPRESSION OF SAR IMAGES WITH MULTIPLICATIVE NOISE

Boban Bondžulić, Vladimir Lukin, Boban Pavlović, Sergii Kryvenko, Dimitrije Bujaković, Oleksandr Arkhipov

Existing synthetic aperture radar (SAR) imagers produce a huge amount of data that can be useful for various applications. Many SARs are installed on-board of airborne or spaceborne carriers and, then, acquired data or images have to be transferred from on-board sensors and processors to on-land centers of further data processing. In such cases, data compression is extremely useful where the use of lossy compression is preferable. Acquired SAR images are contaminated by speckle and this leads to specific effects of speckle suppression and possible existence of optimal operation point (OOP) where compressed image is closer to true image than uncompressed image according to certain metrics. Compression performance depends on several factors including a used coder. Recently Versatile Video Coding (VVC) technique has been put forward that can be also applied to still images. Thus, our goals are to consider whether or not VVC can be used

for SAR image lossy compression, does OOP exist and, if yes, what are coder parameters in OOP. We show that OOP might exist according to compression ratio (CR), different full-reference (FR) and no-reference (NR) metrics, and this happens for quite large CRs. For real-world applications, the OOP position, influenced by speckle intensity, can be estimated using NR metrics or derived from the CR curve, while FR metrics serve as a benchmark under laboratory conditions. The corresponding practical recommendations are given.

Keywords: SAR, VVC, lossy compression, optimal operation point

EKI2.3 (#6890)
ENHANCED 3D OUTDOOR REGISTRATION ALGORITHM USING HYBRID METAHEURISTIC OPTIMIZATION

Nebojša Čvorović, Ana Gavrovska

This paper presents an enhanced registration algorithm integrated with a hybrid metaheuristic optimization method, DE-PSO (Differential Evolution-Particle Swarm Optimization). By combining the global exploration capability of DE with the fast convergence characteristics of PSO, the proposed approach effectively overcomes the local minima limitations commonly encountered in conventional ICP implementations. The proposed method is implemented entirely using free and open-source software and developed in the C++ programming language on a self-generated dataset. Experimental results demonstrate that incorporating the DE-PSO optimization strategy within the registration process significantly improves alignment accuracy, robustness, and overall performance compared to traditional registration approaches.

Keywords: Point cloud, image registration, Particle Swarm Optimization (PSO), Differential Evolution (DE), Iterative Closest Point (ICP), metaheuristic

EKI2.4 (#9043)
A MULTI-LAYER SMART VIDEO SURVEILLANCE BASED ON HUMAN ACTIVITY AND MOVEMENT ANALYSIS

Elhan Dazdarević, Ana Gavrovska

Automation in the video surveillance field has gained significant traction among researchers. The primary objective is to replace traditional human-dependent monitoring with new solutions driven by robust computer vision algorithms. This paper analyzes methods relevant for Human Activity Recognition (HAR) and movement analysis across three distinct scenarios: crowd analysis, sparse object detection, and individual tracking. By integrating CSRNet (Congested Scene Recognition Network) for crowd counting, YOLOv12 (You Only Look Once) for sparse object detection, and IMU-based (Inertial Measurement Unit) individual activity monitoring, we derive multi-stage time series. Given that each stage introduces varying computational complexity, a preliminary analysis of inference latency is presented. The results demonstrate stage-specific performance and offer preliminary insights towards minimizing latency during the monitoring process.

Keywords: Smart video surveillance, Human Activity Recognition (HAR), Crowd counting, YOLOv12, Pose estimation, Inference latency

EKI2.5 (#9844)

MOBILE LASER TEXTURE PROFILING METHOD FOR COST-EFFECTIVE ROAD SAFETY ASSESSMENT

Nikola Slavkovic, Goran Zajic, Ana Slavkovic, Silva Kostic, Mirjana Tomic, Marko Pavlovic

Road surface profile quality plays an important role in defining pavement material functionality. Laser profiling systems are valuable tools for traffic safety, particularly in relation to friction effects. The modelling process begins with contactless remote surface scanning of materials. It is based on the interaction between coherent light and the surface, followed by various signal-processing techniques. Mobile scanning systems are based on multisensory platforms moving along the road surface. It is important to evaluate movement-related effects such as vibrations of the moving system, changes in platform velocity, macro-level surface irregularities, and similar structural material issues. Precise laser signal scanning techniques contribute to the development of risk prediction models that support traffic safety in situations where friction-related problems arise. Moreover, these mobile profiling methods are cost-effective. They improve safety, maintenance planning, and lifecycle cost management while reducing both survey time and traffic disruption without requiring road lane closures.

Keywords: road surface, texture profiling, mobile laser scanning systems, fine-scale change detection, road safety, cost-effectiveness

EK2.1 (#2162)

KOMPARATIVNA ANALIZA JPEG, BPG I VVC TEHNIKA KOMPRESIJE NA SLIKAMA SISTEMA DALJINSKOG OSMATRANJA

Nikola Bukvić, Boban Bondžulić, Milenko Andrić and Dimitrije Bujaković

U ovom radu izvršena je komparativna analiza JPEG, BPG i VVC tehnika kompresije na slikama sistema daljinskog osmatranja. Korišćena je baza slika DOTA v1.0, koja sadrži snimke sa satelita GF-2 i JL-1, kao i sa platforme Google Earth. Nakon podele originalnih slika na blokove dimenzija 1024x1024 piksela, formiran je skup od 15749 slika, od kojih je 90 nasumično odabrano za testiranje. Kvalitet komprimovanih slika procenjen je korišćenjem tri objektivne mere procene kvaliteta, dok je efikasnost kompresije izražena preko reprezentacije u bitima po pikselu i stepena kompresije. Poređenje je izvršeno ujednačavanjem objektivnog kvaliteta i ujednačavanjem broja bita po pikselu. Rezultati pokazuju da BPG i VVC ostvaruju dva do pet puta veću uštedu memorijskog prostora u odnosu na JPEG za isti nivo kvaliteta. Pri istom broju bita po pikselu, BPG i VVC daju bolji objektivni kvalitet, sa razlikama u vršnom odnosu signal šum do 7 dB. Takođe je uočeno da tip degradacije različito utiče na pojedine mere kvaliteta.

Ključne reči: JPEG, BPG, VVC, kompresija slika, daljinsko osmatranje, DOTA, PSNR, SSIM, HaarPSI

EK2.2 (#7712)

UTICAJ KOMPRESIJE SLIKE NA SAKRIVANJE INFORMACIJA U PROSTORNOM DOMENU

Nenad Stojanovic, Branko Vujatović, Sanja Klajic, Boban Bondžulić

Rad predstavlja analizu uticaja kompresije slike sa gubicima na sakrivanje informacija u prostornom domenu metodom zamene bita najmanjeg značaja. Performanse steganografske tehnike određivane su korišćenjem vršnog odnosa signal-šum. Akcenat

je dat na metode kompresije slike sa gubicima, ali je izvršena analiza i za slučaj kada su primenjene tehnike kompresije bez gubitaka. Utvrđeno je da je u oba slučaja osobina neprimetnosti na zadovoljavajućem nivou. Primenom kompresije sa gubicima na steganografske slike dolazi do značajnog oštećenja sakrivene informacije. Pokazano je da je JPEG2000 tip kompresije najotporniji na oštećenja sakrivene poruke. BPG tip kompresije se pokazao kao najefikasniji sa stanovišta uštede memorije, naročito kada je u pitanju kompresija bez gubitaka.

Ključne reči: steganografija, kompresija slike sa gubicima, zamena bita najmanjeg značaja, PSNR

МЕТРОЛОГИЈА / METROLOGY

СЕСИЈА / SESSION (МЛ1+MLI1)

Понедељак, 8. јун / Monday, June 8th Сала 5 / Hall 5 11.15-14.00

Председавајући / Chair:
Dragan Lazić, Tehnički opitni centar - Ministarstvo odbrane, Beograd, Srbija
Neda Spasojević, Tehnički opitni centar - Ministarstvo odbrane, Beograd, Srbija

ML1.1 (#3844)
ODREĐIVANJE MASE NESTANDARDNIH TEGOVA

Dragan Lazic, Slobodan Subotić, Neda Spasojevic, Miloš Jovanović, Miša Markuš, Boris Laštro

Tema ovog rada je određivanje mase nestandardnih tegova, odnosno tegova koji nisu urađeni prema Međunarodnoj preporuci OIML. U radu je opisan postupak određivanje mase tegova sa proračunom merne nesigurnosti

Ključne reči: masa, tegovi, klase tegova, nestandardni tegovi, merna nesigurnost

ML1.2 (#2292)
UTICAJ OSLABLJIVAČA NA MERENJE HARMONIJSKIH IZOBLIČENJA SIGNALA

Neda Spasojevic, Miša Markuš, Aleksandar Atanackovic, Slobodan Subotic, Miloš Jovanović, Dragan Lazić

Ovaj rad razmatra uticaj oslabljivača na merenje harmonijskih izobličenja signala, koji se radi prilagođenja nivoa vezuje na ulaz analizatora spektra. Imajući u vidu frekvencijsku zavisnost slabljenja oslabljivača, izražena je sumnja da njegov uticaj neće biti isti na osnovnoj frekvenciji i njenim harmonicima. Kako u literaturi nije razmatran ovaj aspekt, cilj istraživanja je bio da se utvrdi uticaj oslabljivača na merenje harmonijskih izobličenja. Analiza je obuhvatila tri varijante osnovnog metoda baziranog na merenju harmonijskih izobličenja bez primene oslabljivača i sa njim. Istraživanje je sprovedeno u ograničenim uslovima koji se tiču odabira pogodnih oslabljivača, frekvencije nosioca, merne nesigurnosti itd. Eksperimentalni rezultati su pokazali da frekvencijska karakteristika oslabljivača nema uticaj na merenje harmonijskih izobličenja signala i da je njegov uticaj opravdano zanemaren u literaturi.

Ključne reči: harmonici, relativni sardžaj harmonika, harmonijsko izobličenje, oslabljivač, analizator spektra, merna nesigurnost

ML1.3 (#1142)
POREĐENJE MERENJA STABILNOSTI FREKVENCIJE KORIŠĆENJEM ALANOVE I HADAMARDOVE DEVIJACIJE

Miša Markuš, Neda Spasojević, Aleksandar Atanacković

U radu je opisano na koji način različiti tipovi statističke obrade podataka utiču na rezultate merenja stabilnosti oscilatora u vremenskom domenu. Istraživanje je sprovedeno za oscilatore sa kvarcnom i rubidijumskom bazom, pri čemu je poređenje izvršeno za nekoliko modela analize podataka: Alanova i Hadamardova devijacija, u verzijama sa i bez preklapanja.

Ključne reči: Alanova devijacija, Hadamardova devijacija, kvarc, oscilator, rubidijum, stabilnost, statistika,

MLI1.1 (#4029)
COMPARATIVE EXPERIMENTAL ANALYSIS OF LOAD AND TEMPERATURE EFFECTS ON PRECISION RESISTORS UNDER DIFFERENT THERMAL STABILIZATION CONDITIONS

Slobodan Subotić, Jelena Jovanovic, Miloš Jovanović, Dragan Lazić, Neda Spasojevic, Nikola Jovičić

This paper presents an experimental investigation of self-heating effects in precision resistors under different thermal environments, with a focus on 1 Ω and 10 Ω standards. The study examines resistor behavior under load levels ranging from 2% to 80% of rated power at a controlled ambient temperature of 23 °C. Measurements were performed in both a temperature-controlled oil bath and an air chamber in order to evaluate the influence of heat dissipation conditions. In addition to steady-state analysis, particular attention is given to how resistance and temperature change over time during extended exposure to constant load. Simultaneous monitoring of resistance and internal temperature enabled a detailed assessment of temperature rise (ΔT), resistance variation (ΔR), thermal resistance (RT) and thermal stabilization processes. The results reveal distinct differences between the two environments and highlight the importance of time-dependent effects in understanding self-heating and resistance stability in precision resistors.

Keywords: precision resistor temperature effect power loading effect temperature coefficient thermal resistance thermal stabilization conditions

MLI1.2 (#8860)
PRESSURE AND SOIL MOISTURE SENSORS DEVICE DESIGN IN IRRIGATION AS PART OF THE SMART AGRICULTURE

Vladimir Pejanović, Marjan Urekar, Milica Grubač, Vera Popović

This paper presents the design of a cost-effective and robust PCB device intended for irrigation in smart agriculture, with a specific focus on small and medium-sized farmers. The system's originality is in its dual irrigation regulation, which combines soil moisture data with hydraulic pressure monitoring using the MPX5700AP sensor. Unlike standard solutions that rely solely on moisture levels and timers, this integrated approach enables the detection of critical system failures such as pipe blockages, leakages, or pump "idle running". The hardware is based on the ESP32 microcontroller and utilizes LoRa technology for reliable, long-range communication in rural areas with limited network coverage. The device features a modular, cascade power supply system (+12V to +5V and +3V3) designed to withstand harsh field conditions while protecting sensitive

components from voltage spikes. By optimizing water and electricity consumption, this irrigation device design based on sensors aims to mitigate the negative effects of climate change and global warming, provide predictive maintenance and malfunction detection of the pump and irrigation hose, increase crop yields, and ensure the sustainability of agricultural production through cost effective digitalization.

Keywords: smart agriculture, precision irrigation, esp32, lora communication, soil moisture sensor, hydraulic pressure monitoring, pcb design, sustainable development

MLI1.3 (#2676)

MEASUREMENT AND CONTROL OF THE ANGULAR VELOCITY OF A DC MOTOR VIA A MICROCONTROLLER AND A WI-FI APPLICATION

Aleksa Rančić, Marjan Urekar

This paper contains an explanation of how a fully functional control system is realized on a microcontroller and the different ways the user can interface with it. The main control loop is written in C language, specifically using the FreeRTOS embedded operating system. FreeRTOS enables the microcontroller to handle multiple tasks, seemingly at once. The tasks include handling the system control loop, the Wi-Fi functionality and other human – machine interface solutions this project includes. The PC application written in Python enables the user to communicate with the microcontroller wirelessly.

Keywords: application, Wi-Fi, GUI, microcontroller, DC motor, FreeRTOS

MLI1.4 (#8649)

METROLOGICAL CONSIDERATIONS OF ELECTROOCULOGRAPHY IN HUMAN-COMPUTER INTERFACE SYSTEMS

Jovan Dimitrović, Marjan Urekar

This paper provides insight into how the electrooculogram (EOG) can be measured and used in human-computer interface (HCI) systems. The origin and method of acquisition of the EOG signal are described. The difficulties for achieving good measurements are presented, as well as difficulties for user calibration and the possibilities for further research and exploration. The aim of this paper is to study the metrological difficulties in measuring EOG signals and emphasize the future applications of the EOG based HCI systems in practical uses.

Keywords: electrooculogram, EOG, Human-Computer interface, HCI

MLI1.5 (#1101)

MEASUREMENT OF EULER ANGLES IN AIRCRAFT NAVIGATION SYSTEMS: MEASUREMENT UNCERTAINTY, CALIBRATION AND COMPENSATION TECHNIQUES

Nikola Djordjevic, Aleksandar Pejcic, Igor Vlajnic, Ivan Vesic, Danilo Vukosavljevic, Marjan Urekar

This paper explores how to measure aircraft attitude using Euler angles. It provides basics of this concept. The sensors and filters for determination of attitude are described. In addition, the paper introduces sources of errors and uncertainties, along with calibration and compensation techniques, to reduce errors. The goal is to highlight the importance of accurate measurement of Euler angles for reliable aircraft navigation, control and flight safety.

Keywords: Euler angles, quaternions, attitude, aircraft navigation system, gyroscope, accelerometer, magnetometer, filters, calibration, compensation, measurement uncertainty

MLI1.6 (#7872)
DIGITAL VOLTMETER BASED ON MICROCONTROLLER WITH PC COMMUNICATION AND VISUALISATION CAPABILITIES

Jelena Delić, Marjan Urekar

This paper demonstrates communication between a digital voltmeter that measures different voltage waveforms (sine, triangular, square) from 200 mV to 20 V and an Arduino Leonardo microcontroller which sends information about the measured voltage to the computer. The use of a microcontroller enables data processing and showing the measuring value on the LCD display. One of the main goals of the device is to improve the visual availability of measurement data and processing on a computer. The use of an external LCD display enables a clear, easy-to-read display of the measured voltage, which facilitates the monitoring and analysis of electrical parameters. In addition to better visualization with the LCD, the microcontroller can communicate with the computer, and thus the processing and analysis of the measured data is carried out.

Keywords: Measurements, KiCad, Voltage, Arduino Leonardo, Computer communication

MLI1.7 (#2111)
USING ARTIFICIAL INTELLIGENCE FOR METROLOGICAL IMPROVEMENT OF ECG SYSTEMS

Aleksandar Đuragić, Platon Sovilj, Marjan Urekar

This paper focuses on the analysis of metrological improvements in electrocardiography (ECG) systems over time, with the proposal of an artificial intelligence (AI) algorithm to help improve the diagnostic department of cardiology. The discussion reviews the comparison of analog and digital ECG systems, the limitations of analog ECG systems, the limitations of digital ECG systems and a proposal for an AI model for the automatization of metrological calibration with AI predictions of cardiological diseases in real-time. The main idea is to make the calibration process in real-time much more reliable and automated aiming to save valuable time for operators and try to support medical experts with real-time detection of potential arrhythmia and prediction of cardiovascular conditions by continuously analyzing the live stream of physiological signals coming from digital ECG devices.

Keywords: calibration, prediction, AI, machine learning, digital/analog systems

MLI1.8 (#0084)
POWER QUALITY DISTURBANCE CLASSIFICATIONS IN SMART GRID USING MACHINE LEARNING

Josif Tomić, Aleksandar Đuragić, Platon Sovilj

This paper discusses general aspects of smart grids and focuses on the detection and classification of power quality in smart power grids using machine learning algorithms. Power quality involves monitoring voltage swells, voltage sags, voltage interruptions, harmonics, frequency changes, and complex events involving multiple problems in the power network. The problem of power quality has become particularly important with the increasing use of renewable energy sources, as the inclusion of large consumers and producers of electricity creates significant issues in the power network. This paper presents several machine-learning methods for identifying power system disturbances. For simplicity, the FFT transformation extracts the characteristic features of the voltage signals. After signal decomposition, the following techniques are employed to classify power system disturbance waveforms: Naive Bayes, Support Vector Machine (SVM), K

means, and Gaussian Mixture Model. Identification of grid disturbances can be performed in real-time or as a statistical analysis on a multi-month basis.

Keywords: Power Quality disturbance, Smart grid, Machine Learning, classification

ML1.4 (#6145)
JEDNA METODA ETALONIRANJA STROBOSKOPA UPOTREBOM FOTODETEKTORA U SA POSEBNIM OSVRTOM NA MERNE MOGUCNOSTI

Miloš Jovanović, Dragan Lazic, Slobodan Subotić, Neda Spasojevic, Miša Markuš, Nikola Jovičić, Aleksandar Atanackovic

U radu je predstavljena jedna metoda etaloniranja stroboskopa upotrebom silicijumskog fotodetektora. Predstavljanji su osnovni fizički i matematički rada storposkopa, njihova primena, osnovne karakteristike i ograničenja. Poseban osvrt u radu, dat je na budžet merne nesigurnosti, glavne elemente budžeta merne nesigurnosti, kao i proračun ukupne merne nesigurnosti tokom etaloniranja.

Ključne reči: etaloniranje, stroboskop, fotodetektor

СЕСИЈА / SESSION (MЈI2+MLI2)

Понедељак, 8. јун / Monday, June 8th Сала 5 / Hall 5 15.00-17.15

Председавајући / Chair:
Dragan Denić, University of Niš, Faculty of Electronic Engineering, Serbia
Dragan Pejić, Fakultet tehničkih nauka, Novi Sad, Srbija

ML2.1 (#7015)
LINEARIZACIJA I OBRADA ANALOGNOG SIGNALA SA NTC TERMISTORA ZA PRIMENU U MERNO-AKVIZICIONOM SISTEMU

Goran Miljković, Ivana Ranđelović, Miroljub Pešić and Dragan Denic

U radu je predstavljeno jedno rešenje za linearizaciju i obradu analognog signala dobijenog uz pomoć NTC termistora. NTC termistor se široko primenjuje zbog svoje velike osetljivosti i niske cene, ali je glavni njegov nedostatak nelinearnost karakteristike. Upotrebljen je NTC termistor od 10 kOhm sa uskom tolerancijom od 1% rasipanja u odnosu na nominalne vrednosti. Pri realizaciji elektronskog bloka za linearizaciju i obradu analognog signala NTC termistora je korišćen dualni CMOS operacioni pojačavač MCP6022I/P. Ovaj operacioni pojačavač je pogodan za primenu jer spada u klasu RRIO operacionih pojačavača (Rail to Rail Input and Output). Primenom temperaturnog kalibratora Fluke 9103 urađeno je ispitivanje merenja temperature realizovanim elektronskim blokom i konkretnim termistorom. Eksperimentalni rezultati u temperaturnom opsegu 0-50°C su predstavljeni i analizirani u radu.

Ključne reči: merenje temperature, NTC termistor, linearizacija, temperaturni kalibrator

ML2.2 (#5046)
MOGUĆNOST REŠAVANJA PROBLEMA U DISTRIBUTIVNIM CEVNIM MREŽAMA KORIŠĆENJEM LTSPICE-A

Dragan Pejić, Slobodan Tašin, Đorđe Novaković, Nikola Vojnović, Nemanja Gazivoda

izložena je upotreba programskog alata LTSpice namenjenog za rešavanje električnih i elektronskih kola na rešavanje problema iz oblasti strujanja fluida u distributivnim cevnim mrežama. Primeni alata prethodilo je istraživanje i uočavanje sličnosti i razlika koje postoje između pojava u oblasti elektrotehnike i mehanike, konkretno mehanike fluida. Ranije uočene, relativno malobrojne sličnosti između ove dve oblasti predstavljale su početni podsticaj za njihovo povezivanje, dok su brojne uočene razlike služile kao dodatna motivacija za dalja istraživanja i utvrđivanja izomorfizma. Takođe, dat je prikaz mogućnosti primene LTSpice-a u rešavanju problema za slučaj strujanja nestišljivog fluida, konkretno vode, u kompleksnim cevnim mrežama.

Ključne reči: cevne mreže, fluidi, analogije, programski alat LTSpice

ML2.3 (#3574)
МЕРЕЊЕ КАРАКТЕРИСТИКА ПОЈАЧАВАЧА МОСТА СА МЕРНИМ ТРАКАМА НАПАЈАН АС СИГНАЛОМ

Milica Stojanović, Dragan Živanović, Jelena Đorđević-Kozarov, Milan Simić

У раду су дати експериментални резултати испитивања мерног кола претварача силе при чему је побуда сензора симулирана везивањем паралелне отпорности у једну грану моста. Поред стандардног напајања моста DC напоном, разматран је и рада са пободом наизменичним напоном у циљу смањења утицаја офсета појачавача и генерисаних термоелектричних напона у мосту и прикључним кабловима. Експериментална поставка обухвата DC и AC побуду моста, инструментациони појачавач и одговарајућу мерну опрему. Анализирани су излазни напони моста и појачавача, као и појачање система.

Кључне речи: мерни мост, АС напајање, појачање система

ML2.4 (#6920)
POBOLJŠAN MODEL AKVIZICIONOG SISTEMA ZA MERENJE ELEKTROOKULOGRAFSKOG SIGNALA

Jelena Đorđević Kozarov, Dejan Milić, Jelena Anastasov, Milica Stojanović, Emilie Avignon-Meseldzija

U ovom radu predstavljen je unapređeni model akvizicionog sistema za elektrookulografiju (EOG), zasnovan na suvim elektrodama i jednostavnom hardverskom rešenju, namenjen primeni u okviru laboratorijskih vežbi. Cilj razvoja sistema bio je obezbediti jednostavnu, ponovljivu i ekonomičnu upotrebu, uz kompaktne dimenzije uređaja i napajanje putem standardnog USB interfejsa. Akvizicioni front-end realizovan je korišćenjem diferencijalnog pojačavača sa aktivnom povratnom spregom radi smanjenja uticaja ambijentalnog šuma. Za eliminaciju mrežne interferencije implementiran je aktivni analogni notch filter zasnovan na Bainter topologiji. Performanse predloženog rešenja upoređene su sa prethodno realizovanim pasivnim notch filterom. Rezultati pokazuju da aktivni notch filter ostvaruje uži opseg potiskivanja, bolju selektivnost i stabilnije ponašanje u odnosu na pasivnu realizaciju, uz manju osetljivost na tolerancije komponenti. Posebna pažnja posvećena je analizi uticaja neidealnosti operacionog pojačavača TL072 i tolerancija pasivnih elemenata na performanse filtera. Predloženi sistem predstavlja pouzdanu i ekonomičnu platformu za laboratorijsku nastavu i dalja istraživanja u oblasti akvizicije bioelektričnih signala.

Ključne reči: Elektrookulografija (EOG), Notch filter, Analogna obrada signala, Potiskivanje mrežnog šuma, Ekonomičan akvizicioni sistem

MLI2.1 (#8821)
MULTI-AXIS VIBRATION MEASUREMENT AND VISUALIZATION SYSTEM FOR GAMEPAD CONTROLLERS

Sara Kasapović, Vasilije Bursać, Dragan Pejić, Jovan Rajčević, Bojan Vujičić, Platon Sovilj

This paper presents the design and implementation of a compact multi-axis vibration measurement system for gamepad haptic actuators. Three MPU-6500 MEMS accelerometers are interfaced to a Raspberry Pi Pico (RP2040) microcontroller via SPI, enabling synchronized triaxial acceleration acquisition at a range of different sampling frequencies. Measurements across gamepads employing different haptic actuation technologies demonstrate spatial differentiation of vibration profiles across the device body, with amplitude peaks clearly correlated to actuator placement. The system is a low-cost, open instrumentation platform suitable for objective characterization of haptic feedback devices.

Keywords: Accelerometer, haptic feedback, vibration measurement, gamepad controller, RP2040, signal acquisition, RMS

ML2.5 (#0883)
ANALIZA UPOTREBLJIVOSTI HAMONOVIH PRESLOŽIVIH OTPORNIKA ZA REALIZACIJU TRANSFERA DESET

Sara Bratic, Tatjana Grbic, Dragan Pejic

U ovom radu prikazana je statistička analiza dvije topologije Hamonove mreže za realizaciju transfera vrijednosti 10, primjenom Monte Karlo metode. Uobičajenim korišćenjem Hamonove mreže sa 10 otpornika se dobija vrijednost transfera 100, čime se obezbjeđuje prenos tačnosti sa etalona otpornosti na radni etalon dva reda veličine veći ili manji. Transfer vrijednosti 10 ima poseban značaj jer omogućava prenos tačnosti etalona otpornosti za jedan red veličine, kako na više tako i na niže vrijednosti. Analizirane su dvije konfiguracije: serijsko-paralelna i paralelno-serijska struktura. Vrijednosti otpornika modelovane su kao slučajne promjenljive, a za svaku konfiguraciju sprovedeno je 10^4 realizacija simulacije. Na osnovu dobijenih rezultata određena je raspodjela transfera prikazana na histogramu, date su statističke karakteristike uključujući srednju vrijednost i standardnu devijaciju, kao i raspodjela rezultata prikazana histogramom.

Ključne reči: Hamonova mreža, Monte Karlo metoda, otporničke mreže, statistička analiza, ekvivalentna otpornost, analiza nesigurnosti, tolerancije otpornika, topologija mreže, normalna raspodjela, metrologija

ML2.6 (#2980)
REALIZACIJA SIMULATORA SILOTERMOMETRA

Đorđe Novaković, Nemanja Gazivoda, Sanja Mandić, Dragan Pejić, Jovan Rajčević

U ovom radu prikazano je projektovanje i realizacija simulatora silotermometra, uredaja namenjenog za precizno praćenje temperaturnih profila u silosima. U uvodnom delu rada analizirani su teorijski aspekti merenja temperature u silosima, kao i značaj rane detekcije termičkih promena. Centralni deo rada fokusiran je na hardversku arhitekturu sistema. Poseban akcenat stavljen je na razvoj namenskog firmvera koji omogućava pouzdanu akviziciju i obradu podataka u realnom vremenu. Rezultati testiranja potvrduju

da simulator verno reprodukuje uslove u realnom okruženju, pružajući osnovu za dalju optimizaciju sistema za automatizaciju merenja temperature u silosima.

Ključne reči: silotermometar, simulator, akvizicija podataka, mikrokontroleri, firmver, senzorske mreže

ML2.7 (#3462)
LINEARIZACIJA KARAKTERISTIKE TEMPERATURNOG SENZORA KTY 10-6 PRIMENOM NELINEARNOG OTPORNIKA

Ilija Kisić, Dragan Pejić

U radu je hardverski linearizovana karakteristika temperaturnog senzora KTY10-6 primenom operacionog pojačavača i nelinearnog otpornika. Posmatran je ceo raspoloživi opseg senzora sa inicijalnom nelinearnošću od 15,53 ºC. Primenom metoda koje su opisane u ovom radu nelinearnost je smanjena na 1,85 ºC i 0,47 ºC.

Ključne reči: Temperaturni senzor, Linearizacija karakteristike, Nelinearni otpornik, Operacioni pojačavač, Simulacioni rezultati, Matematički model

ML2.8 (#3335)
PROVERA KARAKTERISTIKA FUNKCIONALNOSTI UREĐAJA ZA GLOBALNO NAVIGACIONI SATELITSKI SISTEM- GNSS ORJENTACIJU I POZICIONIRANJE

Milena Jovanović, Marina Tripković

GNSS je sistem koji omogućava precizno određivanje položaja na Zemlji putem satelitske tehnologije. Ovaj sistem obuhvata više globalnih i regionalnih satelita, koji emituju signale, a prijemnici na Zemlji koriste te signale kako bi izračunali svoju geolokaciju. Sistem se koristi za preciznu navigaciju u raznim oblastima, tako da ima široku primenu u vojsci za orjentaciju i pozicioniranje. Tačno određivanje orjentacije i pozicije od izuzetne važnosti je kako za orjentaciju vojnika na terenu, tako i u određivanju tačne pozicije sredstava, potencijalnog cilja ili trenutnog položaja projektila ili rakete koja leti prema cilju. Sistem GNSS omogućava uvid u pravac severa i položaj sredstva na radnoj karti, zato mora da ispuni zahteve koji se odnose na njegove funkcionalne karakteristike koje moraju biti u granicama dozvoljene greške pri njegovoj eksploataciji. Provera funkcionalnih karakteristika GNSS se vrši sa ciljem da greške određivanja orjentacije i pozicije sredstva na kome je uređaj ugrađen, koje treba da budu u dozvoljenim granicama, tj. nepoklapanje očitanih koordinata i koordinata referentne tačke mora biti u okviru granica koje su definisane.

Ključne reči: GNSS, referentna vrednost ugla azimuta (direktrisa), greška merenja ugla azimuta, greška određivanja orjentacije, greška pozicije

ML2.9 (#5899)
POSTUPCI ISPITIVANJA UTICAJA RAZLIČITIH SREDINA NA FUNKCIONALNOST I MASKIRNOST SREDSTAVA I VOJNE OPREME

Marina Tripković, Milena Jovanović

U prirodnim uslovima teško je odvojiti efekte temperature, vlažnosti, sunčeve radijacije i kiše kojima su često izloženi uređaji koji se primenjuju u vojsci. Laboratorijskim ispitivanjem izdržljivosti uređaja na klimomehanički uticaj sredine, ovi efekti su odvojeni, što predstavlja pogodnost za ispitivanje. Elektronska oprema se koristi obično u uslovima teških klimatskih, hemijskih, fizičkih i mehaničkih naprezanja. Ona se skladišti u različitim klimatskim uslovima i za vreme transporta izložena je različitom mehaničkom naprezanju. Postupci i metode laboratorijskog ispitivanja imaju za cilj da

se utvrdi otpornost uređaja na određena klimomehanička naprezanja u raznim uslovima eksploatacije, skladištenja i transporta. Terenske metode ispitivanja imaju za cilj da se proveri maskirna zaštita vojnih sredstava i opreme u toku istraživanja razvoja i proizvodnje.Ove metode se zasnivaju na analizi snimka ili fotografije napravlje najčešće termovizijskom kamerom, gde temperature objekta ispitivanja predstavlja kontrolni factor. Laboratorijske i terenske metode ispitivanja objekata propisane su vojnim standardom SNO 5706/84 i SNO 8671/01.

Ključne reči: maskirna zaštita, maskirna mreža, IC zračenje, merenje temperature, termovizijska kamera, IC snimak, laboratorijsko ispitivanje, terensko ispitivanje

MLI2.2 (#5899)
AI-BASED PERSONALIZED APPROACH IN TEACHING MEASUREMENT SCIENCE

Milan Dinčić, Jelena Jovanović, Dragan Denić, Goran Miljković, Mare Srbinovska, Marco Faifer, Ivana Ranđelović, Živko Kokolanski, Vladimir Dimčev, Loredana Cristaldi, Christian Laurano, Kiril Demerdžiev, Sina Ronaghi, Dejan Ćirić, Goran Nikolić

This paper presents an AI-driven personalized learning approach for measurement science education aligned with Industry 4.0 and Industry 5.0 principles. It integrates key technologies such as intelligent sensors, IoT, artificial intelligence, Digital Twins, predictive maintenance, energy harvesting, and sensor fusion into a modular curriculum supported by adaptive learning pathways and continuous assessment. The approach combines AI-based personalization with innovative teaching methodologies, including flipped classroom, collaborative learning, simulation-based learning, game-based learning, and industrial case studies. To support these methods, a set of 55 digital teaching materials was developed, comprising simulations, multimedia tutorials, instructional videos, and industrial case studies. The proposed solution establishes a flexible and student-centered educational ecosystem tailored to students' needs and interests, enhancing engagement, strengthening practical competencies, and improving alignment between measurement science education and modern industrial requirements.

Ključne reči: measurement science education, personalized learning, artificial intelligence, Industry 5.0

СЕСИЈА / SESSION (MLI3)

Четвртак, 11. јун / Thursday, June 11th Сала 5 / Hall 5 9.00-11.45

Председавајући / Chair:
Marjan Urekar, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
Jelena Đorđević Kozarov, Fakultet tehničkih nauka, Novi Sad, Srbija

MLI3.1 (#4016)
TEN METROLOGICAL PRINCIPLES FOR UNDERSTANDING AND COUNTERING COGNITIVE WARFARE

Marjan Urekar

Cognitive Warfare (CW) is the deliberate manipulation of human perception, belief, and decision-making through the weaponization of information and it is the defining security challenge of the information age. Enabled by modern technologies, mainly artificial intelligence, amplified by social media algorithms, classic mass media manipulation and refined by decades of psychological operations research, it operates at a scale and

precision previously impossible. Yet, cognitive defense remains qualitative and methodologically incoherent. The root cause is a measurement problem and this paper argues that metrology (the science of measurement) provides the missing formal and conceptual structure, not previously recognized in CW theory. Drawing on the International Vocabulary of Metrology (VIM - JCGM 200), the Guide to the Expression of Uncertainty in Measurement (GUM - JCGM 100), and ISO/IEC 17025:2017, the paper presents ten key principles and show the base role of metrology in CW, using direct analogies how each applies to detecting and suppressing cognitive attacks. Measurement Uncertainty in its basic Type A (statistical) and Type B (structural and adversarial) forms, is placed at the operational center of this new framework.

Keywords: Cognitive Warfare, Metrology, Measurement Uncertainty, GUM, VIM, ISO/IEC 17025, Disinformation, AI manipulation, Psyops

MLI3.2 (#0365)
LOW-COST SENSORS VS INDUSTRIAL METERS IN URBAN DRAINAGE SYSTEMS: BENCHMARKING MEASUREMENT UNCERTAINTY

Damjan Ivetić, Robert Ljubičić, Miona Tomić, Ljiljana Brajović, Miloš Milašinović

Urban Drainage Systems are part of the critical urban infrastructure, needed to enable safe, healthy and comfortable urban living areas. Their task is to mitigate the pluvial flooding risks, or to facilitate the collection of the surface runoff into the underground network of pipes, peak runoff detention/retention and safe release into the receiving water body. Urban Drainage System (UDS) operational control and management rely strongly on the monitored values of relevant hydraulic parameters within the network at key, characteristic locations. From the technical perspective, by increasing the number of measurement locations and reliability of the measurements used in the control process, better operational decisions can be made. Lately, the research spotlight is placed on the possibility of the application of the Digital Twins of the Urban Drainage Systems, for improved system control. To enable real-time representativeness of the Digital Twins it must be supplied with a large amount of reliable measured data. Often, a number of new measuring locations must be established. However, due to the nature of the Urban Drainage Systems, measurements of the hydraulic parameters are complicated, expensive and often attributed to unacceptably high measurement uncertainties. An attempt to address these issues by employing the so called “low-cost” sensors is investigated intensively, and mixed results are achieved. Here, the results of the measurement uncertainty laboratory benchmarks of the selected low-cost and industrial (conventional) meters are presented, obtained within the scope of DIGIDRAIN project. Practical implications are discussed and future field tests are presented.

Keywords: Flow rate measurements, Water level measurements, Urban Drainage Systems, Low-cost sensors, Measurement uncertainty, Laboratory benchmarking

MLI3.3 (#2688)
AN ARDUINO–PYTHON PLATFORM FOR NEAR REAL-TIME SIGNAL ACQUISITION SYSTEMS: DESIGN AND THREE-PHASE IMPLEMENTATION

Goran Vuković, Miodrag Forcan, Đorđe Kovačević, Djuradj Budimir

This paper presents the design and implementation of an Arduino–Python platform for near real-time multi-channel signal acquisition systems, demonstrated through a three-

phase electrical measurement application. The proposed platform integrates an analog signal conditioning board, an Arduino MEGA board for analog-to-digital conversion (ADC), and a PC-based Python application for continuous serial data acquisition and processing, visualization, and storage. Communication between the board and the host computer is established via USB serial interface, enabling continuous acquisition and monitoring of six channels (three voltages and three currents). The capabilities of the platform are evaluated experimentally in a laboratory setup involving a three-phase induction motor. A cohesive data processing pipeline that facilitates the seamless transition from hardware acquisition to Python-based analysis is proposed. The results demonstrate the applicability of the developed platform for laboratory-scale three-phase monitoring and signal analysis.

Keywords: Three-phase signals, Data acquisition, Arduino MEGA microcontroller, Python application

MLI3.4 (#8474)
TOWARD A DIGITAL TWIN OF THE GARRETT SOLENOID FOR TRACEABLE LOW MAGNETIC FIELD METROLOGY

Miloš Davidović, Michal Ulvr, Milena Davidović, Plamen Stamenov, Stuart Harmon, Marco Coisson

This paper presents initial developments of the digital twin for the Garrett solenoid developed within the framework of 24RPT02 MetroMag project. The project aims to strengthen capabilities of European National Metrology Institutes (NMIs) in performing traceable measurements in the low magnetic field range. Garret solenoid was identified as the most suitable to be used as a traveling transfer standard between NMIs to enable easier and faster intercomparison. The development of the digital twin of the Garrett solenoid will aid in documenting transfer standard, associated experimental setups and can aid in estimation of the uncertainty components in magnetic field metrology.

Keywords: digital twin, DC magnetic field metrology, interlaboratory comparison, magnetic field sensing, Garrett solenoid

MLI3.5 (#0438)
IMPROVEMENT OF LPG MASS MEASUREMENT ACCURACY ON A TRUCK SCALE USING AN OPTICAL VEHICLE POSITIONING SYSTEM

Lazar Stojčević, Bojan Petrović, Marjan Urekar

Truck scales are essential measurement systems in industrial logistics, where vehicle mass directly affects financial transactions, safety, and process control. Measurement accuracy depends not only on the metrological characteristics of load cells but also on correct vehicle positioning on the weighing platform. Improper positioning introduces systematic errors due to partial support outside the platform, uneven load distribution, and dynamic instability. This paper presents an optical system for verifying vehicle position on a truck scale in an LPG storage facility. The system is based on photoelectric sensors, a PLC controller, and video surveillance, enabling automatic validation of measurement conditions. The proposed solution prevents weighing when metrological conditions are not satisfied, thereby improving measurement accuracy, repeatability, and reliability. Experimental analysis shows that measurement error can be reduced from several percent (up to 5%) to below 0.1%, corresponding to a reduction of absolute error from approximately 2000 kg to less than 40 kg. The system also enables improved

traceability and integration with higher-level control and enterprise systems in accordance with Industry 4.0 principles.

Keywords: truck scale, LPG, metrology, positioning, PLC

MLI3.6 (#5080)
MEASUREMENT, ACQUISITION AND PROCESSING OF BIOPOTENTIAL SIGNALS FOR EARLY DETECTION OF SLEEP PARALYSIS

Natasa Stojnic, Marjan Urekar

This paper presents a conceptual design of a wearable system for detecting and interrupting sleep paralysis in order to help patients with this disorder. The proposed solution, envisioned as a smart headband, integrates an accelerometer, electrooculography (EOG), and electroencephalography (EEG) for precise monitoring of the user's condition. The detection methodology is based on a hierarchical logic: first, the absence of head movement is analyzed, then the REM phase is identified through the analysis of the EOG signal, while the final confirmation is performed by analyzing the spectral analysis of the EEG signal (FFT and PSD). In a practical implementation, the system is expected to store recorded data and detected events for later analysis.

Keywords: Sleep paralysis, REM phase, BCG, alpha waves, theta waves, EEG, EOG

MLI3.7 (#5291)
ENHANCING THE METROLOGICAL PERFORMANCE OF AUTOMATED FUEL MARKING SYSTEMS: A TRANSITION FROM VOLUMETRIC TO MASS FLOW MEASUREMENT

Bojan Petrović, Lazar Stojčević, Marjan Urekar

Governments often tax fuel products to generate revenues to support and stimulate their economies. They also subsidize the cost of essential fuel products. Fuel taxation and subsidization practices are both subject to fraud. Oil marketing companies also suffer from fuel fraud with loss of legitimate sales and additional quality and liability issues. The use of an advanced marking system to identify and control fraud has been shown to be effective in controlling illegal activity. In order to avoid incorrect detection of the presence of markers, marking systems must enable accuracy, repeatability, and reliability during measurement. In case it turns out that the concentration of markers in the fuel tank at the gas station or in fuel truck is lower or higher than prescribed, the tank or fuel truck would have to be put out of use in order to carry out additional control by authorized state authorities - which causes negative effects on the volume of fuel sales, i.e. leads to financial losses for oil company. Consequently, the selection of a suitable marker measurement system represents a critical aspect of the overall process

Keywords: fuel marking, volumetric measurement, mass measurement, inline blending, metrology

MLI3.8 (#5659)
REAL-TIME ANALOG–DIGITAL SYSTEM FOR MOTOR VIBRATION DETECTION AND ADAPTIVE PWM CONTROL FOR MECHANICAL OSCILLATION REDUCTION

Aleksej Zirojević, Marjan Urekar

Mechanical vibrations are among the most significant indicators of mechanical degradation and improper operation in electric motor–driven systems. Conventional

motor control strategies rely on static Pulse Width Modulation (PWM) parameters, which do not adapt to changing mechanical conditions during operation. This paper presents a real–time analog–digital system for vibration detection and adaptive PWM regulation aimed at reducing mechanical oscillations in electric motors. The proposed system integrates a MEMS accelerometer, real–time signal acquisition and digital processing, and adaptive PWM control implemented on an STM32 Cortex–M microcontroller platform. The key contribution of this work is the direct inclusion of vibration feedback into the motor control loop, enabling real time adaptation of PWM parameters without complex control algorithms or computationally intensive motor models. The solution is designed to be low–cost, resource–efficient, and suitable for embedded and industrial systems, offering improved motor stability, reduced vibration levels, and extended operational lifetime.
Keywords: motor vibrations, adaptive PWM control, MEMS accelerometer, STM32, real–time embedded systems

MLI3.9 (#2225)
TROUBLESHOOTING MODBUS RTU RS-485 COMMUNICATION IN INDUSTRY 4.0 APPLICATIONS

Ana Lazarević, Marjan Urekar

This paper analyzes common communication problems in Modbus RTU networks based on the RS-485 physical layer in industrial systems within the context of Industry 4.0. In such environments, reliable field-level communication is essential for enabling real-time data acquisition, system interoperability, and data-driven industrial processes. The focus is on installation-related issues, including improper topology, incorrect termination, excessive bus length, a high number of connected devices, and electromagnetic interference. Communication quality is evaluated using CRC and timeout errors as indirect indicators of transmission reliability and signal integrity. The physical causes of these problems and their typical manifestations in real systems are discussed. In addition, practical troubleshooting guidelines and corrective measures are proposed. The results indicate that most communication issues originate from improper implementation of the RS-485 physical layer rather than from the Modbus protocol itself.
Keywords: Modbus RTU, RS-485, industrial communication, bus topology, signal integrity, Industry 4.0

ML3.10 (#9658)
DESIGN OF A SMART RECYCLING SYSTEM USING MULTISPECTRAL SENSORS AND READL-TIME CONTROL

Stana Petrovic, Marjan Urekar

This paper presents the design and partial implementation of a smart recycling system aimed at automatic classification and sorting of plastic waste. The system is based on an STM32 microcontroller and combines a proximity sensor for object detection with a multispectral sensor for material analysis. A functional prototype was developed using Proximity Click and Spectral 3 Click modules, where reflected light measurements are processed in real time using a FreeRTOS based software architecture. A simple threshold-based classification algorithm is applied to distinguish between clean plastic and plastic with labels. Experimental testing on a set of plastic samples demonstrated that the system can identify differences in spectral response and perform basic sorting. However, limitations related to environmental conditions and classification accuracy were observed. The proposed solution represents a low-cost and modular approach

suitable for embedded applications and serves as a basis for further improvement using advanced classification methods.

Keywords: smart recycling, multispectral sensing, plastic sorting, STM32, real time systems, FreeRTOS, embedded systems

МИКРОЕЛЕКТРОНИКА И ОПТОЕЛЕКТРОНИКА / MICROELECTRONICS AND OPTOELECTRONICS

СЕСИЈА / SESSION (MO1+MOI1)

Уторак, 9. јун / Tuesday, June 9th Сала 4 / Hall 4 14.30-16.30

Председавајући / Chair:
Zoran Prijić, Faculty of Electronic Engineering, University of Niš, Serbia

MOI1.1 (#0889)
LIVING CELL AS A NONLINEAR ELECTRICAL SYSTEM

Slobodanka Galovic, Dalibor Chevizovich, Zoran Ivic, Masa Tiosavljevic, Giorgos P. Tsironis, Ermuhammad Dushanov

This paper investigates a model of the electrical activity of a single cell with two gating variables and three critical thresholds (uv, uc, 〖u〗_c^si), which introduce additional discontinuous nonlinearities into the system dynamics. It is shown that the resulting formulation belongs to the class of coupled Filippov differential inclusions and may exhibit non-uniqueness of solutions and path-dependent transient behavior in the vicinity of the thresholds. To provide a physical interpretation of these phenomena, an equivalent electrical representation is developed in terms of a network of capacitors, resistors, and voltage-controlled current sources with feedback. The analysis reveals that the model requires the introduction of nonstandard voltage-controlled current sources involving products of the membrane potential and gating variables, as well as ideal switching elements. It is precisely the combination of smooth nonlinearities and ideal thresholds that leads to multivalued vector fields and non-unique transient trajectories. To address this issue, the use of a realistic diode current–voltage characteristic is proposed in place of ideal switching elements. This modification naturally introduces a finite transition time, which physically corresponds to delays in the gating dynamics and, mathematically, results in a smooth regularization of the thresholds. As a consequence, the system transitions from a differential inclusion framework to a system of coupled nonlinear differential equations with a unique solution. These results suggest that the observed non-uniqueness in idealized models may stem from the neglect of intrinsic time scales, and that their proper incorporation leads to a more consistent and physically realistic description of membrane potential dynamics.

Keywords: membrane potential, nonlinear electrical system, differential inclusion, Filippov problem

MOI1.2 (#4379)
ANALYSIS OF RADIATION-INDUCED VARIATION OF ELECTRICAL PARAMETERS IN SIO_2 AND HFO_2/ SIO_2 RADFETS

Miloš Marjanović, Danijel Danković, Goran Ristić, Sandra Veljković, Nikola Mitrović, Erhan Budak, Sandra Miljković, Ercan Yilmaz, Umutcan Gurer, Ozan Yılmaz

This paper presents the fabrication and characterization of RADFET radiation sensors with different gate dielectrics: SiO2 (300 nm and 100 nm) and HfO2/SiO2 (40/5 nm). The devices were irradiated using a 60Co gamma source up to a total dose of 100 Gy. Electrical characterization was performed through transfer characteristics, transconductance, and threshold voltage extraction. The results show a strong dependence of sensitivity on the gate dielectric, with higher sensitivity observed for thicker SiO2 layers compared to the HfO2-based structure.

Keywords: RADFET, MOSFET sensors, threshold voltage shift, ionizing radiation, high-k dielectrics

MOI1.3 (#4738)
INTRODUCTION TO APECS - HETEROGENEOUS INTEGRATION OF ELECTRONIC COMPONENTS AND SYSTEMS

Goran Panic, Matthias Wietstruck, Farabi Ibne Jamal, Markus Fritscher, Batuhan Sütbas, Andreas Mai

This paper gives an overview of IHP activities within the APECS project, a pilot line for heterogeneous integration and advanced packaging technologies, focused on strengthening Europe's semiconductor manufacturing capabilities and chiplet innovation. The activities include the development of wafer-to-wafer and die-to-wafer CMOS-to-BiCMOS Al-to-Al bonding technology, the development of an open source design kit for the IHP Si-interposer process technology, heterointegration of D-band and H-band RF circuits, and the implementation of RISC-V based chiplet for a multi-material sensor demonstrator.

Keywords: heterointegration, packaging, bonding, chiplet, RISC-V

MOI1.4 (#6714)
DETERMINATION OF OPTICAL PROPERTIES OF TWO-LAYER POLYMERS USING PHOTOACOUSTICS AND PHYSICS-BASED MACHINE LEARNING

Miroslava Jordović Pavlović, Marica Popović, Slobodanka Galović, Dalibor Čevizović, Matija Tiosavljević and Konstantin Chizhov

This paper addresses the partial inverse problem in a high-dimensional parametric forward two-layer system in photoacoustics, aiming to estimate layer thickness and optical absorption parameters from frequency-domain amplitude and phase responses. The proposed approach follows a physics-based machine learning optimization procedure and belongs to a class of model-based methods grounded in analytical solutions. A neural network is trained to predict the unknown parameters, while an analytical forward model, derived from the governing equations, is embedded into the loss function. The training objective combines a data-driven component with a physics-based constraint that enforces data consistency, an agreement between numerical experiments and those reconstructed from the predicted parameters through the forward operator. We evaluate the inverse problem on a parametrized forward operator by sampling its output over a defined parameter space. The results demonstrate accurate and stable low-dimensional parameter recovery under model overparameterization, highlighting the effectiveness of integrating an analytical model with data-driven optimization and proving inverse optimization under model degeneracy.

Keywords: photoacoustics, two-layer system, inverse problem, physics-based machine learning, parameter estimation

MO1.1 (#6938)
ANALIZA METODOLOGIJE EKSTRAKCIJE PARAMETARA STATIČKOG SPICE MODELA N-KANALNOG JFET-A

Aleksandra Stojković, Zoran Prijić, Aneta Prijić, Vesna Paunović

Rasipanje električnih parametara pojedinačnih primeraka JFET-a u okviru jedinstvenog tipa zahteva ekstrahovanje parametara SPICE modela ovih tranzistora na osnovu eksperimentalnih strujno-naponskih karakteristika seta uzoraka. U ovom radu su primenjene tri metodologije određivanja parametara statičkog SPICE modela n-kanalnog JFET-a J112. Eksperimentalna merenja odgovaraju uslovima testiranja datim u tehničkim specifikacijama komponente kako bi se izbeglo samozagrevanje. Verifikacija pojedinačnih metodologija je sprovedena primenom modela u LTspice-u i poređenjem dobijenih strujno-naponskih karakteristika sa eksperimentalnim. Ukazano je na najpogodniju metodologiju u zavisnosti od oblasti rada, odnosno konkretnu primenu JFET-a.

Ključne reči: n-kanalni JFET, SPICE model, ekstrakcija parametara, eksperimentalne strujno-naponske karakteristike

MO1.2 (#9953)
УТИЦАЈ ФОТОГЕНЕРИСАНИХ НОСИЛАЦА НАЕЛЕКТРИСАЊА НА ФОТОАКУСТИЧКИ ОДЗИВ ПОЛУПРОВОДНИКА: ПРЕНОСНА ФУНКЦИЈА И СТРУКТУРА НУЛА И ПОЛОВА

Slobodanka Galović, Matija Tiosavljević, Dragan Todorović

У овом раду развијамо операторску формулацију фотоакустичког одзива полупроводника, у којој се спрегнути систем дифузионих и таласних једначина представља преко резолвента у Лапласовом домену. Преносна функција која повезује оптичку побуду и мерени акустички сигнал добија се као пројекција резолвента на мерене величине, што омогућава доследну анализу у временском домену. Добијени одзив има структуру суперпозиције више изворних канала филтрираних термалном и акустичком пропагацијом. Оваква формулација омогућава раздвајање улоге пропагационих процеса и механизама генерисања извора: доминантни полови су одређени термалним и акустичким транспортом, док фотогенерисани носиоци утичу на одзив кроз модификацију амплитуда и фаза појединачних канала, што доводи до појаве нула у укупној преносној функцији. Показујемо да облик преносне функције зависи од карактеристичних просторних и временских скала система, при чему се у одређеним лимитима може свести на ефективне рационалне апроксимације. Овај приступ пружа основу за систематску анализу различитих режима (танак/дебео узорак, кратка/дуга времена) и указује да се избором побуде — посебно поворком импулса са контролисаним параметрима — може управљати релативним доприносима појединачних канала и осетљивошћу на параметре носилаца.

Кључне речи: фотоакустика, полупроводници, временски домен, преносна функција, анализа сигнала

СЕСИЈА / SESSION (MOI2)

Среда, 10. јун / Wednesday, June 10th Сала 4 / Hall 4 9.00-11.15

Председавајући / Chair:
Dana Vasiljević Radović, IHTM-CMTM, Beograd, Srbija

MOI2.1 (#2340)
PARKING SYSTEM BASED ON THE STATIC ANALYSIS OF THE MAGNETIC FIELD

Milan Stojanović, Ljubomir Vračar

Vehicle detection using magnetic field sensors offers significant advantages over alternative methods such as inductive loops or video surveillance. The analysis of dynamic variations in the magnetic field induced by passing vehicles provides higher detection accuracy; however, it is associated with increased energy consumption. As an alternative, a static analysis approach based on periodic sampling is presented in this paper. The issue of detection dead zones—characterized by minimal or negligible variations in the magnetic field along the vertical measurement axis—can be effectively mitigated through the use of a three-axis magnetic sensor and by analyzing the magnitude of the magnetic field.

Keywords: parking system, vehicle detection, magnetic field, magnitude, threshold algorithm

MOI2.2 (#1592)
DESIGN AND FABRICATION OF DRY TI/PDMS FLEXIBLE ELECTRODES FOR WEARABLE ECG MONITORING BELTS

Milena Rašljic Rafajilović, Miona Tomić, Marko Bošković, Miloš Vorkapić, Marija Pergal, Dana Vasiljević Radović and Stefan Ilić

This paper presents the successful design and fabrication of dry, flexible bioelectrodes for electrocardiographic (ECG) measurements. Bioelectrodes were fabricated using flexible materials, such as poly(dimethylsiloxane) (PDMS), and a conductive material, titanium (Ti). Three electrodes were integrated into a belt worn around the chest, with one centrally placed electrode and two distributed to the left and right relative to the chest. This configuration ensures sufficient distance and a stable measurement geometry. The analysis was performed on two longer segments of the signal, labeled as part 1 and part 2, as well as on a short representative segment selected to show signal morphology. HeartPy processing with six-fold temporal upsampling yielded an estimated heart rate of 78.99 bpm for part 1 and 78.90 bpm for part 2. In a short representative segment, QRST components were clearly observed, with a QRS duration of 79.6 ms for the isolated beat. The mean RR interval in that segment was 813.9 ms, corresponding to a heart rate of 73.7 bpm. The results show that with the described configuration, it is possible to register a usable ECG signal with clearly recognizable QRS complexes and T wave.

Keywords: PDMS, flexible electrodes, ECG, Ti, wearable bioelectronics

MOI2.3 (#6932)
A LASER-INDUCED GRAPHENE SENSOR WITH 24-BIT ADC READOUT FOR RADIAL ARTERY PULSE WAVEFORMS

Stefan D. Ilić, Teodora Vićentić, Marko Spasenović

This study demonstrates radial artery pulse waveform acquisition using a laser-induced graphene (LIG) sensor and custom readout electronics. The LIG element was patterned on polyimide tape and mounted at the wrist site of a commercial pulse assessment simulator (BT-CEAB2). The sensor was operated with constant-current excitation, and the voltage drop was digitized using a 24-bit delta-sigma ADC (ADS1220) controlled by an ATmega328P microcontroller. Two-minute recordings were stable and low-noise, enabling robust peak detection with the HeartPy toolkit. The signal quality also allowed clear identification of diastolic peaks following systolic events, and a lightweight peak-

pair algorithm was applied to quantify systolic-to-diastolic timing. The mean systolic-to-diastolic delay was $\Delta t = 169.29$ ms. These results support the use of LIG sensing with compact, high-resolution constant-current readout for future embedded pulse-parameter monitoring.

Keywords: laser-induced graphene, constant-current excitation, ADS1220, 24-bit ADC, microcontroller, pulse simulator, BT-CEAB2, systolic, diastolic, peak detection

MOI2.4 (#0848)
DEVELOPMENT OF A FLEXIBLE MXENE@POLYESTER STRAIN SENSOR FOR EYEBROW MOTION DETECTION

Ivan Pešić, Miona Tomić, Milena Rašljić-Rafajilović, Marko Bošković, Stefan Ilić, Marija Pergal

Wearable sensors capable of detecting subtle facial movements are of increasing interest for healthcare monitoring and assistive communication. In this work, a novel flexible piezoresistive sensor based on MXene@polyester is developed for high-sensitivity detection of eyebrow motion. Ti3C2Tx MXene nanosheets were synthesized via a minimally intensive delamination method (MILD) and deposited onto a woven polyester substrate using vacuum-assisted filtration, forming a uniform and conductive network. Titanium electrodes were sputter-deposited to ensure robust electrical contacts and device flexibility. Scanning electron microscopy (SEM) confirmed the formation of layered MXene structures. Sensor performance was evaluated through real-time measurements, with voltage converted to resistance and $\Delta R(t)$ processed using filtering and peak detection algorithms. The device exhibited stable and reproducible responses to impulsive, sustained, and frowning eyebrow movements. Distinct signal features, including peak amplitude, temporal spacing, and plateau formation, enabled reliable gesture discrimination. Notably, impulsive movements produced periodic responses, sustained movements generated stable plateaus, and frowning induced the highest signal amplitudes. The 50 Ω value refers to MXene@PES before titanium sputtering and silver-paste contacts, while eyebrow-motion data are reported as $\Delta R(t)$ in kΩ; the best signal-to-noise ratio (SNR) was approximately 38 dB, and the mean 10–90% rise time was approximately 211 ms. These results demonstrate that MXene-coated polyester fabrics are a promising platform for sensitive detection of low-strain facial deformations in wearable systems.

Keywords: Mxene, polyester, flexible wearable strain sensor, electrical properties, healthcare monitoring

MOI2.5 (#6669)
TRANSIENT CURRENT TECHNIQUE CHARACTERIZATION OF THE FN80 SILICON PHOTODIODE

Milija Sarajlić, Gregor Kramberger, Stefan Ilić, Bojan Hiti

This paper presents a detailed investigation of the transient charge transport properties of the FN80 silicon photodiode using the Transient Current Technique (TCT). The study addresses a clear research gap, as this type of diode has not previously been characterized with nanosecond temporal resolution using TCT methods. The FN80 device, based on a p–i–n silicon structure, was analyzed using a 980 nm pulsed laser with a spatial resolution of 10 μm, enabling precise mapping of the active area. The resulting electrical signals were recorded with a high-speed oscilloscope and processed to extract key parameters, including charge collection time and generated charge distribution. The results demonstrate the high quality and speed of the FN80 photodiode, highlighting its strong

potential for applications in high-energy physics and synchrotron-based X-ray detection systems.

Keywords: Transient Current Technique (TCT), Photodiode FN80, Charge Transport Dynamics, Time-of-Flight Analysis, High-Speed Semiconductor Detectors

MOI2.6 (#5506)
ALL-DIELECTRIC QBIC METASURFACES AS PLATFORMS FOR SIMULTANEOUS ENHANCEMENT OF PHOTOCATALYTIC PROCESSES AND REFRACTOMETRIC SENSING IN MICROREACTORS

Marko Obradov, Olga Jakšić, Katarina Radulović, Ivana Mladenović, Dana Vasiljević Radović

We present an approach to add functionality to all-dielectric metasurfaces for simultaneous enhancement of photocatalytic processes and refractometric sensing of microreactor channel content by utilizing qBIC states in the visible optical range. We numerically modeled the optical properties of two types of optical metasurfaces: titanium dioxide on silica and silicon on silica. The TiO2 metasurface is ideally suited for the sensing aspect of the desired functionality and enables higher levels of optical field enhancement. However, due to the lack of optical absorption in the semiconductor, additional steps are necessary to use this field enhancement for photocatalysis, though there is some flexibility in how to utilize the supported modes of the structure. The silicon metasurface, on the other hand, uses all supported modes for enhancement of photocatalytic processes due to the high material losses in the semiconductor, but it is practically mandatory to use the added qBIC mode for refractometric sensing.

Keywords: metasurfaces, qBIC, semiconductors, photocatalysis, microreactors

МИКРОТАЛАСНА ТЕХНИКА, ТЕХНОЛОГИЈЕ И СИСТЕМИ / MICROWAVE TECHNIQUE, TECHNOLOGIES AND SYSTEMS

СЕСИЈА / SESSION (MTI1+MT1)

Уторак, 9. јун / Tuesday, June 9th Сала 4 / Hall 4 10.30-11.45

Председавајући / Chair:
Nebojša Dončov, University of Niš, Faculty of Electronic Engineering, Niš, Serbia

MTI1.1 (#6612)
ON THE RELIABILITY OF WAVE DIGITAL MODELS FOR WILKINSON POWER SPLITTERS WITH ARBITRARY SPLIT RATIOS

Biljana Stošić, Marin Nedelchev, Zlatica Marinkovic

The paper presents wave digital models of Wilkinson power splitters for both equal-split and unequal-split (symmetric and asymmetric) configurations. Wilkinson-type splitters are widely used in RF (radio frequency) and microwave circuits for their matched ports and inherent isolation. By translating conventional designs into wave digital frameworks, the proposed models capture power division, reflection, and isolation characteristics efficiently. Unequal-split models are demonstrated to handle arbitrary division ratios while maintaining numerical stability. Simulation results confirm the accuracy of the wave digital models compared to standard circuit simulators, highlighting their potential for rapid analysis, optimization, and prototyping of multiport RF networks. The novelty

of this work lies in providing a unified wave digital modeling approach that efficiently represents both equal and unequal power splits, offering improved computational efficiency and intuitive insight into energy flow in complex microwave circuits.

Keywords: equal and unequal power split, symmetric and asymmetric Wilkinson power splitter, Wilkinson power splitter, Wave Digital Models

MTI1.2 (#6688)
PERFORMANCE COMPARISON OF HARMONIC TAG WITH RF ENERGY HARVESTING CIRCUIT FOR SINGLE-TONE AND DUAL-TONE EXCITATIONS

Aleksandra Đorić, Aleksandar Atanasković, Ksenija Mladenović, Tijana Dimitrijević, Nataša Maleš Ilić

This paper presents an investigation of an integrated harmonic tag combined with an RF energy harvesting circuit implemented in microstrip technology. The study considers both single-tone excitation and dual-tone signals with frequency offsets of 1 kHz, 1 MHz, and 10 MHz. The proposed design incorporates two textile patch antennas operating at 2.45 GHz and 4.9 GHz, along with a harmonic tag functioning at these frequencies. The tag includes a nonlinear element, specifically a Schottky diode, which enables the generation of harmonic components. A diplexer is employed to separate the fundamental frequency from the 2nd harmonic, while the energy harvesting module utilizes a voltage doubler rectifier operating at 2.45 GHz. To ensure efficient energy transfer across the system, impedance matching networks are carefully designed between the antennas and the harmonic tag, as well as between the rectifier and the tag. The performance of the system is evaluated through simulations carried out in Keysight Advanced Design System (ADS) under different input power conditions. The obtained results provide insight into the behavior of both the harmonic tag and the RF energy harvesting circuit, including metrics such as generated 2nd harmonic power, harvested DC output, and overall conversion efficiency.

Keywords: harmonic tag, RF energy harvesting, RF rectifier, Schottky diode, voltage doubler

MTI1.3 (#0248)
POSSIBILITIES OF A NEW SIW CAVITY AS A MICROWAVE DIELECTRIC WATER SENSOR

Dusan Nesic

An experiment with a specially made microwave SIW cavity sensor was given. The SIW cavity structure consists of a microstrip tape on a substrate which is then completely covered with metallization using conductive textile, without via-holes. The material under test (MUT) area is a formed rectangular hole in the SIW structure that has only the bottom metallization. Specific experiments with water as MUT were tested.

Keywords: microwaves, microstrip, SIW cavity, dielectric sensor, conductive textile

MTI1.4 (#8780)
ANN-BASED APPROACH FOR EFFICIENT BANDWIDTH ESTIMATION OF BLADE DIPOLE ANTENNAS

Ksenija Mladenović, Zoran Stanković, Nebojša Dončov and Olivera Pronić-Rančić

This paper presents an approach based on electromagnetic (EM) analysis and artificial neural networks (ANN) for the efficient bandwidth estimation of a planar blade dipole

antenna. The neural model is based on a MultiLayer Perceptron (MLP) architecture, which relates the antenna's geometric parameters, specifically its length and tapering coefficient, to the lower and upper operating frequency bounds. The results demonstrate that the proposed MLP model provides high predictive accuracy with a drastic reduction in computational time compared to conventional EM simulations, making it an effective tool for rapid antenna design.

Keywords: blade dipole antenna, EM model, ANN model

MTI1.5 (#4207)
NUMERICAL ANALYSES OF HUMAN BODY IMPACT TO PARAMETERS OF WEARABLE ANTENNA UNDER DEFORMATIONS

Jugoslav Joković, Tijana Dimitrijevic, Aleksandar Atanasković, Nebojsa Dončov

This paper investigates the impact of the human body on impedance matching of wearable microstrip antennas under bending conditions. A cylindrical 3-D Transmission Line Matrix (TLM) in-house solver with conformal mesh is used for parametric analysis, enabling accurate modeling of curved geometries and antenna–body interaction. The study focuses on separating body-induced effects on reflection coefficient and resonant frequency from bending deformation-related mechanisms such as patch elongation, substrate thickness reduction, and permittivity variation. Results show that body loading significantly degrades impedance matching, while bending can partially reduce this effect by decreasing electromagnetic coupling with tissue. The proposed approach provides an efficient and physically consistent framework for predicting antenna performance in realistic wearable environments.

Keywords: Wearable antennas, bending, impedance matching, body loading, cylindrical TLM, conformal modeling

НОВИ МАТЕРИЈАЛИ / NEW MATERIALS IN ELECTRICAL AND ELECTRONIC ENGINEERING

СЕСИЈА / SESSION (HM1+NMI1)

Уторак, 9. јун / Tuesday, June 9th Сала 1 / Hall 1 9.00-11.00

Председавајући / Chair:
Nebojša Mitrović, University of Kragujevac, Faculty of Technical Sciences, Čačak, Serbia
Vesna Paunović, University of Niš, Faculty of Electronic Engineering, Niš, Serbia

NMI1.1 (#3770)
THICKNESS–MORPHOLOGY CORRELATIONS AND EFFECTIVE MEDIUM DESCRIPTION IN P3HT:PCBM ORGANIC SOLAR CELLS INVITED LECTURE

Jovana Gojanović

As classical silicon electronics approach the physical limits of Moore's Law and the global energy transition demands rapid advancements in solar photovoltaics, organic semiconductors have emerged as a distinct material class to address both challenges. Organic solar cells (OSCs) offer unique advantages over silicon photovoltaics, including mechanical flexibility, solution-based processing, and tunable optical properties. This study focuses on the intrinsic characteristics of organic materials that directly influence solar cell performance, specifically addressing recent trends in thickness-insensitive

devices and donor/acceptor (D/A) interface orientation. In light of these advancements, the authors previous findings are reviewed and their implications are highlighted. Prior investigations analyzing P3HT:PCBM based OSCs with different active layer thicknesses (ALTs) operating in both photodetector and solar cell modes was reconsidered. A comprehensive drift–diffusion model was utilized to reproduce experimental photocurrent spectra and current density-voltage characteristics. The research demonstrated a non-monotonic variation of optical and electrical parameters with ALT, revealing strong and tight correlation between film thickness and morphology. Furthermore, comparable performance between bilayer and bulk heterojunction (BHJ) devices challenges the common assumption that BHJ materials function as a single effective medium. Instead, the findings indicate that spatial arrangement and domain orientation strongly influence charge carrier photogeneration and recombination, proving that BHJ materials must be treated as ensembles of D/A interfaces rather than homogeneous layers.

Keywords: organic semiconductors, organic solar cells, thin film thickness, morphology, effective medium

NMI1.2 (#4833)
TESTING THE ADHESIVE PROPERTIES OF EPOXY RESIN FOR BONDING ALUMINUM ALLOY PARTS AND THE POSSIBILITY OF EXTENSION OF THEIR SERVICE LIFE

Nikola Nedeljković, Vera Obradović, Ivana Mladenović, Dana Vasiljević-Radović, Marija Vuksanović, Stefan Dikić, Radmila Jančić-Hainemann

This study examined the adhesion between anodized aluminum alloy 7075 and epoxy adhesive, focusing on extending the adhesive's service life. Characterization methods included Vickers microhardness (HV), Atomic Force Microscopy (AFM), Owens-Wendt-Rabel-Kaelble (OWRK) analysis, and shear testing. Results showed that non-anodized samples with epoxy had the highest HV values. AFM confirmed that anodization increases surface roughness, while the epoxy formed a uniform, defect-free film. OWRK analysis indicated that epoxy-coated samples had the highest surface energy, dominated by the polar component, confirming hydrophilicity and favorable adhesion. Shear testing revealed that anodized and primed samples bonded with epoxy beyond its nominal service life achieved the highest shear stress, demonstrating the potential to extend adhesive usability. The adhesion parameter b was also the highest for anodized and primed samples, confirming superior bonding performance. Overall, anodization combined with priming enhanced adhesion and supported the sustainable extension of epoxy adhesive service life.

Keywords: epoxy resin, aluminium alloy, adhesion, anodization, mechanical properties, service life

NMI1.3 (#7941)
BORON-INDUCED MICROSTRUCTURAL AND TRAP OPTIMIZATION FOR IMPROVED NIR PERSISTENT LUMINESCENCE IN $CaSnO_3:Cr^{3+}$ PHOSPHORS

Sofiia Maleeva, Zoran Ristić, Maxim Ivanov, Miroslav D. Dramićanin

Boron co-doping is employed to optimize microstructure and trap distribution in $CaSnO_3:Cr^{3+},Gd^{3+},Na^{+}$ phosphors for enhanced near-infrared (NIR) persistent luminescence. The addition of boron induces liquid-phase sintering, leading to grain growth (~32 μm) and a ~40% increase in photoluminescence intensity. The optimized

composition with 4 at.% B shows improved emission and energy storage characteristics of the material. Decay analysis ($n \approx 0.97$) reveals a tunneling-controlled recombination mechanism, while trap engineering extends the afterglow beyond 2 h. The results demonstrate that combining boron-assisted microstructural control with Gd^{3+}/Na^{+}-mediated crystal-field and defect engineering is an effective route to high-performance NIR persistent phosphors.

Keywords: $CaSnO_3$ perovskite, Cr3+ -doped phosphors, Near-infrared luminescence, Persistent luminescence

NMI1.4 (#6470)

STRUCTURAL, MORPHOLOGICAL AND OPTICAL PROPERTIES OF POLY(METHYL METHACRYLATE)-YTTRIUM ALUMINUM GARNET

Ivana Stajcic, Bozidar Najdanovic, Zorica Lazarevic, Aleksandar Stajcic, Maja Rabasovic, Marija Jovanovic, Vesna Radojevic

The design of polymer-ceramic composites with tunable optical response remains a challenge in advancing efficient and adaptable optoelectronic materials. In this work, we report an investigation of poly(methyl methacrylate) (PMMA) composites reinforced with yttrium aluminum garnet (YAG) particles, focusing on the coupling between garnet-based emitters and transparent polymer matrix at low filler loadings. High-purity YAG with controlled submicron particle size distribution was incorporated into PMMA via solution processing, enabling uniform dispersion and preservation of structural integrity. Comprehensive characterization using electron microscopy, diffraction analysis and infrared spectroscopy confirms phase purity, high crystallinity and subtle interfacial interactions that do not disrupt the polymer backbone but induce measurable vibrational shifts. Most importantly, time-resolved fluorescence analysis reveals an enhancement of emission intensity accompanied by a red shift and spectral broadening in PMMA-YAG composites compared to pristine PMMA. This behavior indicates synergistic light-matter interactions arising from the hybrid structure. The results demonstrate that even minimal YAG incorporation can effectively modulate optical emission pathways, offering a controllable strategy for tailoring photonic responses. These findings provide new insight into the structure-property relationships in polymer-garnet systems and establish PMMA-YAG composites as promising candidates for next-generation light-emitting and photonic devices, where tunability, processability and optical efficiency are simultaneously required.

Keywords: composite, PMMA, structural, optical,

NMI1.5 (#1105)

RESONANCE-ENHANCED SENSITIVITY IN AN AMORPHOUS SOFT MAGNETIC ALLOY SAMPLE – TEST FIXTURE MICROWAVE SYSTEM

Vedran Ibrahimović, Nebojsa Mitrovic

This paper studies the field-dependent microwave response of an amorphous soft ferromagnetic alloy sample (ribbon or microwire) measured in a vector network analyzer (VNA) and test-fixture (TF) system. The results indicate that the apparent negative real part of impedance should not be interpreted as a true intrinsic negative resistance of the sample, but rather as a resonance-related effect associated with ferromagnetic resonance and the reference-based VNA/TF measurement procedure. To further clarify this phenomenon, attenuation curves reported in the literature were digitized, reconstructed, and used to synthesize the corresponding microwave S-parameter response. The

influence of embedding and de-embedding conditions on the field sensitivity was analyzed. TF can modify the resonance region and significantly change magnetic-field sensitivity. In the analyzed case, the best result was obtained for a configuration with one cascaded TF section and grounded opposite side of the coaxial sample, yielding a sensitivity improvement of about 670% compared with the standalone synthesized response.

Keywords: magneto-impedance, amorphous alloy, ferromagnetic resonance, vector network analyzer, de-embedding, apparent negative resistance, sensitivity

NM1.1 (#1586)
UTICAJ HOLMIJUMA NA MIKROSTRUKTURU I SPECIFIČNU ELEKTRIČNU OTPORNOST BARIJUM TITANATNE KERAMIKE

Miloš Đorđević, Vesna Paunovic, Aneta Prijić, Zoran Prijić

U ovom radu vršeno je ispitivanje specifične električne otpornosti (ρ) i temperaturnog koeficijenta specifične električne otpornosti (α) BaTiO3 keramike dopirane holmijumom. Koncentracija jona Ho3+ kretala se od 0.01 at% do 1.0 at%. Uzorci su pripremljeni konvencionalnom metodom sinterovanja u čvrstom stanju i sinterovani na temperaturi od 1320 °C. Analiza mikrostrukture pokazala je da koncentracija dopanta direktno utiče na veličinu zrna. Kod uzoraka sa 0.01 at% Ho, veličina zrna kretala se u opsegu od 10 μm do 30 μm, dok je daljim povećanjem koncentracije (0.1 at% Ho) ona opala na 5–20 μm. Najmanja veličina zrna zabeležena je kod uzoraka sa 0.5 at% Ho (2–3 μm) i 1.0 at% Ho (0.2–2 μm). Za sve uzorke specifična električna otpornostnost merena je u temperaturnom intervalu od 30 °C do 170 °C i u frekventnom opsegu od 100 Hz do 1 MHz. Porast temperature doveo je do povećanja otpornosti. Od sobne temperature do 100 °C taj porast je blaži, nakon čega sledi nagli skok vrednosti. Nasuprot tome, povećanje frekvencije dovodi do pada specifične otpornosti, sa posebno izraženim padom iznad 200 kHz. Pored specifične električne otpornosti, ispitivan je i temperaturni koeficijent specifične električne otpornosti (α). Kod svih ispitanih uzoraka potvrđen je PTC efekat (pozitivni temperaturni koeficijent otpornosti) u temperaturnom opsegu od 30 °C do 128 °C.

Ključne reči: mikrostruktura, BaTiO3 keramika, specifična električna otpornost

РОБОТИКА И ФЛЕКСИБИЛНА АУТОМАТИЗАЦИЈА / ROBOTICS AND FLEXIBLE AUTOMATION

СЕСИЈА / SESSION (ROI1)

Уторак, 9. јун / Tuesday, June 9th Сала 1 / Hall 1 14.30-16.30

Председавајући / Chair:
Kosta Jovanović, University of Belgrade – School of Electrical Engineering, Belgrade, Serbia

ROI1.1 (#0042)
AN OVERVIEW OF COMPUTER-AIDED METHODS FOR DESIGNING COMPLIANT AND SOFT ROBOTIC SYSTEMS

Giovanni Berselli

Compliant Mechanisms (CMs), along with Soft Robotic devices formed therewith, may be defined as engineering systems achieving force and motions transmission via the

deflection of flexible members. CMs have increasingly gained a strong foothold in the scientific arena owing to their hinge-less nature, shock resistance, potential single-piece manufacturability, safety in human-machine interaction, minimal maintenance requirements, and adaptability to work in unstructured environments. In parallel, current advances in the production of inherently compliant sensory-motor apparatus, as well as progresses in the development of robust control methods, are paving the way to practical CM adoption in a large variety of engineering fields, here including healthcare, manufacturing, inspection/maintenance, and agrifood. In light of these considerations, the objective of the present talk is to critically discuss, on the basis of our experience, engineering methods and related Computer-Aided Engineering (CAE) tools allowing for the (automatic) computation of accurate CM models and for the shape optimization of complex-shaped CMs comprising out-of-plane displacements, distributed compliance, and non-linear materials. Within this scenario, a strong integration between different design tools is desirable to improve the work of robotics engineers, reducing the number of errors and speeding up the design process. We hence present a strong integration between 3D computer-aided design models and multidomain simulations applied to the design of compliant, tendon-driven, robotic hands/grippers. The integrated design framework is employed to optimize: i) a four-fingered reconfigurable gripper comprising highly deformable components; ii) a compliant anthropomorphic hand/wrist system for possible usage in humanoid robotics.

Keywords: Compliant Mechanisms (CMs), Computer-Aided Engineering (CAE) tools, tendon-driven robotic hands/grippers

ROI1.2 (#2719)

QUASI-STATIC NORMAL FORCE DISTRIBUTION OF THE OFF-ROAD ROBOTIC VEHICLE IN THE ROBOSHEPHERD SYSTEM

Miša Tomić, Miloš Simonović, Vukašin Pavlović, Miloš Milošević, Nikola Vitković, Milan Banić

This paper presents a quasi-static analytical model for normal force distribution in a skid-steering mobile robot operating on uneven terrain. The model accounts for terrain inclination through pitch and roll angles, enabling the analysis of load transfer between wheels. In addition, interaction forces arising from wire connections are incorporated, extending the formulation to physically connected multi-robot systems. Unlike conventional models that consider isolated robots, the proposed approach captures internal coupling effects introduced by flexible links. The model is based on equilibrium equations and provides explicit expressions for normal forces as functions of terrain and system parameters. The formulation is particularly suitable for systems such as RoboShepherd and provides a foundation for further dynamic analysis and control design in off-road multi-robot applications.

Keywords: skid-steering robot, uneven terrain, multi-robot systems, wire interaction,

ROI1.3 (#2122)

COMPARATIVE ANALYSIS OF MOTION CONTROL ARCHITECTURES FOR TRAJECTORY TRACKING ON A DIFFERENTIAL-DRIVE MOBILE ROBOT

Dimitrije Čabrilo, Aleksandar Kičić, Milutin Nikolic

Abstract—Motion control is a fundamental requirement for any mobile robot operating in a time-critical environment such as a robotics competition, where every trajectory is a sequence of moves spanning a wide range of amplitudes that the chosen controller must

handle reliably. A fixed-gain PID is the stan- dard starting point for differential drive robot (DDR) motion control, yet its constant gains limit adaptability, which is a property that this study examines across move amplitudes, with payload and surface variation left for future work. Conversely, more elaborate control architectures sometimes add complexity without delivering a measurable benefit. This paper presents an experimental comparison of five motion control architectures implemented on the same physical differential-drive robot built for the Eurobot 2026 competition: a decoupled dual-channel PID used as a baseline, a gain-scheduled PID, a pure feedforward controller based on a trapezoidal velocity profile, a feedforward controller combined with PID feedback, and a fuzzy PID. All architectures are evaluated under identical conditions on two elementary motion primitives - straight-line point-to-point translation and rotation in place - at multiple magnitudes. Performance is assessed using root mean square error (RMSE), integral of absolute error (IAE), settling time, overshoot, and maximum control effort. The feedforward + PID achieves the best overall performance, and the results provide evidence-based guidance for architecture selection in competitive and educational differential-drive applications.

Keywords: PID controller, Gain scheduling, Feedforward control, Fuzzy PID, Trajectory tracking, Differential drive, Trapezoidal velocity profile, Eurobot

ROI1.4 (#4530)
BALANCE PRESERVATION OF A BIPEDAL ROBOT USING A LINEAR QUADRATIC REGULATOR

Luka Ostojić, Milutin Nikolić

Maintaining balance of legged robots in two-legged stance remains challenging due to underactuation, nonlinear dynamics, and unilateral ground contact. This paper presents balance control of a bipedal robot using a linear quadratic regulator (LQR) based on two simplified models: the acrobot and flywheel inverted pendulum. The developed control approach is implemented on the Solo12 quadrupedal robot, which is required to balance on only two legs. Simulations are carried out in Julia and in the MuJoCo physics simulator. The control law explicitly enforces contact constraints, ensuring positive vertical ground reaction force and maintaining horizontal force within friction limits. Results show that the acrobot-based LQR stabilizes the system for small initial angle deviations and brief external perturbations, but fails for larger offsets. The flywheel-based LQR exhibits a wider stability region in Julia but does not transfer well to MuJoCo due to discrepancies between the flywheel model and the actual dynamics of the Solo12 robot.

Keywords: legged robot, LQR, simulation

ROI1.5 (#4361)
SELF-SUPERVISED VISUAL SERVOING FOR OBJECT-MODEL-FREE ROBOT ARM ALIGNMENT VIA AUTONOMOUS SPIRAL DATA COLLECTION

Nikola Stojic, Igor Babić, Darko Lukić, Mirko Raković

In this paper, we present AlignIt, a self-supervised visual servoing system for robot arm alignment that requires no CAD model, markers, tags, or manually labeled training data. An autonomous spiral trajectory (50 waypoints, 10 episodes, 500 data sets in total) is executed above a single reference pose defined by the operator, thereby generating a densely labeled set of RGB images paired with relative pose errors in SE(3) space, encoded as 9D vectors using the continuous 6D rotation representation. An EfficientNet-

B0-based regression network maps a single RGB image to the corresponding 9D pose-error vector. During deployment, the network's predictions are decoded back into SE(3) transformations and applied iteratively as position servo control commands on the UFactory Lite 6 robot arm, with the system converging when the positional error falls below 2mm and the orientation error below 4 degrees for 10 consecutive steps. In this implementation we used an Intel RealSense D435i camera, without prior knowledge of the object CAD model or scene geometry.

Keywords: visual servoing, self-supervised learning, robot arm alignment, pose error regression, 6D rotation representation, object-model-free robotics

ROI1.6 (#9718)
FRONTAL-PLANE INVERSE DYNAMICS AND FATIGUE METRICS OF THE PULL-UP

Jovana Kocić, Petar Spasić, Marko Rančić, Milos Petrović, Jelena Aleksić, Filip Bečanović

The pull-up is a fundamental closed kinematic chain exercise widely used in strength training, yet its biomechanics remain under-investigated compared with lower-extremity tasks. This paper presents a complete, from-scratch workflow for the frontal-plane inverse-dynamic analysis of pull-ups. Five young healthy participants performed pull-ups in a laboratory setting while retroreflective markers were tracked by an optical motion-capture system. A planar rigid-body model of the body and upper limbs was established, body-segment inertial parameters were assigned from published anthropometric data, and inverse kinematics, followed by inverse dynamics, were implemented from first principles. Joint angles, net joint moments, and joint powers at the shoulder and elbow are reported and discussed. Results are consistent with the expected bilateral loading pattern and reveal the dominant role of the shoulder adduction moment during the concentric phase. Across repetitions, decreasing mean propulsive velocity (MPV) together with changes in complementary fatigue metrics indicate progressive alterations in coordination and control. The dataset will be made available to the community.

Keywords: Rigid-body modeling, Biomechanics, Motion capture, Pull-up

ROI1.7 (#7551)
MUJOCO_BIOMECHANICS: A BIOMECHANICAL PIPELINE PYTHON PACKAGE INSIDE MUJOCO

Marina Svilar, Dušan Mišković, Kosta Nedeljković, Marko Tepavčević, Branko Lukić, Filip Bečanović

Biomechanical simulation and analysis of human motion requires both anatomically plausible body models and reliable data-processing pipelines. This paper presents two open-source Python tools for MuJoCo: one for procedural generation of anthropometrically consistent human models in the MuJoCo XML format from height, weight, and biological sex, and one for motion-capture processing with inverse kinematics, inverse dynamics, and ground reaction force estimation. By leveraging MuJoCo's contact-model-based inverse dynamics, the pipeline requires only kinematic data of anatomical landmark points as input for biomechanical reconstruction. Validation on a countermovement vertical jump (CMJ) dataset shows that joint-angle and joint-moment trajectories remain consistent with reference values reported in the literature, while estimated ground reaction force profiles show moderate agreement with measured forces and leave room for future improvement through automatic parameter calibration.

Keywords: Motion Analysis, Biomechanics, Simulation, MuJoCo,

ROI1.8 (#9313)
SIMULATING CONTACT WITH FRICTION IN MULTIBODY SYSTEMS USING STAGGERED PROJECTIONS

Anastasija Rakić, Teodora Srećković, Filip Bečanović and Kosta Jovanović

Frictional contact simulation is a fundamental challenge in computer graphics and robotics, requiring a delicate balance between physical accuracy, computational performance, and numerical stability. This paper begins with a foundational analysis of the challenges inherent in contact modeling, detailing the trade-offs that confront traditional simulation methods. Building upon this analysis, we present our implementation of the Staggered Projections (SP) algorithm, a velocity-level formulation for resolving frictional contact in multibody systems. We explore the core principles of the method, which decomposes the complex, coupled contact problem into a sequence of more manageable projection operations. Our evaluation demonstrates the algorithm's capacity to robustly handle challenging scenarios, such as large-scale stacking and friction-dependent structures. However, its most significant limitation lies in the high computational complexity in complex environments.

Keywords: Frictional Contact, Multibody Dynamics, Staggered Projection, Constrained Optimization, Physically Based Simulation

RO1.1 (#7870)
PRIMENA SIMULIRANOG KALJENJA U ENERGETSKI EFIKASNOM PLANIRANJU ROBOTSKE PROIZVODNJE VELIKE RAZNOVRSNOSTI I MALIH SERIJA

Ognjen Aleksić, Nikola Knežević, Zaviša Gordić, Mileta Žarković

U radu se razmatra problem optimizacije proizvodnog rasporeda u uslovima velike raznovrsnosti i malih serija (eng. High-Mix, Low-Volume, HMLV) sa ciljem smanjenja troškova električne energije. Posmatrani sistem obuhvata kolaborativnog robota koji učestvuje u procesu montaže dve vrste fiskalnih kasa, pri čemu različite operacije robota imaju različitu energetsku potrošnju. Optimizacija je sprovedena u dva koraka: određivanje optimalnog rasporeda delova po kutijama u cilju minimizacije potrošnje energije, i optimizacija vremenskog rasporeda proizvodnje u skladu sa promenljivim cenama električne energije. Za rešavanje problema korišćen je metaheuristički algoritam simuliranog kaljenja, koji omogućava efikasno pretraživanje velikog prostora mogućih rešenja. Rezultati simulacija pokazuju da predloženi pristup može ostvariti značajne uštede troškova električne energije, naročito u uslovima manjih proizvodnih serija, karakterističnih za HMLV okruženje. Dobijeni rezultati ukazuju na to da inteligentno planiranje proizvodnje može unaprediti energetsku efikasnost bez dodatnih ulaganja u opremu, što je od posebnog značaja za mala i srednja preduzeća.

Ključne reči: HMLV proizvodnja, optimizacija rasporeda, simulirano kaljenje, kolaborativni robot, energetska efikasnost

СЕСИЈА / SESSION (PO2+ROI2)

Среда, 10. јун / Wednesday, June 10th Сала 1 / Hall 1 9.00-11.15

Председавајући / Chair:
Aleksandar Rodić, University of Belgrade – Institute Mihajlo Pupin, Belgrade, Serbia

ROI2.1 (#1167)
COLLABORATIVE AGRO-ROBOTIC SYSTEM FOR INTENSIVE FARMING – CONCEPT AND FUNCTIONALITY

Aleksandar Rodić

This paper presents a novel concept of a collaborative multifunctional agro-robotic system for intensive farming, designed to address key challenges in modern agriculture, including labor shortages, increasing production costs, and the need for sustainable and efficient crop management. The proposed system is based on a multi-agent architecture in which multiple mobile agro-robots operate cooperatively within a shared field environment. Each robot is capable to operate independently or cooperatively as part of the multi/robots team. Robot is equipped with a modular structure, including an omnidirectional mobile platform, a Cartesian manipulator for ground-level operations, and advanced perception systems for autonomous harvesting. A key feature of the system is its collaborative capability, enabling both robot-to-robot and human–robot interaction. Robots communicate wirelessly with each other and a central base station, allowing dynamic task allocation, path optimization, and real-time coordination. In the event of a robot failure, neighboring units autonomously redistribute tasks, ensuring continuity of operation and system robustness. Additionally, the system incorporates human operators as support agents, where robots provide intuitive visual and audio signals to request assistance for battery replacement or unloading harvested produce. The paper further presents methods for field mapping, localization, and navigation using a combination of aerial imaging, sensor fusion, and AI-based perception. Optimization strategies for multi-robot scheduling are introduced to minimize total operation time and energy consumption under real-world constraints. Experimental considerations demonstrate that the proposed system enables scalable, cost-effective deployment in row-based crop production such as peppers, strawberries, and vineyards. The results indicate that collaborative agro-robotic systems have strong potential to significantly enhance productivity, reduce dependency on manual labor, and support the transition toward smart and sustainable agriculture.

Keywords: agro-robots, autonomous systems, collaborative robots, AI-driven robotic production

ROI2.2 (#6839)
STRUCTURE AND CONTROL OF COMPLIANT TENDON-DRIVEN AGRO-ROBOTIC ARM DESIGNED FOR HIGH-VALUE FARMING

Aleksandar Rodić

This paper presents a novel concept of a compliant, multifunctional agro-robotic arm intended for application in intensive agricultural production. The proposed system is designed as a lightweight, tendon-driven, redundant manipulator with seven degrees of freedom (7-DOF), capable of operating in unstructured outdoor environments. The robot is optimized for tasks such as harvesting, pruning, and planting, while ensuring adaptability, low cost, and energy efficiency. A compliant mechanical structure and cable-driven actuation system are introduced to improve robustness and safety in interaction with plants and environment. Key performance indicators (KPIs) are defined to evaluate system effectiveness in real agricultural conditions. The concept aims to provide an affordable and scalable solution for small and medium-sized farms for intensive agricultural production.

Keywords: agro-robot, tendon-driven robotic arm, compliant robot, redundant robot, precision agriculture

ROI2.3 (#4304)
COMPARATIVE EVALUATION OF GEOMETRY-BASED PLANE SEGMENTATION METHODS IN STRUCTURED AGRICULTURAL ENVIRONMENTS

Petar Stamenković, Damir Krklješ, Ivan Mezei

Autonomous systems in precision agriculture rely on accurate scene understanding, navigation, and object detection. Structured environments, such as raised beds, are common in agriculture, where precise geometric analysis is critical for robot operations. One of the most important tasks for this use case is plane segmentation and parameter extraction. Due to real-world agricultural conditions such as uneven terrain, random occlusions, wind, and sun, various methods have been developed to focus on speed, accuracy, and robustness of the solution. This paper compares four geometry-based methods across three paradigms: consensus-fitting, region-growing, and topology-driven. RANSAC is evaluated through two independent implementations — PCL in C++ and Open3D in Python — resulting in five tested implementations in total. Depth images coming from an OAK-D stereo camera are sourced to a point cloud and used as an input. As a starting point, an artificial raised bed of blueberries is constructed and used for experiments and testing. Standard metrics, including root mean square (RMS), planarity, roughness, inlier count, and execution time, are used for benchmarking. The evaluation showcases the strengths and weaknesses of tested methods for the agricultural use case.

Keywords: agricultural robotics, plane segmentation, depth images

ROI2.4 (#1033)
ARCHITECTURE AND DESIGN OF AN EDGE GPU SYSTEM FOR AUTONOMOUS PERCEPTION OF MOBILE ROBOTS IN PRECISION AGRICULTURE

Stanislav Čeman, Nikola Ružić, Veljko Todić, Kosta Jovanović

This research explores the development of a sophisticated edge-computing architecture designed for autonomous visual perception tasks of mobile manipulators in precision agriculture. By moving high-intensity computational workloads from remote cloud servers to a localized, GPU-accelerated infrastructure, the system achieves a high degree of responsiveness and reliability, fundamental for real-time robotic systems. The proposed solution integrates an NVIDIA Jetson module with an RBKairos mobile platform, using hardware-specific deep learning optimizations and precise manipulation logic. Experimental validation indicates that this design substantially mitigates temporal instabilities in the control loop and enhances the system energy autonomy by 12%, allowing greater duration of autonomous field operations.

Keywords: edge perception, robotic manipulation, NVIDIA Jetson, hardware acceleration, precision agriculture

ROI2.5 (#9542)
THE DESIGN OF A PETRI NET–BASED CONTROL SYSTEM FOR UNDERACTUATED ADAPTIVE ROBOTIC GRIPPER

Lazar Matijasevic, Dusan Nedeljkovic, Zivojin Suvajac and Zivana Jakovljevic

To facilitate ever-growing need for customized production, modern automation requires extensive development of advanced adaptive systems for robotic grasping. Among many approaches, the application of underactuated mechanisms has proven to solve many challenges that the mass customization paradigm imposes. They enable simpler design

of actuation mechanisms which can be controlled using less complex algorithms. As a rule, control systems of underactuated grasping devices can be modeled as discrete-event systems and a variety of control methods have been developed for their operation. Amongst these, Petri Net-based methods provide an effective framework for modeling and controlling such systems with event-driven behavior and sensor-based decision making. This paper presents the design of Petri Net-inspired control system for an adaptive two-finger underactuated robotic gripper. This system is presented in the form of control interpreted Petri Net with defined actions and conditions, and its real-world applicability is experimentally verified using different grasping scenarios.

Keywords: robotic grasping, underactuated robotic gripper, control, Petri Net,

ROI2.6 (#2070)
INTEGRATION OF EDGE-AI OBJECT DETECTION AND VISION-GUIDED ROBOT MANIPULATION FOR INDUSTRIAL AUTOMATION

Ilija Ristanović, Luka Filipović, Jana Jelić, Goran Kvaščev and Milan Ristanović

The increasing use of AI-based computer vision and industrial robotics in automation has created new demands on production systems. Automated production lines that integrate object detection and classification with robotic manipulation require reliable, deterministic, and flexible PLC-based control solutions. This paper demonstrates the development of a sustainable and innovative industrial solution capable of performing a pick-and-place process by executing data acquisition, decision-making through neural-network inference, and the generation of actuator control commands. The proposed solution integrates an industrial PLC with a NPU (Neural Processing Unit) module to control a robotic arm. The entire process, from perception to control, is implemented on industrial-grade edge devices. The system is demonstrated through a representative industrial use case in which six classes of objects are detected, classified, and sorted into designated positions, serving as an example of a broader class of assembly, sorting, packaging, and material-handling processes. The solution was tested and achieved over 96% accuracy in a six-class object-detection task, while successfully controlling an anthropomorphic robotic arm. The results indicate that the proposed solution is highly adaptive, sustainable, and versatile, enabling easy integration into new production lines as well as the upgrading of existing ones.

Keywords: Edge AI, Industrial Computer Vision, Object Detection, PLC-Based Control, Robotic Manipulation, Vision-Guided Robot, Pick-And-Place, Industrial Automation,

ROI2.7 (#1376)
3D OBJECT DETECTION AND CLASSIFICATION IN ROBOTICS USING STEREO VISION

Marija Bojović, Aleksandar Rodić

This paper addresses the problem of determining the position and orientation of 3D objects within a robot's workspace. The primary objective is to enable the robot to map a scene and store the spatial arrangement of objects, allowing for its later reconstruction. The solution is implemented through two distinct approaches: the first integrates the MATLAB environment with the ChatGPT model for multimodal image analysis and descriptive identification, while the second relies on a locally trained Convolutional Neural Network for shape classification. In both approaches, MATLAB is used for image processing, segmentation, and precise computation of object coordinates and orientation angles. The paper provides a comparative analysis of these approaches in terms of accuracy, response time, and practical applicability in real-world robotic systems.

Keywords: Robotics, Computer vision, ResNet18, MATLAB, ChatGPT API, Stereo calibration, Object detection, Object classification

ROI2.8 (#1799)
SEMANTIC SEGMENTATION IN AUTONOMOUS MOBILE ROBOTS BASED ON CNN WITH FAST ATTENTION

Luka Tankosić, Aleksandar Jokić, Milica Petrovic, Zoran Miljković

This paper presents the development of a convolutional neural network architecture for semantic segmentation in autonomous mobile robots. The model comprises a mix of traditional CNNs and transformer-based attention modules. ResNet18 and ResNet34 are employed as backbone models with fast attention modules integrated at the end of each ResNet level. The SUNRGBD dataset is used for training and evaluation, while the final network is tested on a real mobile robot TIAGo. An extensive parameter-tuning procedure is conducted to determine optimal parameters and assess the model's sensitivity to changes in parameters. The proposed approach aims to improve segmentation performance while meeting real-time computational constraints.

Keywords: semantic segmentation, ResNet, fast attention, autonomous mobile robot, deep learning, TIAGo

ROI2.9 (#5251)
NEUROERGONOMIC COBOT-ASSISTED SETUP FOR RAPID TRAINING AND OPERATOR MOBILITY

Zaviša Gordić, Nikola Knežević, Branko Lukić, Kosta Jovanović

This paper presents a setup for a human-centered training environment in assembly manufacturing. Building on a previously developed neuroergonomic, cobot-assisted workstation, the approach extends a factory-validated system toward training-oriented applications. After outlining the baseline architecture, the paper proposes an enhanced use of its modular components - cognitive monitoring, motion recognition, adaptive interfaces, and collaborative robotics - to enable closed-loop, individualized training. A methodology for leveraging multimodal worker-state indicators to dynamically adjust instruction and assistance is introduced. The framework for implementation and validation in industrial settings is discussed, with focus on learning efficiency, operational performance, and ergonomics. The proposed approach is expected to accelerate skill acquisition, improve workforce flexibility, and enhance overall production efficiency.

Keywords: neuroergonomics, worker-centricity, Industry 5.0, cobot

RO2.1 (#2669)
KREIRANJE VIRTUALNOG OKRUŽENJA ZA PREMOŠĆAVANJE JAZA IZMEĐU SIMULACIJE I STVARNOSTI NA ZADATKU MONTAŽE POMOĆU ROBOTA

David Seničić, Filip Bečanović, Dobrica Janković, Luka Veličković, Mihajlo Stevanović, Kosta Jovanović

Ovaj rad pruža sveobuhvatnu analizu arhitektonskog sistema za kreiranje naprednih virtuelnih okruženja namenjenih prevazilaženju jaza između simulacije i stvarnosti u domenu robotske montaže. Kroz prizmu montaže složenih kontaktno-intenzivnih zadataka, kao što je manipulacija i umetanje različitih komunikacionih kablova u serverska kućišta, rad detaljno opisuje tehničke, softverske, i hardverske prepreke koje otežavaju razvoj robotskih rešenja bez upotrebe realne opreme. Virtualna okruženja su

konstruisana kao skalabilni sistem koji verno preslikava realne sklopove kao i njihove međusobne interakcije. Skalabilno bezbedno virtuelno okruženje omogućavaju trening i testiranje neuralnih mreža adaptivne vizualno-motorne politike pre nego što se rešenje testira na pravom robotskom sistemu. Rad opisuje sve potrebne korake da se simulira i obuči polisa veštačke inteligencije da bi robotski sistem izvršavao zadatke u sub-milimetarskoj preciznosti.

Ključne reči: Sim2real gap, simulacija, ROS2, arhitektura, montaža,

ROI2.10 (#2872)

DEEP LEARNING AND SYNTHETIC DATA GENERATION FOR HUMAN POSE ESTIMATION IN AUTONOMOUS ROBOT SYSTEMS

Mladen Dinčić, Ivan Ćirić, Miloš Simonović, Mladen Kuzev, Nikola Ivačko

Human pose estimation has become a critical component in the development of autonomous robotic systems, enabling machines to perceive and interpret human body positions in real time. Applications range from autonomous vehicles, where accurate detection of pedestrian motion, whether walking, running, or falling is essential for safe navigation, to humanoid robots capable of learning through human motion imitation, as well as medical rehabilitation systems that monitor patient movements during therapy. This paper presents a systematic review of deep learning methods for human pose estimation, with particular emphasis on their applicability in autonomous robotic systems. We analyze and compare state-of-the-art approaches, focusing on key performance parameters such as accuracy, inference speed, and computational requirements, providing a structured overview of the current landscape in this rapidly evolving field. One of the significant challenges in training pose estimation models is the availability of large and diverse datasets. In this context, we discuss the potential of synthetic data generation as a promising direction, offering several advantages over real-world data collection, the ability to produce large quantities of training samples, controlled variation of environmental conditions such as lighting, contrast, and viewing angles, as well as precise ground truth annotations that enable reliable model evaluation. Finally, initial results from a real-world implementation of a pose estimation system are presented and discussed in the context of existing approaches, highlighting practical potential and directions for future research.

Keywords: Human Pose Estimation, Deep Learning, Autonomous Robotic Systems, Synthetic Data, Computer Vision

ВЕШТАЧКА ИНТЕЛИГЕНЦИЈА / ARTIFICIAL INTELLIGENCE

СЕСИЈА / SESSION (ВИ1+VII1)

Понедељак, 8. јун / Monday, June 8th Сала 3 / Hall 3 9.00-11.00

Председавајући / Chair:
Miljan Vučetić, Vlatacom Institute of High Technology, Belgrade, Serbia
Nemanja Ilić, Vlatacom Institute of High Technology, Belgrade, Serbia

VII1.1 (#0217)
AN ANALYSIS OF THE PERFORMANCE OF MODELS FOR DIRECT SERBIAN SPEECH-TO-ENGLISH TRANSLATION

Milana Vitković, Svetlana Krunić, Siniša Suzić, Nosek Tijana

Automatic speech translation has become an important area of research with the development of deep learning and large multi-lingual models. In this study, we investigate Serbian-to-English speech translation using Whisper and SeamlessM4T models. We evaluate the performance in three different scenarios: zero-shot speech translation, cascaded approach where ASR models are fine-tuned on Serbian using the Južne Vesti and ParlaSpeech corpora, and translation is performed with both proprietary (GPT-4o) and open-source models (Salamandra-7B-Instruct and EuroLLM-1.7B) and finally, we explore end-to-end adaptation by fine-tuning models directly on a parallel Serbian–English cor-pus for speech-to-text translation. Evaluation on the Južne Vesti test set using BLEU, METEOR, and WER metrics shows that direct fine-tuning improves translation performance compared to zero-shot and cascaded approaches, while open-source trans-lation models could provide a viable alternative when proprie-tary systems are unavailable. These results highlight the im-portance of task-specific adaptation and parallel speech–translation data in improving translation quality for low-resource languages like Serbian.

Keywords: automatic speech translation, automatic speech recognition, machine translation, whisper, seamlessm4t

VII1.2 (#1414)
TO SLIDE OR TO SNIP? LLM FINE-TUNING FOR SENTIMENT ANALYSIS OF LONG SERBIAN MOVIE REVIEWS

Aleksandra Todorović, Vuk Batanović

We establish the first fine-tuned transformer results on the SerbMR dataset, evaluating strategies for long-form sentiment analysis in Serbian, a morphologically rich language. Using BERTić, a widely used large language model for Serbian and closely related languages, we compare two strategies for handling the limited context window: truncation (head-only and tail-only) and sliding-window-based aggregation (mean pooling, max pooling, majority voting, and a rule-based heuristic). Evaluation is performed across binary (2-class) and ternary (3-class) classification schemes. The fine-tuned BERTić achieves 93.76% accuracy on the binary task and 74.55% on the ternary task, an improvement of approximately 9 and 12.5 percentage points respectively over the best reported results of linear classifiers. The sliding window with mean pooling proves to be the strongest overall strategy, most notably on the harder ternary task, but its 45% runtime overhead offers only marginal gains over tail-only truncation in the binary setting. The consistent advantage of tail-only over head-only truncation across all

conditions suggests that evaluative language in Serbian movie reviews concentrates towards the end of the text.

Keywords: Sentiment analysis, Serbian NLP, BERTić, Document-level classification, SerbMR

VII1.3 (#0315)
FUSE-T GATED RESIDUAL LATE FUSION OF TEXT SEMANTICS AND THREAD TOPOLOGY FOR UNSEEN-EVENT RUMOUR CLASSIFICATION IN CONVERSATIONAL REPLY GRAPHS

Aleksandar Stankovic

Rumours on social media spread rapidly during breaking events, while early evidence is often sparse, noisy, and highly event-specific. Text-only classifiers can overfit to keywords and writing style tied to particular events, while structure-only propagation models struggle when discussion trees are small. This paper presents Fuse-T, a gated residual late-fusion architecture for binary rumour classification on conversational reply graphs. FuseT uses a pre-trained language model as a stable semantic backbone and injects graph propagation cues as a controlled additive residual. A learned element-wise gate modulates the injected topology signal and is initialized near zero to avoid covariate shift on the text classifier. We evaluate Fuse-T on leave-one-event-out (LOEO) generalization across seven events from the PHEME collection. Across events, Fuse-T improves average Macro-F1 from 62.13% (text-only RoBERTa) and 62.42% (text-attributed GNN baseline) to 65.68%. In an early-detection setting using only the first 10 minutes of replies, Fuse-T retains robust performance (about 63% Macro-F1), while structure-only models degrade substantially.

Keywords: rumour detection, early classification, multi-modal fusion, graph neural networks, GraphSAGE, RoBERTa, PHEME

VII1.4 (#4187)
EVALUATION OF VGG16-BASED TRANSFER LEARNING STRATEGIES FOR POLLEN CLASSIFICATION FROM RECONSTRUCTED DIGITAL HOLOGRAMS

Dimitrije Stefanović, Nikša Jakovljević, Marko Panić

Reliable pollen classification is an essential step in estimating airborne pollen concentration, a key indicator for environmental monitoring and allergy forecasting. This study addresses the problem of classifying six pollen taxa from reconstructed digital holographic images, as a step toward potential improvement of automated concentration assessment systems. Four training strategies were evaluated: three VGG models were trained end-to-end, one trained with randomly initialized weights, another initialized with frozen pretrained ImageNet weights and third fine-tuned entirely by allowing all layers to update during training. The fourth fine-tuned VGG was employed as feature extractor that was then combined with a support vector machine (SVM) classifier. Despite strong morphological similarities among certain pollen taxa, all models showed promising results, with fine-tuned strategies achieving the best performances, demonstrating the capability of deep learning for accurate pollen classification applicable to real-time monitoring systems. The experiments confirmed a high degree of robustness and generalization, paving the way for the development of enhanced methodologies that can further improve the reliability of the classification and expand to a larger number of pollen taxa.

Keywords: Machine learning, transfer learning, image classification, digital holography, pollen grains

VII1.5 (#4492)
AUTOMATED CHEMICAL VULNERABILITY ASSESSMENT OF CANVAS PAINTINGS FROM XRF SPECTRAL IMAGING USING DEEP LEARNING AND FOUNDATION MODELS

Dimitrije Pesic, Janko Vukobratovic, Aleksandra Stojanovic, Giulia Ristori, Stefano Ridolfi, Maja Gajic-Kvascev, Goran Kvascev

This paper presents the design of an automated pipeline for chemical vulnerability assessment of canvas paintings from XRF spectral imaging. The design is based on the recognition of the materials used (from XRF data) and on the physico-chemical prediction of time- and condition-dependent degradation of these materials. The pipeline that processes XRF spectra and, for each element, calculates the signal intensity by integrating within a window around the corresponding peak, with the linearly interpolated background below the peak subtracted, was developed. The two-dimensional maps of the elements (calcium, titanium, iron, copper, and lead-single emission line) were created using the resulting peak intensities. The Pearson correlation coefficients were calculated for two independent scans on detector 10264 to evaluate the reproducibility of the inputs. The coefficients for relevant elements (Ca, Ti, Fe, Cu, Pb) achieve $r > 0.98$, confirming excellent quantitative reproducibility and that the instrumental setup remains stable over time. The system chains self-supervised denoising, physics-based element extraction, NMF decomposition, a literature-grounded CVI, and SAM-based region segmentation—requiring no expert-labeled training data. Thirteen segments were automatically identified by SAM, and six per-region mean CVI values for the highest-risk segments were labeled. The whole procedure typically requires extensive expert analysis, while using this pipeline, the process takes under 70 seconds (on an Intel Core i5-12450H with 16GB RAM)

Keywords: XRF, Spectral Imaging, Deep Learning,

VII1.6 (#7018)
ROBUSTNESS OF GRAPH NEURAL NETWORKS UNDER STRUCTURAL AND FEATURE CORRUPTIONS

Zorana Štaka, Marko Mišić

GNNs are successfully used in various tasks and domains involving working with graph data. However, their robustness under realistic, non-adversarial corruptions is underexplored. In this paper, we provide a systematic evaluation of GNNs under structural and feature corruptions at different levels of severity. To provide a more comprehensive evaluation, four models are used: GCN, GAT, GraphSAGE, and GIN, and four datasets: Cora, CiteSeer, PubMed, and OGBN-ArXiv. To ensure our findings are statistically meaningful, a rigorous statistical evaluation is conducted with multiple seeds, including the Wilcoxon signed-rank tests for pairwise comparison, Benjamini-Hochberg false discovery rate, and effect sizes. Results indicate that feature corruptions are more damaging to the model performance than structural ones under inference-time corruptions. Robustness of GNNs is driven more by corruption type and severity than by the model architecture. Also, homophily and calibration have statistically significant but limited correlation with predictive performance. Therefore, to properly evaluate GNNs' reliability, clean-test accuracy is insufficient; rather, the evaluation of model performance under diverse corruption settings using a statistically rigorous procedure is necessary.

Keywords: GNN, robustness, graph corruptions, inference-time evaluation, node classification, homophily

VII1.7 (#6154)
FLOW MATCHING POLICY FOR BEHAVIORAL CLONING

Mihailo Radović, Filip Marčić

Behavioral cloning (BC) is a foundational imitation learning paradigm, but many standard continuous-control BC baselines rely on unimodal Gaussian policies or other relatively low-expressivity action parameterizations. Consequently, they struggle to capture the complex, multi-modal strategies present in diverse offline datasets, such as those containing human, medium-quality, or mixed trajectories, leading to a significant performance gap. To address this limitation, we introduce the Flow Matching Policy (FMP), a highly expressive representation for continuous control BC. Our approach models the conditional action distribution as a continuous-time normalizing flow, learning an observation-conditioned velocity field to transport a simple base noise distribution into the empirical action distribution. Evaluations against strong Gaussian and diffusion policy baselines across standard continuous control benchmarks demonstrate that the FMP consistently achieves competitive or superior performance. These results suggest that continuous-time flow models are a promising alternative for capturing highly complex and varied behaviors from noisy data.

Keywords: behavioral cloning, flow matching policy, Gaussian policy, diffusion policy

VII1.8 (#8038)
METAHEURISTIC OPTIMIZATION OF BOOSTING AND HYBRID MACHINE LEARNING MODELS FOR IOT INTRUSION DETECTION: A REVIEW

Ninoslava Jankovic, Aleksandar Petrovic, Petar Spalevic

The rapid expansion of Internet of Things (IoT) infrastructures has significantly increased the attack surface of modern digital ecosystems. Due to constrained computational resources and heterogeneous device architectures, traditional intrusion detection mechanisms are often inadequate for IoT environments. Machine learning techniques have emerged as efficient solutions for intelligent intrusion detection systems, while metaheuristic optimization algorithms have demonstrated sub stantial improvements in feature selection and hyperparameter tuning processes. This paper provides a comprehensive review of metaheuristic optimized machine learning approaches for IoT intrusion de tection. Existing methods are systematically categorized based on optimization strategy, learning architecture, and application domain. Particular emphasis is placed on boosting-based models, deep learning frameworks, and hybrid multi-level optimization strategies. Furthermore, commonly used datasets, evaluation methodologies, and performance trends are analyzed to identify current research directions and limitations. The study highlights emerging trends, including domain-specific IoT applications and hybrid optimization frameworks, while identifying open challenges related to benchmarking, deployment efficiency, and generalization across heterogeneous IoT scenarios.

Keywords: IoT, cyber security, intrusion detection, AI, metaheuristics

VII1.9 (#5960)
A COMPARATIVE STUDY OF KAN AND NEURAL ODE MODELS FOR LR-DDOS ATTACK DETECTION IN IOT NETWORKS

Dušan Drinić, Marija Novičić, Goran Kvaščev

In recent years, cybersecurity has become a critical aspect of modern network systems, as Internet of Things (IoT) networks continue to grow rapidly across various application domains. While these advancements bring significant benefits in terms of connectivity and functionality, they also introduce increased security and privacy risks. One of the most challenging threats is the Low-Rate DDoS (LR-DDoS) attack, which can cause significant damage to target systems using minimal resources and traffic, typically representing only a small portion of total network activity, making detection highly difficult. In this paper, we propose and evaluate two models, a modified Kolmogorov–Arnold Network (KAN) and a Neural Ordinary Differential Equation (Neural ODE), under the same experimental conditions. Experiments are conducted on the CICIoT2023 dataset using a 5-fold cross-validation strategy and standard evaluation metrics including Accuracy, Precision, Recall, and F1-score. The results show that both models achieve high and stable performance, with accuracy above 96% and strong generalization capabilities. Overall, the study demonstrates the effectiveness of both approaches while highlighting their different trade-offs in detection performance and computational efficiency.

Keywords: Low-rate DDoS, neural networks, KAN, Neural ODE, IoT, datasets

СЕСИЈА / SESSION (VII2+VI1)

Понедељак, 8. јун / Monday, June 8th Сала 3 / Hall 3 15.00-17.15

Председавајући / Chair:
Miljan Vučetić, Vlatacom Institute of High Technology, Belgrade, Serbia
Nemanja Ilić, Vlatacom Institute of High Technology, Belgrade, Serbia

VII2.1 (#1300)
POS TAGGING AND ERROR ANALYSIS FOR SERBIAN USING NLTK AND THE MULTEXT-EAST TAGSET

Nikola Vukotić, Suzana Stojković, Jovana Stojanović

This paper presents a part-of-speech (POS) tagger for the Serbian language that supports the complete MULTEXT-East morphosyntactic tagset containing 681 unique morphosyntactic descriptors (MSDs). Five statistical taggers from the NLTK library were trained on the SrWaC corpus comprising 3.66 million sentences and evaluated on a test set of 915,224 sentences (over 8 million tokens). The Perceptron tagger achieved the highest exact-match accuracy of 95.36%. In addition to tagger development, a detailed per-attribute error analysis was conducted across eight MSD positions: part of speech, type, gender, number, case, person, formation, and specificity. The analysis reveals that case disambiguation presents the greatest challenge with 97.25% accuracy, while formation and specificity attributes achieve near-perfect accuracy above 99%. Furthermore, approximately 50.1% of all errors involve multiple attribute positions simultaneously, indicating cascade error patterns. The attribute-level error analysis for Serbian POS tagging conducted in this paper provides insights into future improvements of both statistical and neural approaches.

Keywords: POS tagging, Serbian language tagger, MULTEXT-East, morphosyntactic tagging, NLTK

VII2.2 (#0200)
DEEP LEARNING METHODS WITH MODEL COMPRESSION FOR STATE-OF-HEALTH AND REMAINING-USEFUL-LIFE PREDICTION OF LITHIUM-ION BATTERIES

Nemanja Grujičić

State of health (SOH) and remaining useful life (RUL) represent factors of the utmost importance to contemporary battery management systems. This paper proposes an approach to SOH and RUL prediction that integrates deep learning with robust regression, primarily to mitigate the influence of the capacity regeneration phenomenon (CRP) on the quality of prediction. Application of both long short-term memory (LSTM) and gated recurrent units (GRU) is considered, along with layer normalization that helps train more robust models. Furthermore, the prospects of model compression are analyzed through the lens of dynamic quantization. The utility of the proposed approach is verified on the NASA dataset that contains actual measurements for several lithium-ion batteries. The proposed models demonstrate strong performance, achieving a mean absolute percentage error (MAPE) of less than 0.7%, as well as relative RUL prediction error as low as 0.99%. Furthermore, an ablation study on layer normalization has shown that this component yields models that are more resilient to the capacity regeneration phenomenon. Model compression proves to be effective as well, since it leads to minimal degradation of performance, with MAPE loss below 1%. Finally, we provide a short overview of further research directions.

Keywords: lithium-ion batteries, state of health, remaining useful life, deep learning, robust regression, model compression

VII2.3 (#0238)
TOWARDS EVOLUTIONARY GENERAL INTELLIGENCE: A SEMIOTIC-BASED COGNITIVE ARCHITECTURE FOR AUTONOMOUS AGENTS

Alexander Serov

This paper examines the theoretical challenges of creating universal autonomous cognitive agents. General intelligence systems must possess capabilities that are currently unattainable. These include, in particular, the ability to autonomously learn from multimodal data streams and the implementation of higher mental functions. One of the most important criteria for creating AGI is the ability of an artificial system to reproduce cognitive activity based on mental images different from those used by humans. In this context, the concept of universality takes on special meaning. We examine the problem of the universality of cognitive architecture from the perspective of embodying constructivist ideas within the methodological framework of biosemiotics. In our discussion, we utilize the results of developing architecture based on a cognitive core and capable of autonomous intellectual development. In this paper, we emphasize the special role of the problem of modeling the process of world perception and address methods for solving the Symbol Emergence Problem. To illustrate the practical results of our work, we present the basic technical details of a numerical method developed for modeling the processes of preconscious cognitive activity of an autonomous agent.

Keywords: AGI, Cognitive Architecture, Biosemiotics, Autonomous Evolutionary Agents, Constructivist Learning

VI1.1 (#9934)
HIBRIDNI ANN MODEL ZA PROCENU IZLAZNE SNAGE FOTONAPONSKOG SISTEMA UZ INTEGRACIJU PVSYST SIMULACIJE: STUDIJA SLUČAJA ZA REGION NIŠA

Dragan Pantić

U radu je prikazan hibridni pristup modelovanju izlazne snage fotonaponskog sistema primenom veštačkih neuronskih mreža. Predloženi model integriše meteorološke podatke, rezultate PVsyst simulacije i eksperimentalna merenja, čime se omogućava preciznija aproksimacija realnog ponašanja sistema. Analiza je sprovedena na mrežno povezanom fotonaponskom sistemu nominalne snage 1 kW u regionu Niša, korišćenjem skupa podataka za period od 2018. do 2022. godine sa ukupno 43 824 satna uzorka. Performanse modela evaluirane su primenom standardnih statističkih metrika (RMSE, MAE i R^2), uz dodatnu analizu raspodele greške i slaganja prediktovanih i merenih vrednosti. Dobijeni rezultati pokazuju da predloženi ANN model ostvaruje značajno unapređenje tačnosti u odnosu na PVsyst simulaciju, sa vrednostima RMSE = 0.0107 kW, MAE = 0.0056 kW i R^2 = 0.9973, u poređenju sa RMSE = 0.0582 kW i R^2 = 0.9209 za simulacioni pristup. Analiza greške potvrđuje odsustvo sistematskog odstupanja i dobru generalizaciju modela. Rezultati rada ukazuju na značajan potencijal hibridnih data-driven pristupa za unapređenje modelovanja i predikcije proizvodnje fotonaponskih sistema u realnim uslovima rada.

Ključne reči: fotonaponski sistemi, PVsyst, hibridni model, prognoza, ANN, OIE

VI1.2 (#4511)
BIO-INSPIRISANA ADAPTIVNA PRIVREMENA MEMORIJA ZA AUTONOMNU VOŽNJU U CARLA SIMULATORU

Miroslav Milovanović, Marko Milojković, Saša Nikolić, Miodrag Spasić

Ovaj rad istražuje efekat algoritma pojačanog učenja i formiranja funkcije nagrade za upravljanje autonomnim vozilima u CARLA simulacionom okruženju. Sistematsko poređenje on-policy i off-policy metoda dubokog pojačanog učenja otkriva da off-policy metode, konkretno Soft Actor-Critic i Twin Delayed Deep Deterministic Policy Gradient, konzistentno konvergiraju ka degenerativnim stacionarnim strategijama u scenarijima gradske vožnje, dok on-policy metode održavaju optimalno ponašanje u vožnji. Nadovezujući se na ovo saznanje, u radu je predložena Endokrina Privremena Memorija (EPM) kao bio-inspirisani dodatni sloj za Proximal Policy Optimization (PPO). EPM uvodi naučeni signal rizika α koji dinamički kontroliše koliko brzo Gated Recurrent Unit integriše nove informacije. Princip je pozajmljen iz biologije - hormon stresa kortizol na sličan način reguliše brzinu formiranja memorija u mozgu. Kada je rizik nizak, α ima malu vrednost, tako da se memorija sporo menja i agent vozi glatko i stabilno. Sa povećanjem rizika, α raste, omogućavajući brzu inkorporaciju novih senzorskih informacija. Eksperimentalna evaluacija je demonstrirala da PPO proširen EPM modulom postiže 28% nižu negativnu kumulativnu nagradu u poređenju sa osnovnim PPO modelom, uz održavanje 87% brzine vožnje koju je osnovni model imao. Ovi rezultati podržavaju hipotezu da adaptivna privremena modulacija, bazirana na biološkim endokrinim principima, pruža efikasan mehanizam za poboljšanje stepena sigurnosti kod upravljanja autonomnim vozilima.

Ključne reči: pojačano učenje, autonomna vožnja, bio-inspirisano upravljanje, privremena memorija

VI1.3 (#5942)

ADAPTIVNI TELEMETRIJSKI-VOĐEN IOT SISTEM SA SAMO-OPORAVLJANJEM ZASNOVAN NA PROFILISANJU PONAŠANJA UREĐAJA ZA PAMETNU INFRASTRUKTURU

Isidora Simeunovic

Sisteme pametne infrastrukture zasnovane na Internetu stvari (IoT) karakterišu visoka heterogenost uređaja, dinamični uslovi rada i potreba za visokom pouzdanošću. Tradicionalni pristupi detekciji grešaka oslanjaju se na statičke pragove i ručno definisana pravila, što ograničava adaptivnost sistema. U ovom radu predlaže se telemetrijski-vođen adaptivni model sa samo-oporavljanjem zasnovan na profilisanju ponašanja IoT uređaja. Predloženi model koristi kontinuirano prikupljanje telemetrije za izgradnju dinamičkog profila normalnog rada uređaja. Detekcija anomalija zasniva se na odstupanju od individualnog ponašanja uređaja, nakon čega samo-oporavljajući modul autonomno aktivira mehanizme oporavka. Predložena arhitektura omogućava proširenje sa modulima za edge računarstvo, digitalnog blizanca i mašinskog učenja radi podrške prediktivnom održavanju. Rad predstavlja arhitekturu sistema, algoritam rada i konceptualnu validaciju kroz scenarije pametne infrastrukture. Predloženi pristup omogućava povećanje pouzdanosti, smanjenje potrebe za manuelnom intervencijom i skalabilnu primenu u pametnim gradovima, energetskim mrežama i industrijskim IoT sistemima.

Ključne reči: telemetrijski-vođen samo-oporavak IoT, profilisanje ponašanja uređaja, adaptivna pouzdanost IoT sistema, pametna infrastruktura, samo-oporavak IoT, analiza telemetrije, detekcija anomalija

VI1.4 (#8890)

PREDIKCIJA AKADEMSKOG USPEHA STUDENATA U VISOKOM OBRAZOVANJU PRIMENOM MAŠINSKOG UČENJA: SISTEMATSKI PREGLED LITERATURE

Sara Đorđević, Marija Punt

Primene veštačke inteligencije u obrazovanju danas su brojne, među kojima se kao značajna izdvaja predikcija akademskog uspeha studenata metodama mašinskog učenja. Cilj ovog rada je identifikacija i analiza trendova u primeni metoda mašinskog učenja u predikciji akademskog uspeha studenata u visokom obrazovanju u poslednjih pet godina. Sistematski pregled literature u ovoj oblasti sproveden je na osnovu unapred definisanih kriterijuma, a za obezbeđivanje transparentnosti i nepristrasnosti korišćene su smernice ukazane PRISMA protokolom za sistematske preglede literature. U analizu je uključeno 46 studija. Rezultati su pokazali da se najčešće u predikciji akademskog uspeha implementiraju ansambl i klasični modeli, a da je izuzetno učestalo eksperimentisanje sa hibridnim modelima. Performanse modela su evaluirane korišćenjem metrika od kojih su najčešće tačnost i površina ispod ROC krive. Podaci koje ove studije koriste su prevashodno akademski i demografski, uz porast upotrebe podataka sa LMS platformi.

Ključne reči: mašinsko učenje, predikcija akademskog uspeha, visoko obrazovanje, sistematski pregled

VI1.5 (#6252)
PRIMJENA VJEŠTAČKE INTELIGENCIJE ZA AUTOMATSKO OCJENJIVANJE I PREDIKCIJU USPJEHA UČENIKA

Dobrislav Drakul

U radu je primenjen Random Forest algoritam mašinskog učenja radi utvrđivanja faktora koji najviše utiču na postignuća studenata. Posmatrane su dve nezavisne promenljive: aktivnost na nastavi (interakcija na predavanjima i vežbama, ocenjena od 0 do 10) i broj bodova na predispitnim obavezama (0–70). Krajnji cilj je predviđanje nivoa znanja kodiranog kao 0 (slabo – ocena 5), 1 (srednje – ocene 6–8) i 2 (visoko – ocene 9–10). Eksperiment je sproveden na realnim podacima 250 studenata tokom dve školske godine, a proširen je simulacijom preko 9600 instanci u MATLAB-u. Random Forest model je pokazao visoku tačnost i jasno istakao da predispitne obaveze imaju znatno veći uticaj na konačni uspeh nego aktivnost na nastavi. Rezultati su u skladu sa prethodnim istraživanjima i pružaju konkretne smernice za unapređenje nastavnog procesa.

Ključne reči: Random Forest, mašinsko učenje, predviđanje, studentskih postignuća, predispitne obaveze, aktivnost na nastavi, educational data mining

AKTUELNOSTI U OBRAZOVANJU U ELEKTROTEHNIČKOM I RAČUNARSKOM INŽENJERSTVU / EDUCATION

СЕСИЈА / SESSION (ЕДУ1+EDUI1)

Среда, 10. јун / Wednesday, June 10th Сала 2 / Hall 2 9.00-11.15

Председавајући / Chair:
Jelica Protić, Univerzitet u Beogradu – Elektrotehnički fakultet, Beograd, Srbija

EDUI1.1 (#9062)
STRUCTURE-AWARE THESIS CONTENT DESCRIPTION USING LARGE LANGUAGE MODELS

Luka Hrvačević, Janko Tufegdžić, Matija Dodović, Marko Mišić

This paper addresses the problem of automated generation of structured descriptions of master thesis content using large language models (LLMs). In academic practice at the University of Belgrade, School of Electrical Engineering, this section describing the structure and content of a thesis is typically written manually in a formal and standardized style, requiring consistent coverage of all thesis chapters while preserving clarity and coherence. To alleviate the burden of doing such labor-intensive work for the academic staff, we propose a LLM-based approach. We propose a structure-aware approach that leverages the inherent organization of the thesis by decomposing the task into chapter-level description generation, followed by section assembly and stylistic refinement. Instead of relying on a single end-to-end generation step, the proposed pipeline processes each chapter independently, ensuring better control over content coverage and reducing the risk of hallucinations and structural inconsistencies. The approach is evaluated on a collection of 5 master theses using multiple LLMs, including Qwen, Gemma, and Mistral. Evaluation combines lexical, semantic, and composite metrics, as well as LLM-based factual consistency assessment. Experimental results show that the proposed structure-aware pipeline produces coherent and semantically accurate descriptions, with Mistral achieving the highest scores of the chosen models.

Keywords: large language models, structure-aware generation, text summarization, automated report generation

EDUI1.2 (#5322)
BILINGUAL CODE COMMENT EVALUATION WITH LARGE LANGUAGE MODELS

Matija Dodović, Janko Tufegdžić, Miloš Milošević, Dražen Drašković

Code comments play an important role in software development and programming education, as they help explain implementation intent and may indicate whether students understand the underlying code. However, automated assessment of comment correctness becomes more challenging in bilingual educational settings, where students may write comments in either English or a local language such as Serbian. This paper investigates the use of open large language models for binary classification of code-comment correctness in English and Serbian. We construct a bilingual dataset in which the same code fragments are paired with English and Serbian comments sharing the same correctness labels, and evaluate several code-oriented and general-purpose LLMs using a few-shot prompting strategy. The results show that Qwen3 and Qwen2.5-Coder achieve the strongest performance across both language conditions, while other models exhibit larger variation, particularly on Serbian comments. Pairwise McNemar tests further show that several observed differences between models are statistically significant. Overall, the findings suggest that LLM-based code-comment evaluation is a promising direction for programming education, but also highlight the need for multilingual evaluation when applying such systems in local-language educational contexts

Keywords: Large Language Models, Code Comments, Comment Correctness, Serbian Language, Programming Education, Few-Shot Prompting, Natural Language Processing, Artificial Intelligence

EDUI1.3 (#0618)
EDUCATION AND R&D SYNERGY - CHANCE FOR THE IMPROVEMENT OF ACADEMIC CURRICULUMS

Predrag Stolić, Zoran Jovanović, Željko Mravik, Marko Jelić, Sonja Jovanović

In the delivery of higher education, there is a need for students to work in real conditions, with real data and real-world examples. Therefore, it is necessary to increasingly enrich practical teaching in new study programs with real-life practice. However, this presents a challenge, since industrial, business, and other real-world data, as well as insight into actual processes and configurations, are in most cases unavailable or restricted due to the nature of operations. For this reason, this paper highlights research projects in which higher education institutions often participate, and which can compensate for these limitations. Such projects can provide students, within future study programs, with opportunities to acquire practical, real-world knowledge that will genuinely benefit their future engineering work. Through real-life examples, the paper will demonstrate both the primary and extended potential of this approach, as well as its sustainability.

Keywords: academic curriculum, flow controller, experiment, higher education, PLC, project

EDUI1.4 (#8111)
INTEGRATING VIRTUAL ASSISTANTS INTO THE PROGRAMMING LEARNING PROCESS WITHIN IT STUDIES

Ana Veljić, Marko Marković, Srđan Maričić

In the modern higher education environment of the field of Information Technology (IT), the application of modern technological tools is more and more oriented toward the integration of the existing gap between theoretical and applied knowledge. One of the major problems in the development of IT courses is the process of introductory programming, often associated with high levels of cognitive load and varied levels of student performance. This paper aims to investigate the pedagogical potential and operational application of the integration of AI-based tools of virtual agents in the process of programming education. This is based on the theoretical background of the constructivist approach and the self-regulated learning (SRL) model. The empirical part of the research, carried out among IT students, examines their views concerning the usefulness of virtual assistants in overcoming syntax barriers and improving problem-solving fluency. The research findings suggest that although AI tools greatly alleviate cognitive load and motivate learners, it is necessary to apply a didactic approach in order to develop genuine computational thinking. The research findings contribute to the discussion aimed at improving the quality of IT study programs and making them compatible with the changing needs of the global labor market.

Keywords: Virtual Assistants, Programming Education, AI in Education, IT Studies, Student Perception

EDU1.1 (#6849)
VIZUELIZACIJA PERFORMANSI RAČUNARSKIH SISTEMA

Teodora Radaljac, Jelica Protić

Gradivo predmeta Performanse računarskih sistema obuhvata niz matematičkih modela čije ponašanje studenti teško stiču samo kroz klasičnu nastavu. U ovom radu se opisuje veb aplikacija razvijena u Python/Streamlit okruženju koja studentima omogućava da eksperimentišu sa parametrima tih modela i odmah vide rezultat na grafiku. Aplikacija je podeljena u tri modula, a to su performanse hardvera, sistemi masovnog opsluživanja i otvorene mreže, i pokriva celokupan kurs, od Amdahl-ovog zakona do MVA algoritma. Rad daje pregled srodnih alata (JMT, JMCH, Jupyter notebook rešenja), opisuje arhitekturu aplikacije, prikazuje pet odabranih vežbi i razmatra kako se alat može uklopiti u nastavu.

Ključne reči: performanse računarskih sistema, vizualizacija, interaktivno učenje, Streamlit

EDU1.2 (#6998)
INTERAKTIVNI SIMULATOR ZA UNAPREĐENJE RAZUMEVANJA ALGORITAMA PRETRAGE

Đorđe Lončar, Vladimir Jocović, Adrian Milaković, Luka Hrvačević, Jelica Protić

Ovaj rad predstavlja simulator razvijen kao veb aplikacija, a namenjen boljem razumevanju algoritama pretrage u nastavi. Algoritmi pretrage često predstavljaju izazov za studente zbog visokog nivoa apstraktnosti i složenosti izvršavanja. Postojeća rešenja su uglavnom ograničena u pogledu vizualizacije, kontrole simulacije i interaktivnosti. U radu je predložen simulator koji omogućava kreiranje grafova, podešavanje težina grana i heuristike, odabira algoritma i izvršavanje algoritma uz detaljan prikaz svakog koraka.

Predloženi pristup predstavlja koristan alat u nastavi koji doprinosi dodatnom razumevanju algoritama pretrage nad grafovima.

Ključne reči: simulator, vizualizacija, graf, pretraga, edukacija

PRIDRUŽENA SESIJA – ФОРЕНЗИКА / FORENSICS

СЕСИЈА / SESSION (ФО1 + FOI1)

Понедељак, 8. јун / Monday, June 8th Сала 2 / Hall 2 11.15-14.00

Председавајући / Chair:
Radovan Radovanović, Kriminalističko-policijski univerzitet, Beograd, Srbija

FOI1.1 (#2841)
FORENSIC ENGINEERING CASE STUDY OF AL/CU BIMETALLIC JOINTS PRODUCED BY CONTINUOUS-DRIVE FRICTION WELDING WITH AND WITHOUT POST-WELD HEAT TREATMENT
INVITED PAPER

Bojan Gligorijević, Radovan Radovanović, Veljko Milašinović, Stefan Dikić, Milan Jovanović

The influence of the thickness, phase composition, and morphology of Al_xCu_γ intermetallic compound (IMC) interlayers on the mechanical integrity of Al/Cu bimetallic electrical connectors was investigated through experimental simulation under dynamic and static conditions. Al/Cu joints were produced by continuous-drive friction welding (CDFW) and subsequently modified either by extending friction time (dynamic conditions) or by post-weld heat treatment at 325 °C for 1 and 12 h (static conditions). In the as-welded state, joints exhibited discontinuous Al_2Cu interlayers with thicknesses below 0.5 μm. Under static conditions, IMC interlayers evolved into continuous multilayered structures (Al_2Cu, AlCu, and Al_4Cu_9) with thicknesses up to ~7.3 μm, while dynamic conditions produced thinner and less uniform interlayers (<1.6 μm), typically consisting of continuous Al_2Cu and discontinuous Al_4Cu_9. Despite the greater thickness and structural complexity of IMC interlayers formed under static conditions, these joints consistently exhibited higher ultimate tensile strength and comparable or improved elongation at break relative to dynamically formed joints. The results indicated that IMC interlayer thickness alone was not a reliable parameter for assessing mechanical integrity. Instead, phase composition, morphology, and thickness distribution must be considered as well. From a forensic engineering perspective, variations in IMC thickness between central and peripheral regions, thickness non-uniformity, and phase constitution provide valuable indicators of manufacturing conditions and service history. These findings highlight the importance of comprehensive interfacial characterization for improving the accuracy of failure analysis and root cause identification in Al/Cu systems.

Keywords: Al/Cu bimetallic joints, intermetallic compounds, continuous-drive friction welding, post-weld heat treatment, forensic engineering

FOI1.2 (#5827)
ACTIVE AND PULSED THERMOGRAPHY: ADVANCED MULTIDISCIPLINARY APPROACHES FOR DETECTION AND QUANTITATIVE CHARACTERIZATION OF SUBSURFACE DEFECTS

Dragan Knežević, Magdalena Dragović, Milesa Srećković, Milja Knežević

Active and pulsed thermography are advanced non-destructive techniques for detecting subsurface defects in infrastructure, civil, and industrial systems, as well as in forensic and conservation analyses. These methods rely on controlled thermal or laser stimulation, enabling identification of anomalies such as insulation damage, electrical overloads, leaks, structural weaknesses, and layered material irregularities. Contemporary approaches incorporate advanced signal processing, machine learning algorithms, and numerical modeling of thermal processes. This allows a transition from qualitative detection to quantitative characterization of defects. The integration of high-resolution thermographic systems with advanced data analysis ensures reliable anomaly detection and enhances result interpretation.

Keywords: active thermography, pulsed thermography, infrared thermography, non-destructive testing (NDT), subsurface defect detection, signal processing, machine learning, quantitative defect characterization, thermal stimulation, numerical modeling

FOI1.3 (#7437)
QUANTITATIVE NON-INVASIVE LASER ASSESSMENT OF MICROCIRCULATION AND VASCULAR FUNCTION IN CARDIOVASCULAR DIAGNOSTICS

Миља Кнежевић, Марија Бојановић, Драган Кнежевић

Modern cardiovascular monitoring increasingly employs non-invasive laser-based methods for precise assessment of microcirculation and vascular function. In this study, Laser Doppler Flowmetry (LDF) was used to measure tissue perfusion, Laser Speckle Contrast Imaging (LSCI) enabled contactless wide-field imaging of microcirculation, and Laser Doppler Vibrometry (LDV) assessed pulse wave velocity and mechanical vibrations of arteries. Pilot measurements on healthy volunteers and patients with hypertension and diabetes demonstrated high accuracy and the potential for early detection of vascular dysfunction. Future studies may incorporate larger cohorts, machine learning, and numerical modeling to enhance predictive capabilities. These approaches provide a contemporary, multidisciplinary framework for clinically relevant cardiovascular diagnostics.

Keywords: Cardiovascular monitoring, non-invasive diagnostics, Laser Doppler Flowmetry (LDF), Laser Speckle Contrast Imaging (LSCI), Laser Doppler Vibrometry (LDV), microcirculation, vascular function, pulse wave velocity (PWV), vascular dysfunction

FO1.1 (#7983)
INOVATIVNE TEHNOLOGIJE U FUNKCIJI SPASAVANJA LJUDI IZ RUŠEVINA

Mihajlo Milošević, Lazar Miladinović, Radovan Radovanović, Snežana Stojićić

Moderni pristupi spasavanju integrišu naprednu tehnologiju, specijalizovanu obuku i međunarodnu saradnju kako bi povećali efikasnost i smanjili rizike za spasioca. Ključne tehnologije uključuju dronove, robote opremljene senzorima, termalne kamere i softver za analizu stabilnosti ruševina. Obuka spasilaca obuhvata tehničke veštine, rad sa psima tragačima i pružanje osnovne psihološke podrške. Međunarodni standardi, kao što su

INSARAG, omogućavaju bolju koordinaciju i interoperabilnost između timova. Prevencija se postiže kroz obrazovanje građana, poboljšanje sistema za rano upozoravanje i promociju gradnje otporne na zemljotrese. Veštačka inteligencija dodatno pomaže u analizi podataka i prepoznavanju obrazaca kako bi se identifikovala prisutnost preživelih. Ovi pristupi ne samo da ubrzavaju proces spašavanja, već i značajno doprinose bezbednosti i pripravnosti zajednica za potencijalne prirodne katastrofe.

Ključne reči: prirodna katastrofa, spasavanje, rizici, obuka

FO1.2 (#2679)
PROTOKOLI REAGOVANJA U VANREDNIM SITUACIJAMA ZA VOZILA NA ELEKTRO POGON

Lazar Miladinović, Mihajlo Milošević, Vojkan Zorić

Globalni trend razvoja u automobilskoj industriji jeste uvođenje vozila na elektro pogon, koja pored pozitivnih efekata na životnu sredinu, utiču na pojavu novih bezbednosnih rizika za sve učesnike u saobraćaju. Kako nisu jasno definisani normativni zahtevi, niti procedure reagovanja u slučaju akcidenta na vozilima na elektro pogon, u praksi se javljaju i bezbednosni rizici po sve učesnike u saobraćajnom udesu i vatrogasce spasioce koji reaguju na navedene vanredne situacije. Uzevši u obzir i veliki broj različitih modela vozila na elektro pogon koji se mogu javiti na tržištu, navedeni bezbednosni rizici su još izraženiji, tako da se u narednom periodu mora jasno definisati protokol delovanja vatrogasaca spasioca prilikom pojave vanrednih situacija u kojima učestvuju vozila na elektro pogon, a kasnije i način obuke. U radu su dati pregledi aktuelnih saznanja o bezbednosnim rizicima, predlozi protokola reagovanja u slučaju pojave vanredne situacije i edukacije vatrogasaca spasioca.

Ključne reči: protokol reagovanja, edukacija vatrogasaca, vozila na elektro pogon, saobraćajne nesreće, požar

FO1.3 (#2582)
МЕТОДИ ДЕТЕКЦИЈЕ МИКРОТРАГОВА ЕКСПЛОЗИВА НАКОН АКТИВИРАЊА НА МОТОРНИМ ВОЗИЛИМА - ПРИКАЗ РЕАЛНИХ СЛУЧАЈЕВА

Никола Зорић, Радован В. Радовановић, Весна Петровић, Војкан Зорић

У раду су представљени методи за оперативну детекцију микротрагова експлозива који су пронађени на увиђајима након активирања експлозивних направа, као и у случајевима активирања минско-експлозивних средстава, те њихов значај у форензичкој науци. У већем броју реалних случајева коришћене су импровизоване експлозивне направе, као и моделовани пластични експлозиви активирани електронским уређајима. Најчешће коришћени лаб.методи за детекцију микротрагова употребљеног експлозива након детонације, су инфрацрвена спектрофотометрија са фуријевом трансформацијом (FTIR) и гасна хроматографија са масеном спектрометријом (GCMS). Обрадом добијених резултата дошло се до податка о врсти коришћеног експлозива, који у оперативној обради помаже бржем проналаску извршиоца тог кривичног дела.

Кључне речи: Метод детекције, Микротраг, Експлозив, Експлозивна направа, Инфрацрвена спектрофотометрија са фуријевом трансформацијом, Гасна хроматографија са масеном спектрометријом

FO1.4 (#0363)
PRIMENA MASENE SPEKTROMETRIJE U FORENZIČKOJ IDENTIFIKACIJI DIZEL GORIVA U PRODUKTIMA SAGOREVANJA

Lazar Miladinović, Nenad Selaković, Radovan Radovanović, Nevena Puač

Ovaj rad prikazuje eksperimentalnu analizu produkata sagorevanja različitih građevinskih materijala u prisustvu dizel goriva kao akceleratora, primenom masene spektrometrije. Ispitivani su uzorci cigle, laminata, tepisona, tarketa i vinila. Sagorevanje uz dodatak dizel goriva rezultovalo je pojavom karakterističnih masenih obrazaca akceleratora, sa dominantnim signalima u oblastima m/z 43 i 57, kao i u višem masenom opsegu m/z 69–71 i m/z 91, koji se mogu dovesti u vezu sa fragmentacijom alifatskih i aromatskih komponenti dizel goriva. Primenom diferencijalne analize masenih spektara omogućeno je izdvajanje signala koji potiču od produkata sagorevanja u prisustvu akceleratora, uz efikasno uklanjanje uticaja atmosferskih gasova. Posebno je uzeto u obzir da detektovani signali potiču od neutralnih vrsta uzorkovanih iz gasne faze, koje se jonizuju unutar masenog spektrometra. Dobijeni rezultati pokazuju da kombinacija masene spektrometrije i diferencijalne analize predstavlja pouzdan pristup za identifikaciju prisustva dizel goriva u složenim požarnim ostacima.

Ključne reči: masena spektrometrija, akcelerator sagorevanja, forenzička analiza, požarni ostaci, spektar

FO1.5 (#8633)
БАЛИСТИЧКА ПРОБОЈНОСТ КАО ИНДИКАТОР КОНСТРУКЦИОНЕ РАЊИВОСТИ У VEHICLE FORENSICS СИСТЕМУ

Sara Petković, Radovan Radovanovic, Zoran Milanovic

Савремена возила представљају сложене кибер-физичке системе у којима су механичке конструкције, електронске контролне јединице и комуникационе мреже интегрисане у јединствену безбедносну архитектуру. Континуирано генерисање дигиталних података путем бројних сензора и повезаних модула омогућило је развој форензике аутомобила и паметних возила (vehicle forensics) као специјализоване дисциплине. Анализа записа из EDR модула, CAN-bus комуникације и телематичких система омогућава прецизну реконструкцију догађаја и објективно утврђивање релевантних чињеница у истражним поступцима. Ипак, код блиндираних и безбедносно модификованих возила дигитална анализа није довољна за свеобухватно разумевање инцидента. Балистичка оштећења и деформације материјала могу указивати на структурне дисконтинуитете и зоне смањене отпорности, отварајући питање да ли се пробој може тумачити као индикатор системске конструкционе рањивости. Управо интеграција дигиталне и механичко-балистичке експертизе представља централни истраживачки изазов савременог vehicle forensics приступа.

Кључне речи: vehicle forensics, балистичка пробојност, конструкциона рањивост, блиндирана возила, дигитална форензика возила, EDR и CAN-bus анализа, структурни дисконтинуитети, форензичка реконструкција инцидената

FO1.6 (#8160)
ИНТЕРАКЦИЈА ПСИЛОЦИБИНА СА ФУНКЦИОНАЛИЗОВАНИМ НАНОМАТЕРИЈАЛИМА: МЕХАНИЗМИ И ПРИМЕНА СЕРС СПЕКТРОСКОПИЈЕ У УЛТРАБРЗОЈ ТОКСИКОЛОШКОЈ АНАЛИЗИ

Milica Gajić, Radovan Radovanović, Nevena Puač

У овом раду истражују се сложени физичко-хемијски механизми на додирној површини између наноматеријала и биолошких система. Фокус је на процесима адсорпције молекула псилоцибина на специфично пројектованим хибридним наноструктурама. Овај рад нуди решење за оптимизацију плазмонских граница фаза како би се постигла ултрасензитивна детекција аналита у сложеним биолошким матрицама. Детаљно су анализирани ефекти површинске функционализације на селективност и фактор појачања у оквиру површински појачане Раманове спектроскопије (Surface - Enhanced Raman Spectroscopy - SERS). Резултати показују да модификација површине увођењем карбоксилних и амино група драматично побољшава афинитет везивања. То се дешава кроз формирање специфичних водоничних веза и електростатчких интеракција. Ова хемијска структура површине омогућава стварање „врућих тачака“ (hotspots) високог интензитета локализованог електромагнетног поља. Тиме се граница детекције (Limit of Detection - LOD) спушта на фемтомоларни ниво (10e-15 M). Резултати постављају темељ за развој преносивих наносензора који омогућавају идентификацију у реалном времену, што је од кључног значаја за рад на терену.

Кључне речи: псилоцибин, површинска функционализација, хибридне наноструктуре, SERS спектроскопија, граница детекције (LOD), форензичка токсикологија

FO1.7 (#4389)
ULOGA FORENZIKE U BEZBEDNOSTI ELEKTRONSKOG POSLOVANJA

Slađana Pantelić

Razvoj informacionih tehnologija i interneta doveo je do naglog širenja elektronskog poslovanja. Sve veći broj finansijskih transakcija, razmena podataka i poslovnih procesa odvija se u digitalnom okruženju. Međutim, paralelno sa tim rastu i bezbednosni rizici, poput sajber napada, krađe podataka i različitih oblika digitalnih prevara. U tom kontekstu, Digitalna forenzika ima ključnu ulogu u zaštiti sistema elektronskog poslovanja, a biće prikazani primeri i mogućnosti zaštite. The development of information technologies and the internet has led to a rapid expansion of electronic business. An increasing number of financial transactions, data exchanges, and business processes take place in a digital environment. However, parallel to this growth, security risks are also increasing, such as cyber attacks, data theft, and various forms of digital fraud. In this context, digital forensics plays a key role in protecting e-business systems, and examples and protection possibilities will be presented.

Ključne reči: elektronsko poslovanje, bezbednosni rizici, zaštita sistema, electronic business, security risks, system protection

PRIDRUŽENA SESIJA – ХЕРИТОЛОГИЈА / HERITOLOGY

СЕСИЈА / SESSION (HE1)

Среда, 10. јун / Wednesday, June 10th Сала 3 / Hall 3 10.15-11.15

Председавајући / Chair:
Magdalena Dragović, Univerzitet u Beogradu – Građevinski fakultet, Beograd, Srbija

HE1.1 (#1099)
TRIBOELEKTRIČNI EFEKAT I NJEGOVA PRIMENA KOD ODEĆE
POZVANI RAD

Dušan Nešić

Triboelektrični efekat (Triboelectrification or triboelectric effect) je čest efekat koji dovodi do elektrostatičkog naboja. Efekat nastaje usled sastavljanja i rastavljanja ili trenja odgovarajućih materijala. To može da dovede do elektrostatičkog pražnjenja (Electrostatic discharge-ESD) a time i do velikog rizika. Ovo posebno važi i za elektroniku na odeći (e-textile) koja je u sve većoj upotrebi. Metode ublažavanja kod tekstila su uglavnom načini odvođenja naelekrtisanja, tj nekog uzemljenja (grounding). Međutim, postizanje brzog raspada naboja i smanjenja energije pražnjenja uključuje kompromise između izolacije i vodljivosti. Provodni elementi potiču pražnjenje, ali i olakšavaju prenos energije kada su izloženi visokim naponima. Izolacione tkanine ograničavaju energiju pražnjenja, ali produžuju zadržavanje naelektrisanja. Triboelktrični efekat se sve više iskorišćava kao pojava, gde se mehanički pomeraj pretvara u električni signal usled sastavljanja i rastavljanja ili trenja odgovarajućih materijala. Donorski materijali daju elektrone a akceptorski ih primaju. Sastavljanje i rastavljanje površina materijala podrazumeva i kontakt koji se pomera sa pokretnim materijalom što može biti i problem. Rešenje može biti u tome da gornju materijal, koji vrši površinsko trenje, nema kontakte i da su oni na dva donja materijal a koji su nepokretni. Takav je slučaj i kod odeće gde postoji znatan broj parova materijala. Kod odeće se u potpunosti koristi unutrašnji prostor kako bi se povećala kontaktna površina i tako povećala izlazna snaga i osetljivost. Triboelektrični efekat služi za detekciju dodira (tactical sensors) ili za prikupljanje energije mehaničkih vibracija (energy harvesting). Triboelektrični signal je po prirodi naizmeničan. Jednosmerna struja za napajanje baterije ili pak LED diode mora da prođe kroz ispravljač, što može da bude dodatni zahtev. Nasuprot ovoga, može se koristi naizmenični signal i transfer energije preko zavojnice (coil). Pored ovoga postoji i tribonaponski efekat (tribovoltaic) gde se koriste poluprovodnici, a generacija je slična kao i kod PIN fotodioda, što znači da je jednosmerna.

Ključne reči: triboelektrični efekat, elektrostatičko pražnjenje, elektronika na odeći, uzemljenje

HE1.2 (#8037)
ПРЕДЛОГ РЕКОНСТРУКЦИЈЕ ЛОКАЦИЈЕ ХРИШЋАНСКОГ САКРАЛНОГ ОБЈЕКТА НА ОСНОВУ МАПЕ ПОДЗЕМНИХ ВОДОТОКОВА НА УЖОЈ ТЕРИТОРИЈИ БЕОГРАДА

Dragan Petrović, Ema Petrović, Magdalena Dragović

Две хиљадугодишње светске и европске цивилизације, Винчанска и Лепенски вир, су нашле своје уточиште на обали реке Дунав, од којих је Винча у непосредној

близини града Београда. Дунав је од давнина представљао свету реку и извор живота за народе који су живели на њеним обалама. Београд тиме носи део карактера ова два цивилизајска и духовна средишта, повезана другом реком по величини у Европи. Велики број подземних водотокова и термалних извора Београда је укључен у дунавски слив. Ове везе су данас слабије уочљиве због урбаног развоја града. Имена изворишта и правци њихових токова, указују на могућу повезаност са местима градње богомоља (цркве, или манастири). О њима нема много података, због значајног протока времена (још пре Турских освајања). Једно од посебних места - извориште Бибијиног потока, у центру Београда, везано за ранохришћанску свету мученицу Вивијан (Бибијан) страдалу 362 године, је изабрано за студију случаја у контексту шире теме. Рад се бави и одговорима на питања зашто је овај лековити извор из времена Рима и Турака, у урбаном делу старог Београда, понео име светитељке и зашто се њено поштовање задржало код Рома. Рад такође наговештава да, слично овом изворишту, Славујев поток, Врачарски поток, Вилине воде и др. упућују на постајање других духовних средишта/објеката на територији града Београда.

Кључне речи: Лековито изворište, подземни водотокови Београда, сакрални објекат, реконструкција локације

HE1.3 (#5464)
REKONSTRUKCIJA ŽELEZNIČKIH PRUGA ZA GC PROFIL - PRIMENA 3D MODELOVANJA SVETLOG OTVORA TUNELA

Nevena Kasapović, Magdalena Dragović, Luka Lazarević, Marko Pejić, Jana Matić

Rekonstrukcija postojećih železničkih pruga, a naročito pruga koje su deo TEN-T mreže, podrazumeva obezbeđenje slobodnog profila GC u cilju usklađivanja sa savremenim evropskim standardima interoperabilnosti. Ovaj profil omogućava saobraćaj voznih sredstava većih dimenzija i razvoj intermodalnog transporta. Poseban izazov za primenu slobodnog profila GC u projektima rekonstrukcije predstavljaju postojeći tuneli, koji su projektovani prema ranijim standardima, odnosno prema slobodnim profilima manjih dimenzija. U takvim uslovima projektanti se često suočavaju sa kolizijom između postojeće konstrukcije tunela i zahtevanog slobodnog profila GC. Rešavanje ove kolizije zahteva razmatranje različitih tehničkih rešenja, koja moraju uzeti u obzir tehnička, ekonomska i eksploataciona ograničenja, pri čemu osnovu za analizu treba da predstavlja detaljan geodetski snimak svetlog otvora tunela.

Ključne reči: Železnički tunel, slobodni GC profil, osovina koloseka, oblak tačaka tunela, geometrijski model, 3D rekonstrukcija

HEI1.1 (#5695)
FICTITIOUS SHELL METHOD FOR STRESS–STRAIN ANALYSIS OF AN ARCH DAM: RASLOVIĆI DAM CASE STUDY

Vlado Trnavac, Vladan Kuzmanović, Magdalena Dragović, Aleksandar Savić

This paper presents an innovative numerical method for analysis of arch dams. Dam and interacting rock mass are approximated using line (beam) finite elements. Unlike well known ‘single cantilever, multiple arch method’ and ‘multiple cantilever, multiple arch method,’ this approach employs ‘extended arches and cantilevers,’ whereby the interacting rock mass is modeled with the same beam elements as the dam, but with different cross sections and corresponding mechanical properties. Furthermore, to distribute hydrostatic load onto dam onto the beam elements, a ‘fictitious shell’ is

introduced – an auxiliary numerical element that discretizes surface load through influence areas and transfers equivalent loads to the arches and cantilevers. This approach simplifies the calculation of hydrostatic load distribution on the dam beam elements and provides more realistic representation of dam–rock interaction. The application of Fictitious Shell Method is demonstrated on the case of Raslovići Dam on the Morača River in Montenegro.

Keywords: Arch dam, FEM Model, Fictitious shell method, Stress–strain analysis, Line(beam)finite elements

PRIDRUŽENA SESIJA - MULTIDISCIPLINARNA

СЕСИЈА / SESSION (MD1+MDI1)

Понедељак, 8. јун / Monday, June 8th Сала 5 / Hall 5 9.00-11.00

Председавајући / Chair:
Vladimir Arsoski, Univerzitet u Beogradu – Elektrotehnički fakultet, Beograd, Srbija

MDI1.1 (#1044)
FRACTIONAL-ORDER MODELING OF MAGNETO-IMPEDANCE IN AMORPHOUS AND NANOSTRUCTURED MAGNETIC MATERIALS INVITED PAPER

Vedran Ibrahimovic, Nebojsa Mitrovic

Fractional-order modeling is a multidisciplinary framework widely used to describe memory, nonlocality, and distributed dynamics in fields such as control theory, dielectric dispersion, and complex physical systems. In this work, that framework is applied to the microwave permeability spectra of amorphous CoFeB thin films. Published experimental complex-permeability curves were digitized and fitted using three fractional-order intrinsic models combined with an explicit skin-effect correction. Model selection was performed using the corrected Akaike information criterion. The results showed that a simpler fractional-order model was sufficient for thinner films, whereas thicker films required a more flexible formulation. The proposed approach provided good agreement with the experimental spectra and preserved a clear physical interpretation by separating intrinsic magnetic dispersion from thickness-dependent skin-effect effects.

Keywords: fractional modeling, magnetoimpedance, permeability, skin effect, CoFeB films, microwave magnetics

MDI1.2 (#1685)
ELECTRICAL AND TENSILE PROPERTIES OF COPPER-MAGNESIUM ALLOYS USED FOR ELECTRIC WIRES AND CABLES

Zoran Karastojković, Vukašin Milić, Milesa Srećković and Nada Ratković Kovačević

Pure copper is rather used as a good electric conductor, but it's mechanical properties first of all yielding and tensile strength are not at levels that is needed for some kinds of cables. For increasing the bearing capacity of an electric cable aluminum was used, where the steel wire is used as a core, with considerably higher strength than of a copper or aluminum. Many efforts have been made in finding the proper material, it means an alloy, with satisfied carrying capacity but small lowering of the electrical conductivity.

For such application here will be analyzed a binary alloy on a copper base with magnesium as a main constituent. For cables both mechanical and electrical bearing capacity are of importance. In reality the yielding strength could be more important than the tensile strength. These data are important both for producer and user. The behavior of these properties needs discussion from a metallurgical point of view.

Keywords: electric cables, low alloyed copper, electrical conductivity, bearing capacity

MDI1.3 (#4446)

ADVANCES AND CHALLENGES IN QUANTUM DOT SOLAR CELLS

Emad Mohammadkhani, Vladimir Arsoski

This paper reviews recent progress and limitations in quantum dot solar cells (QDSCs). Significant characteristics of quantum dots (QDs), such as a tunable bandgap and multiple exciton generation, make them interesting for applications in state-of-the-art photovoltaic devices. Furthermore, recently fabricated QD-based solar cells demonstrated significant mechanical strength in flexible applications. However, the stability of these devices under environmental factors such as heat, moisture, and ultraviolet (UV) light is debatable and represents an important topic of scientific research. Currently, the highest quantum efficiency, up to 18.3%, has been achieved by hybrid solar cells that combine perovskites and quantum dots manufactured from toxic compounds. Future research efforts will focus on identifying materials for environmentally friendly and efficient devices.

Keywords: Quantum Dots Solar Cell, Photovoltaics, defect passivation, Multiple Exciton Generation, Nanocrystals

MDI1.4 (#1096)

A HYBRID METAHEURISTIC ALGORITHM FOR SOLVING THE LAND CONSOLIDATION PROBLEM

Aleksa Samardžija, Dušan Samardžija

Land consolidation is a land management process aimed at reducing fragmentation of agricultural land while maintaining the original area and value. As such a combinatorial problem falls under the category of NP hard problems it is essential to apply an optimization technique based on metaheuristic algorithms. In our work we propose a greedy metaheuristic method based on using memetic algorithms and through our experiments show very promising results.

Keywords: Genetic algorithm, Metaheuristics, Simulated annealing, Parallel processing, Land consolidation

MD1.1 (#0670)

NESAVRŠENOSTI OPTIČKIH TELESKOPA I UTICAJ ZEMLJINE ATMOSFERE

Katarina Jevtić, Ljiljana Konjević, Miodrag Malović

Za teleskope reflektore, koji se svakodnevno koriste u posmatračkoj astronomiji, vezan je niz nesavršenosti koje nastaju usled inherentnih optičkih osobina primarnog ogledala, gde je najuočljivija sferna aberacija. Pored nesavršenosti samog optičkog sistema, uticaj turbulentne optički nestabilne ("zaprljane") Zemljine atmosfere sve više ograničava kvalitet posmatranja, što je posebno izraženo u amaterskoj astronomiji. Za analizu efekata oba faktora (mane teleskopa i atmosfere) korišćeni su Fridov parametar, kao mera distorzije upadnog talasnog fronta i Kolmogorovljev model atmosferske turbulencije. Krajnji rezultati prikazani su u vidu raspodele intenziteta zračenja u ravni

slike dobijeni su primenom Furijeove optike i Furijeovih transformacija na kompleksnu amplitudu talasa za kružnu aperturu. Oni pokazuju da pri vrednostima Fridovog parametra manjim od 5 cm sferna aberacija prestaje da bude dominantan faktor degradacije slike.

Ključne reči: Furijeova optika, Fridov parametar, atmosferska turbulencija, kompleksna amplituda, intenzitet zračenja, Erijev disk

MD1.2 (#4336)
MERENJA AMBIJENTALNOG NIVOA ELEKTRIČNIH I MAGNETSKIH POLJA U STAMBENIM OBJEKTIMA U BLIZINI VISOKONAPONSKIH DALEKOVODA

Marija Nikolić, Milesa Srećković, Aleksandra Janićijević, Ljubinko Timotijević, Lazar Timotijević, Aco Janićijević

Kao što je poznato u oblasti električnih, magnetskih i elektromagnetskih polja (0 – 300 GHz) koriste samo najosnovniji vidovi zaštite, jer se u potpunosti ne poznaju sva biološka dejstva ovih polja na ljudski organizam, a samim tim i rizici usled izlaganja. Važno je napomenuti da se aktivna zaštita odnosi samo na električna polja, jer ne postoji materijal koji bi značajno oslabio magnetsko polje. Pri izlaganju magnetskim poljima osnovne mere zaštite se projektuju i planiraju u odnosu na definisana rastojanja od izvora, a u skladu sa administrativnim merama koje podrazumevaju poštovanje odgovarajućih propisa i pravilnika kojima bi se regulisao bezbedan rad u zonama bliskim izvorima magnetskih polja. U ovom radu je ocena „ambijentalnog nivoa“ gustine magnetskog fluksa ELF polja sprovedena adekvatnim merenjima za planirane lokacije (u dvorištima i kućama) koje se nalaze na udaljenosti između 30 do 500 m oko visokonaponskih postrojenja na osnovu jednokratnih tzv. „spot“ merenja izvršenih u preko 100 mernih tačaka. Dobijene vrednosti upoređivane su sa odgovarajućim referentnim nivoima za stanovništvo iz smernica Međunarodne komisije za zaštitu od nejonizujućih zračenja (ICNIRP).

Ključne reči: Radiofrekventno zračenje, bazne stanice, efekti na zdravlje, karakteristike EM polja mrežnih frekvencija, uticaj na životnu sredinu, frekvencijski-selektivna „spot” merenja

MD1.3 (#7501)
SAVREMENA TELEKOMUNIKACIONA REŠENJA NA RUDARSKIM MAŠINAMA ZA POVRŠINSKO OTKOPAVANJE

Branimir Davidović

Rudarska mašina otkopava materijal koji se transportuje predajnom i prijemnom trakom transportera do mesta koje je namenjeno za odlaganje materijala. Upravljanje otkopavanjem materijala, kretanjem trakastih transportera, vrši se savremenim MASTER industrijskim PLC računarom, odgovarajućim brojem SLAVE PLC računara i mreže za elektrooptičku i bežičnu komunikaciju. Startovanje rada prijemne trake odvija se bežičnom komunikacijom slanjem signala starta za rad. Neprekidno napajanje je realizovano trofaznim naponom 6000 VAC i u skladu je sa savremenim dizajnima mašinskih rešenja za ovu klasu rudarskih mašina. Elektrooptička komunikacija je realizovana pomoću elektrooptičkih konvertora, multimodnih i monomodnih optičkih kablova. Elektrooptički konvertori sa elektronikom i memorijama su zamenili nepouzdane stare kontaktere i upravljačku logiku sa velikim brojem bakarnih žica i prekidača. U radu su prikazane rudarske mašine velikog gabarita, koje zbog svojih dimenzija, visine 50m i širine 130m, igraju veliku ulogu u proizvodnji električne energije. Upravljanje starim elektromotornim pogonima je zamenjeno sa novim

sofisticiranim pogonima realizovanim sa frekventnim regulatorima. Upotreba optičkih kablova je omogućila bolju i stabilniju komunikaciju. Optički kablovi su zamenuli veliki broj bakarnih kablova. Nedostatak implementacije optičkih kablova u ovom rešenju je mogućnost njihovog mehaničkog oštećenja. Pojava 5G mreža i IoT tehnologije, optimizuje postojeću komunikaciju sa optičkim kablovima na rudarskim mašinama.

Ključne reči: Rudarska mašina, PLC, Napajanje mašine, Multimodni kablovi, Elektromotorni pogon, 5G, IoT

MDI1.5 (#1410)

SPEED OF ULTRASOUND IN HARDENED ALKALI ACTIVATED CEMENT MIXTURES

Luka Rubinjoni, Aleksandar Savić, Milesa Srećković, Aco Janićijević

Alkali activated cements (AAC) and concrete are a promising alternative to Portland cement (PC) based materials. Originally used as auxiliary cement materials in Portland cement mixtures, coal fly ash (FA) and ground granulated blast furnace slag (BFS) can be utilized on their own, or as a mixture through the process of alkali activation. The resulting cements and concrete have reduced carbon footprint, compared to PC, and can excel in thermal stability, set times, and strength. Alkali activated cements have potential both as construction materials, and in special applications such as radioactive waste conditioning. As part of the ongoing research into the properties of alkali activated fly ash and ground granulated blast furnace slag pastes, we have examined FA, BFS, and a 50:50 by weight mixture of FA and BFS, activated by water glass and cured at room conditions, and measured the speed of ultrasound in the cast samples. The results contribute to practical applications of non destructive evaluation methods used both in construction, and radioactive waste management.

Keywords: alkali activated binder, geopolymer, ultrasound, non-destructive testing

PRIDRUŽENA SESIJA - DIGITALIZACIJA U NAUCI

СЕСИЈА / SESSION (DIG1)

Среда, 10. јун / Wednesday, June 10th Сала 3 / Hall 3 9.00-10.15

Председавајући / Chair:
Danica Mamula Tartalja, Akademija tehničko-umetničkih strukovnih studija Beograd, Srbija

DIGI1.1 (#4953)
LINGUISTIC DIMENSIONS OF COMMUNICATION IN MOBILE HEALTH
INVITED PAPER

Gordana Jelić, Danica Mamula Tartalja

In the field of mHealth, effective communication among participants in the healthcare system is crucial for achieving positive outcomes. Additionally, it facilitates ongoing interaction between patients, healthcare professionals, and digital health systems. mHealth expands this area of communication beyond traditional clinical interactions by including SMS messages, online health forums, and continuous data streams from wearable devices. These diverse communication channels generate large amounts of unstructured, multimodal data that require advanced computational methods for proper

interpretation. This survey explores different approaches to language analysis and multimodal data processing within the mHealth environment, along with available resources and open research challenges. These challenges include the lack of annotated corpora for Serbian (a low-resource language), data interoperability issues, and concerns related to privacy and ethics. The focus is on natural language processing (NLP) techniques, including sentiment analysis, text classification, and named entity recognition, applied to user-generated content such as SMS messages, online forum discussions, and electronic health records (EHRs). These methods enable the extraction of valuable insights from large volumes of unstructured textual data, facilitating health monitoring, early detection of pathological conditions, and improved patient engagement. Data collected from wearable devices provide valuable physiological and contextual information, further enriching communication streams and supporting more accurate and personalized health assessments. Particular attention is given to the challenges of analyzing informal and highly variable language characteristic of technology-mediated discourse, including the use of slang, abbreviations, and non-standard spelling in Serbian. Semantic analysis, combined with NLP techniques, can help identify ambiguities, unclear formulations, contradictory statements, and other semantic errors. The importance of communication as a fundamental component of the healthcare system is emphasized, as is the potential to integrate NLP techniques with wearable device data to develop scalable, adaptive, and personalized healthcare solutions. Effective communication analysis can enhance decision-making processes and optimize mHealth interventions. The integration of language analysis and sensor data for the development of advanced, personalized mHealth solutions, along with improved capabilities for real-time understanding of user behavior and health status, represents a promising direction for future research and highlights the need for further investigation and standardization in this domain.
Keywords: mobile health, communication, natural language processing, technology-mediated discourse, wearables

DIGI1.2 (#1075)

ENHANCING EFFICIENCY IN SPECIFIC APPLICATIONS THROUGH THE USE OF DIFFERENT TYPES OF BLOCKCHAIN TECHNOLOGIES

Djordje Mladenovic, Miloš Bukumira, Milanko Kragović, Slobodan Čabarkapa

Abstract This paper explores the fundamental concepts of Blockchain technology, its various forms, methods and areas of application, as well as the advantages and limitations associated with its use. In addition, the paper discusses possible directions for the future development of Blockchain systems. The main objective is to introduce readers with little or no prior knowledge to the core principles of Blockchain technology and to provide guidance in selecting the most suitable type of Blockchain for specific applications. Therefore, we will introduce a completely new way of applying this technology in the creation of digital currency based on art. Because of the increasing popularity and broad range of applications of Blockchain technology, the number of related studies and articles has grown significantly. As a result, it may be challenging for readers to identify the most relevant direction when exploring specific topics. This paper therefore aims to assist readers in selecting an appropriate path for further research while also presenting new perspectives on the potential use of Blockchain technology. For the authors, this paper represents an initial step toward addressing challenges in Blockchain systems through optimization techniques supported by artificial intelligence, as well as exploring the use of this technology in building a sustainable value system.
Keywords: blockchain, digital currencies, artbased currency, smart contracts, decentralization

DIGI1.3 (#8420)
FLY ASH FROM THERMAL POWER PLANTS: TRANSFORMING INDUSTRIAL RESIDUE INTO A CONSTRUCTION RESOURCE

Jovo Jelic, Snežana Nenadović, Ljiljana Kljajević

During coal combustion in thermal power plants, harmful substances such as sulfur oxides, nitrogen oxides, as well as CO_2, and fine particulate matter are released. Additionally, wastewater is generated along with residual materials in the form of fly ash and slag. Fly ash consists of fine inorganic particles separated from flue gases by electrostatic precipitators, while larger particles settle as slag. The quantity and characteristics of fly ash and slag depend on the coal composition and the combustion technology used. They are disposed of in landfills near thermal power plants when not considered useful, leading to soil contamination, heavy metal leaching into the food chain, and atmospheric dispersion of fine ash particles, posing risks to ecosystems and human health. This represents a more than sufficient argument for the increasing focus on their potential applications aimed at reducing environmental impacts and enhancing the value of these industrial residues. Their use in the construction industry, especially as an additive or partial substitute for cement in concrete, reduces CO_2 emissions and helps protect the environment. Using fly ash in building roads, bridges, dams, and even large high-rise structures shows that industrial residues can become sustainable materials with considerable economic and environmental benefits.

Keywords: fly ash, industrial residue, environment, sustainable materials

DIG1.1 (#8477)
PRIMENA ALGORITAMA MAŠINSKOG UČENJA ZA KLASIFIKACIJU CTG SIGNALA U OBLAKU

Enis Osmani, Milorad Paskaš

Digitalizacija u zdravstvu, podržana primenom tehnologija veštačke inteligencije (AI) i Interneta stvari (IoT), nudi značajne mogućnosti za poboljšanje dijagnostike, praćenja pacijenata i optimizaciju medicinskih procesa. Microsoft Azure platforma pruža širok spektar rešenja koja omogućavaju zdravstvenim ustanovama da integrišu AI i IoT tehnologije kako bi se poboljšao kvalitet nege i povećala operativna efikasnost. U ovom radu ispituju se načini na koje se veštačka inteligencija i IoT tehnologije, podržane Microsoft Azure platformom, mogu primeniti u optimizaciji zdravstvenih usluga kroz analizu podataka kardiotokografije. Posebna pažnja posvećena je primeni ovih tehnologija u praćenju vitalnih parametara pacijenata, prediktivnoj analitici i poboljšanju operativne efikasnosti zdravstvenih ustanova. Razmatraju se izazovi i ograničenja povezana sa implementacijom ovih tehnologija, kao i potencijalna rešenja za njihovo prevazilaženje. Prikazani su konkretni primeri primene, sumirani su ključni nalazi i razmatrane su buduće perspektive razvoja u ovoj oblasti.

Ključne reči: IoT, mašinsko učenje, veštačka inteligencija, Microsoft Azure, računarstvo u oblaku

DIG1.2 (#0322)
ČISTA ENERGIJA I ZELENA GRADNJA NA PUTU KA ODRŽIVOJ BUDUĆNOSTI

Ana Stošović, Jovo Jelić

Čista energija u funkciji zelene gradnje je ključni koncept savremene arhitekture i urbanizma. Ona se oslanja na obnovljive izvore energije i uz primenu principa zelene

gradnje, značajno doprinosi smanjenju negativnih uticaja na životnu sredinu i povećanju energetske efikasnosti objekata. Korišćenje obnovljivih izvora povećava održivost zgrada, smanjuje operativne troškove i poboljšava ekološki otisak, čime direktno podržava koncept zelene gradnje i održivog urbanog razvoja. Investiranje u zelenu gradnju bi trebalo da znači dugoročnu uštedu energije i novca, kao i podstrek razvoju lokalne energetske infrastrukture. U radu se razmatra značaj integracije ovih pristupa i ukazuje na njihove prednosti u unapređenju energetske efikasnosti i kvaliteta života. Zelena gradnja predstavlja važan korak ka održivom razvoju i zaštiti životne sredine, a primena čiste energije je njen osnovni element.

Ključne reči: energetska efikasnost, čista energija, obnovljivi izvori energije, energetska infrastruktura, održivi razvoj, ekološki otisak

DIG1.3 (#8138)
TSI NOISE OKVIR ZA PRAĆENJE BUKE U ŽELEZNIČKOM SEKTORU

Sanja Jevtić, Sonja Ketin, Marko Bursać, Dušan Vujović

Rad će dati pregled okvira za procenu buke u železničkom okruženju (vozila). Posebno će se komentarisati tehničke specifikacije za interoperavilnost za smanjenje buke, ali sa stanovišta postavke opreme za merenje, u skladu sa preporučenim okvirima, regulativom i standardima.

Ključne reči: TSI NOIse, Rolling stock (vozna sredstva), buka

PRIDRUŽENA SESIJA - TOPLOTNE PERFORMANSE SLOŽENIH STRUKTURA. MODELOVANJE I PRIMENA

СЕСИЈА / SESSION (TP1)

Четвртак, 11. јун / Thursday, June 11th Сала 4 / Hall 4 9.00-11.00

Председавајући / Chair:
Radovan Gospavić, Univerzitet u Beogradu – Građevinski fakultet, Beograd, Srbija

TP1.1 (#1446)
DINAMIČKE TERMIČKE KARAKTERISTIKE OMOTAČA ZGRADE I NJIHOV ZNAČAJ U PROJEKTOVANJU ENERGETSKI EFIKASNIH ZGRADA
POZVANI RAD

Zorana Petojević

Predavanje razmatra dinamičke termičke karakteristike omotača zgrade i njihov sve veći značaj u projektovanju energetski efikasnih zgrada. Dinamičko termičko ponašanje građevinskih elemenata — koje obuhvata nestacionarni prenos toplote, toplotnu inerciju, vremenski (fazni) pomak i faktor prigušenja temperaturne oscilacije, kao i uticaj promenljivih optičkih karakteristika elemenata omotača i režima ventilacije — ima značajnu ulogu u formiranju unutrašnje temperature i toplotnih opterećenja sistema za grejanje, ventilaciju i klimatizaciju u uslovima promenljivih spoljašnjih uticaja. Savremena istraživanja pokazuju da stacionarni pokazatelji performansi omotača nisu dovoljni za pouzdano predviđanje energetskih performansi zgrada, naročito u klimatskim uslovima sa izraženim dnevnim temperaturnim oscilacijama ili u objektima sa povremenim radom sistema za grejanje, ventilaciju i klimatizaciju. Napredni fasadni sistemi, kao što su dinamičke, adaptivne, ventilisane i klimatski responzivne fasade,

mogu značajno smanjiti potrebe za hlađenjem i grejanjem, često nadmašujući performanse konvencionalnih statičkih fasada za 30–65% zahvaljujući regulaciji prenosa toplote, strujanja vazduha i sunčevih dobitaka u realnom vremenu. U predavanju se takođe ističe kako dinamička termička svojstva utiču na dimenzionisanje sistema za grejanje, ventilaciju i klimatizaciju, strategije njihovog rada i uslove termičkog komfora, kao i kako integrisana optimizacija omotača zgrade i HVAC sistema može dovesti do značajnih energetskih ušteda, kako kod novih zgrada tako i kod rekonstrukcija. Pored toga, razmatraju se i aspekti održavanja, pri čemu se naglašava da praćenje dinamičkih performansi fasada omogućava pravovremeno otkrivanje degradacije sistema i očuvanje dugoročne energetske efikasnosti. Sveukupno posmatrano, razumevanje i primena dinamičkih termičkih karakteristika predstavljaju važan preduslov za projektovanje visokoperformantnih, klimatski responzivnih i otpornijih zgrada.

Ključne reči: dinamičke termičke osobine, omotač zgrade, nestacionarni prenos toplote, energetska efikasnost

TP1.2 (#7726)
MODELOVANJE TERMIČKIH PERFORMANSI VIŠESLOJNIH GRAĐEVINSKIH ZIDOVA U DINAMIČKIM USLOVIMA KORIŠČENJEM ELEKTRIČNIH ANALOGIJA

Milan Stamenić, Zorana Petojević, Milica Mirković Marjanović, Goran Todorović, Radovan Gospavić

U radu je analiziran transport toplote i temperaturska raspodela unutar različitih tipove višeslojnih zidova od interesa u građevinarstvu, kod kojih je jedan od slojeva od betona. Razmatran je nestacionarni slučaj transporta toplote u vremenskom domenu. Pretpostavljeno je da su svi slojevi unutar posmatrane strukture homogeni i da su fizički i termalni parametri materijala od kojih je struktura sastavljena konstantni i nezavisni od temperature. Predstavljeni su rezultati za četiri vrste betona:uobičajeni konstruktivni beton, beton sa recikliranim betonskim agregatom kao i betoni sa delimičnom zamenom cementa letećim pepelom i zgurom visokih peći. Iz prikazane analize proizilazi da je modelovanje transporta toplote korišćenjem električnih analogija, odnosno RC kola, potpuno ekvivalentno numeričkom rešavanju polazna parcijalne diferencijalne jednačine (Furijeova jednačina) zajedno sa korespondentnim početnim i graničnim uslovima, korišćenjem prostorne diskreditacije. Polazna nestacionarna Furijeova jednačina je predstavljena odgovarajućim sistemom običnih diferencijalnih jednačina prvog reda. Posmatrani sistem je rešen u vremenskom domenu. Prikazani su numerički rezultati u vremenskom i frekventnom domenu koji predstavljaju pobudu na impulsni temperaturski odziv na spoljašnjim površinama zida. Dobijeni numerički rezultati su upoređeni sa analitičkim rešenjima.

Ključne reči: temperaturska raspodela, višeslojni građevinski pregradni zidovi, impulsni odziv, RC kolo, vremenski domen

TP1.3 (#7842)
NUMERIČKO MODELOVANJE NELINEARNOG TRANSPORTA TOPLOTE U VIŠESLOJNIM RAVANSKIM STRUKTURAMA SA TEMPERATURSKI ZAVISNIM TERMALNIM PROVODNOSTIMA

Radovan Gospavić, Goran Todorović, Zorana Petojević and Milica Mirković Marjanović

U radu je razmatrana numerička simulacija nelinearnog transporta toplote u višeslojnoj planarnoj strukturi sa temperaturski zavisnim parametrima. Analiziran je nestcionaran

slučaj pri čemu je usvojeno da je termičaka provodnost jednog ili više slojeva unutar posmatrane planarne struktute temperaturno zavisna dok su ostali parametri materijala konstantni. Prostornom diskretizacijom i korišćenjem metoda konačnih razlika polazna parcijalna diferencijaln jednačina je svedena na nelinearni sistem običnih diferencijalnih jednačina sa odogovarajućim graničnim i početnim uslovima. Korišćenjem električnih analogija pokazano je da je dobijeni sitem jednačina ekvivalnetan nelinearnom RC kolu u kome su pojedine otpornosti modelovane nelinearnim elementima. Analizirani su slučajevi linearne i kvadratne temperaturske zavisnosti termalne provodbosti. U slučaju linearne temperatirske zavisnosti termalne provodnosti pri rešavanju nelinearnog sistema korišćen je Pikard-ov metod iteracija, dok su u slučaju kvadratne temperatiurske zavisnosti poređeni numerički rezultati dobijeni Njtnov-im i Pokard-ovim iterativnim metodom. Numerička simulacija je sprovedena u vremenskom domenu.

Ključne reči: numerička simulacija, nelinearni transport toplote, višeslojna planarna struktura, temperaturski zavisna termalna provodnost

TP1.4 (#4360)
ЕЛЕКТРИЧНЕ АНАЛОГИЈЕ У МОДЕЛОВАЊУ ДИФУЗИВНИХ ПРОЦЕСА: ОГРАНИЧЕЊА И ОПАСНОСТИ СКУПЉЕНИХ (LUMPED) МОДЕЛА

Slobodanka Galovic, Dalibor Chevizovich, Edin Suljovrujic

У многим физичким системима и експерименталним мерењима битне су промене скаларног поља (температура, густина честица или наелектрисања) или флукса тог поља (топлотни флукс, масени флукс, струја) генерисане побудом на површини узорка. За моделовање динамике ових промена се често користе скупљена (lumped) електрична кола са пасивним елементима (најчешће RC филтрима). У овом раду показујемо да електрична аналогија дистрибуираног система (система са расподељеним параметрима) представља тачан опис не само просторне динамике већ и варијација поља и флукса на површинама узорка, док скупљени модели настају као апроксимација, важећа само у ограниченим условима. Кроз формалну анализу дифузионих процеса, приказ дистрибуираног система као електричног вода и његову двоприступну (Т или П) репрезентацију, демонстрирамо када се преносна функција дифузивног система може апроксимирати RC филтрима а када таква апроксимација води ка погрешним закључцима. Рад наглашава да скупљени модели нису аналогија, већ апроксимација, чија примена мора бити строго контролисана.

Кључне речи: простирање топлоте, дифузија наелектрисања, масена дифузија, електрична аналогија, скупљени модели

TP1.5 (#5434)
RAZVOJ ECO-ROCKET INDEKSA: ANALIZA EKOLOŠKOG UTICAJA RAZLIČITIH TIPOVA RAKETNIH GORIVA

Petar Cvetković, Milesa Srećković, Aleksandar Savić

Živimo u dobu intenzivnog razvoja raketne industrije i naglog porasta broja lansiranja tokom godina. Skaliranje ove delatnosti prate razne posledice i dolazi do značajnijeg i rastućeg štetnog ekološkog uticaja različitih tipova raketnih goriva. Postojeća istraživanja na temu usmerena su uglavnom na pojedinačne aspekte, što otežava sveobuhvatno poređenje. U ovom radu razvijen je sveobuhvatan indeks koji omogućava objektivnu evaluaciju ekološkog uticaja različitih tipova raketnih goriva, zasnovan na objedinjenju više ekoloških indikatora u jedinstveni kvantitativni skor: Eco-Rocket

Total. Indeks je zasnovan na principima LCIA (Life Cycle Impact Assessment) metodologije, uz proširenje metodoloških okvira kroz integraciju relevantnih indikatora za raketna goriva, uvođenje težinskih faktora i izračunavanje normalizovanog brojčanog skora. Podaci su dobijeni pomoću NASA CEA simulacija i OpenLCA analiza, literature, stehiometrijskih proračuna i Proxy matematičkih modela i sve dobijene vrednosti pomnožene su adekvatnim težinskih faktorima. Rezultati rada verifikovani su poređenjem sa relevantnim istraživanjima, ali se razlikuju po sveobuhvatnosti parametara i kvantitativnim rezultatom koji omogućava direktno poređenje goriva. Dodatno, verodostojnost dobijenih rezultata proverena je analizom osetljivosti tokom koje je model pokazao pouzdanost na umerene promene težinskih faktora. Razvijeni indeks ima više realnih scenarija upotrebe, pogotovo u evaluaciji ekološkog uticaja u razvojnim fazama novih raketnih goriva i mogućnost nadogradnje i prilagođavanja po potrebi.

Ključne reči: indeks, Eco-Rocket Total, ekološki uticaj, raketna goriva, LCIA

PRIDRUŽENA SESIJA – ZAŠTITA ŽIVOTNE SREDINE / ENVIRONMENTAL PROTECTION

СЕСИЈА / SESSION (EP1+EPI1)

Уторак, 9. јун / Tuesday, June 9th Сала 5 / Hall 5 9.00-11.00

Председавајући / Chair:
Ivan Lazović, Institut nuklearnih nauka Vinča, Beograd, Srbija
Uzahir Ramadani, Institut nuklearnih nauka Vinča, Beograd, Srbija

EPI1.1 (#8451)
MAPPING SEASONAL PM2.5 DISTRIBUTION IN NOVI SAD: FROM SENSOR-BASED OBSERVATIONS TO LAND USE REGRESSION MODELING
INVITED LECTURE

Sonja Dmitrašinović, Miljan Šunjević, Maja Brborić, Vladimir Rajs, Jelena Radonić

Air pollution in Serbia is characterized by emphasized seasonal variability, with the heating period representing the most critical phase in terms of fine particulate matter (PM2.5). Understanding both short-term dynamics and spatial distribution of PM2.5 in urban environments remains a key challenge. The research focuses on the assessment of PM2.5 variability in Novi Sad, combining high-resolution sensor measurements with spatial modeling perspectives. A field campaign was conducted at 21 locations across urban, industrial, mixed-use, and background environments during heating and non-heating seasons. The use of low-cost sensors enabled detailed insight into short-term fluctuations and daily patterns of PM2.5 concentrations. Wind and pollution roses were employed to explore dominant dispersion patterns and to better understand the influence of prevailing meteorological conditions on pollutant transport. To support data reliability, sensor measurements were compared with reference measurements, demonstrating a satisfactory level of agreement and confirming their suitability for further analysis and spatial interpretation. As a key outcome, high-resolution seasonal prediction maps of PM2.5 are presented as an extension of previously developed Land Use Regression (LUR) models for Novi Sad, representing the first implementation of

this approach in Serbia. These maps reveal spatial distribution patterns, pollution hotspots, and potential exposure gradients across the urban area. In addition, a preliminary assessment of chronic health impacts based on PM2.5 exposure at selected monitoring locations will be discussed. Particular attention will be given to the interpretation of prediction maps and their role in understanding spatial exposure patterns in urban environments.

Keywords: Urban environment, Particle pollution, Land use regression modelling, Health risk assessment

EPI1.2 (#9187)
CORRELATION ANALYSIS OF INDOOR/OUTDOOR AIR POLLUTANTS IN RESIDENTIAL MICROENVIRONMENTS

Natalija Jolović, Ksenija Raković, Nemanja Novaković, Aleksandar Petrović, Miodrag Živković, Uzahir Ramadani

Understanding air pollutant behaviour and interactions has become increasingly important due to the growing impact of air quality on human health and environmental conditions. Indoor Air Quality (IAQ) has emerged as a significant metric for public health concern in recent decades. Recent studies indicate that people spend more of their time indoors, further emphasizing the importance of understanding indoor air quality dynamics. Poor IAQ plays a substantial role in the development of respiratory and cardiovascular diseases, as well as long-term adverse health effects. Therefore, this study analyses Indoor/Outdoor Air Quality Dataset, which contains air quality measurements collected from two indoor residential rooms and one outdoor environment. The analysis focuses on relationships between several important environmental and pollutant parameters.The obtained analysis supports a better understanding of correlations between dominant pollutants which fluctuate in residential microenvironments. Pollutant concentrations in indoor microenvironments exhibit significantly greater variability and temporal fluctuations compared to outdoor measurements. Despite this instability, several pollutant relationships remain consistent across different indoor environments, suggesting the presence of underlying interaction patterns. These findings highlight the importance of continuous air quality monitoring, as well as a deeper understanding of indoor air dynamics in residential settings. Given the critical role of air quality in everyday living spaces. The study also suggests several considerations that may contribute to improving residential indoor environmental conditions.

Keywords: air quality, indoor air pollution, correlation analysis, residential microenvironments, environmental monitoring

EPI1.3 (#7105)
HYPERPARAMETER OPTIMISATION OF LSTM NETWORKS FOR IN-FIELD LOW-COST AIR QUALITY SENSOR CALIBRATION

Nikola Mirkov, Aleksa Tanasković, Dušan Topalović, Viša Tasić

Low-cost air quality sensors (LCS) offer an unprecedented opportunity to monitor urban pollution with high spatial resolution. However, their physical readings are highly susceptible to environmental cross-sensitivities, particularly hygroscopic growth effects during winter heating seasons. While Long Short-Term Memory (LSTM) networks have emerged as a powerful tool to model these complex temporal dependencies and calibrate raw sensor outputs against reference-grade instrumentation, their performance remains heavily dependent on the manual, often sub-optimal configuration of their structural and training hyperparameters. This work introduces a systematic, automated framework for

the in-field calibration of a co-located network of five low-cost sensors (PAQMON 1.0 mobile air quality monitor integrating the NOVA SDS011 optical sensor for PM2.5 and PM10 detection based on Mie light scattering, together with the AM2302/DHT22 module for temperature and relative humidity measurements) against a regulatory reference station (SEPA). To transcend standard trial-and-error tuning, we implement a modular, automated hyperparameter optimization pipeline using Optuna, fully tracked and orchestrated via MLflow as our MLOps engine. The optimization space is parameterized to simultaneously explore structural configurations, specifically the temporal lookback window length and recurrent cell dropout and training dynamics, including the initial learning rate and scheduler decay thresholds. Evaluating the methodology on a field-campaign dataset, the Optuna-guided search rapidly converged on optimal configurations, yielding highly accurate calibrations for fine particulate matter (PM2.5). The automated framework successfully isolated the ideal temporal window necessary to counteract humidity-induced biases while maintaining a computationally efficient network footprint. Conversely, coarse particulate matter (PM10) calibration remained challenging, exposing distinct environmental non-linearities that hyperparameter variations alone could not fully mitigate. By integrating MLflow, we demonstrate a reproducible, production-ready MLOps toolchain capable of managing individual model registries for heterogeneous sensor nodes, establishing a robust path toward scaling high-fidelity edge-calibration in municipal sensor networks.

Keywords: Air-Quality Monitoring, Low Cost Sensors, LSTM Networks, Hyperparameter Optimisation, MLOps

EPI1.4 (#8350)
PROBABILISTIC MODELLING OF ILCR USING MONTE CARLO SIMULATION FOR THE SAME INSTITUTIONS

Rastko Jovanović, Marija Živković, Ivan Lazović, Emilija Krantić, Gvozden Tasić, Milić Erić, Zoran Marković

A probabilistic risk assessment estimated the Incremental Lifetime Cancer Risk (ILCR) from inhalation of PAH-bound PM2.5 for children attending the school and kindergarten in Bor. Input parameters—measured PAH concentrations, TEQ values, inhalation rates, exposure durations, body weight and exposure frequency—were represented by probability distributions based on field data and literature. Monte Carlo simulation (≥10,000 iterations) quantified uncertainty and variability in ILCR estimates. Median ILCR values were generally at or below common benchmark thresholds, but upper-percentile (e.g., 95th) risks exceeded acceptable levels, particularly for winter exposure scenarios. Sensitivity analysis identified TEQ concentration and exposure duration as the dominant contributors to ILCR variability. Results highlight that while typical risk may be low, a non-negligible probability of elevated cancer risk exists for children during high-emission periods. Recommendations include emission control, enhanced ventilation, reduced exposure time during peak pollution, and continued monitoring to reduce uncertainty and protect vulnerable populations.

Keywords: ILCR, PAH, Monte Carlo, risk assessment

EP1.1 (#9283)
PROCENA KVALITETA VAZDUHA I VENTILACIONIH USLOVA U ŠKOLSKOM OBJEKTU NA OSNOVU KONCENTRACIJE CO_2 I RAZLIKE ENTALPIJE

Aleksandra Lazaravić, Ivan Lazović, Ana Jovanović, Ana Cumbo, Emilija Krantić, Marija Živković, Uzahir Ramadani

Ovaj rad predstavlja sveobuhvatnu analizu kvaliteta vazduha u zatvorenom prostoru na osnovu merenja koncentracije CO_2, temperature, relativne vlažnosti i razlike entalpije na više mikrolokacija unutar obrazovnog objekta. Entalpija, kao termodinamički parametar, opisuje energetsko stanje vazdušnog sistema, dok je koncentracija CO_2 ključni indikator potrebe za ventilacijom u zatvorenim prostorima. Rezultati pokazuju izražene prostorne gradijente parametara kvaliteta vazduha, što ukazuje na neujednačene uslove u različitim delovima objekta. Kao takvi, naglašavaju značaj adekvatne ventilacije i primene termodinamičkih pokazatelja u proceni toplotnog komfora. Pored toga, ukazuje se na uticaj kvaliteta vazduha na kognitivne performanse korisnika prostora, pre svega na koncentraciju i pažnju, što se direktno odražava na efikasnost učenja kod dece.

Ključne reči: koncentracija CO2, entalpija, kvalitet vazduha, toplotni komfor

EP1.2 (#1669)
PAH U FRAKCIJI PM2,5 U ŠKOLI I VRTIĆU U BORU: KONCENTRACIJE, SEZONSKE VARIJACIJE I TEQ EKVIVALENTI

Marija Živković, Rastko Jovanović, Viša Tasić, Jelena Radovanović, Ivan Lazović, Emilija Krantić

U ovom radu prikazane su koncentracije policikličnih aromatičnih ugljovodonika (PAH) određenih u frakciji PM2,5 čestica u vazduhu unutrašnjeg prostora i spoljašnje sredine jedne osnovne škole i jednog vrtića u Boru tokom grejnog i negrejnog perioda 2012. Uzorci su analizirani metodom GC–MS za 16 prioritetnih PAH. Ukupne koncentracije PAH-ova bile su nešto više tokom zimskih meseci, i uglavnom su koncentracije pojedinačnih PAH-ova bile više u vazduhu spoljašnje sredine u poređenju sa koncentracijama u vazduhu unutrašnjeg prostora. Toksični ekvivalenti (TEQ) preračunati prema benzo[a]pirenu korišćeni su za prikaz kancerogenog potencijala mešavine PAH. Nivo TEQ-a u unutrašnjem prostoru bio je pod uticajem infiltracije spoljašnje emisije i potencijalnih unutrašnjih izvora. TEQ nivoi su bili viši tokom grejnog perioda. Rezultati upućuju na potrebu za ciljanim smanjenjem emisija, poboljšanjem ventilacije i sezonskim merama u obrazovnim ustanovama radi smanjenja dugoročnih zdravstvenih rizika kod dece.

Ključne reči: PAH, sezonske varijacije, TEQ ekvivalenti, škole

EP1.3 (#0625)
LOW-COST SISTEM ZA MONITORING KONCENTRACIJE UGLJEN-MONOKSIDA ZASNOVAN NA ARDUINO PLATFORMI

Dušan Topalović, Uzahir Ramadani, Milan Radivojević, Viša Tasić, Marijana Pavlov-Kagadejev, Vladan Kamenović

Rad prikazuje razvoj low-cost sistema za monitoring koncentracije ugljen-monoksida (CO) u realnom vremenu, zasnovanog na Arduino Mega mikrokontroleru i elektrohemijskom senzorskom modulu (ZE07-CO). Sistem omogućava kontinuirano merenje koncentacije CO u opsegu od 0–500 ppm, akviziciju podataka, vremensko označavanje i skladištenje na SD kartici. Integracija sata realnog vremena omogućava

preciznu vremensku analizu, dok dodatni senzori obezbeđuju merenje temperature i relativne vlažnosti. Eksperimentalna validacija pokazala je visoku korelaciju sa komercijalnim CO monitorom ($R^2 > 0.8$), čime je potvrđena primenljivost sistema za indikativni monitoring i analizu trendova koncentracija CO u zatvorenim prostorima.

Ključne reči: Monitoring, Ugljen-monoksid, Low-cost, Arduino, Akvizicija podataka

EP1.4 (#4951)
METODOLOGIJA PROVERE I KONTROLE KVALITETA (QA/QC) PODATAKA LOW-COST SENZORA: EKSPERIMENTALNI SKUP PODATAKA O KVALITETU VAZDUHA U STAMBENOM OKRUŽENJU

Uzahir Ramadani, Ivan Lazović, Slobodan Radojević, Mirkov Nikola, Andrej Šoštarić, Gvozden Tasić, Rastko Jovanović

Primena low-cost senzora kvaliteta vazduha (LCS) značajno je proširila mogućnosti praćenja zagađenja u zatvorenom i spoljašnjem prostoru. Međutim, njihova upotreba u naučne i regulatorne svrhe ostaje ograničena nedostatkom sistematski validiranih i transparentno dokumentovanih skupova podataka. Iako broj studija zasnovanih na LCS uređajima kontinuirano raste, javno dostupni skupovi podataka koji istovremeno obezbeđuju satno usrednjene vrednosti i eksplicitno definisan i mašinski čitljiv QA/QC okvir i dalje su retki. Ovaj rad popunjava identifikovani istraživački jaz, objavljivanjem otvorenog skupa podataka satno usrednjenim vrednostima prikupljenih u porodičnoj kući (dve unutrašnje prostorije i jedna spoljašnja lokacija) tokom perioda jul–septembar 2025. godine. Skup podataka obuhvata temperaturu (T), relativnu vlažnost (RH), pritisak (P), frakcije suspendovanih čestica (PM$_1$, PM$_{2.5}$, PM$_{10}$), koncentraciju CO$_2$ i VOC indeks (gde je dostupan). Skup podataka je praćen transparentnim i reproduktivnim QA/QC okvirom koji uključuje dijagnostiku pokrivenosti, analizu uzastopnih nedostajućih vrednosti, pragovne provere fizičkih i proizvođačkih granica, detekciju anomalija primenom robusne medijane apsolutnog odstupanja (MAD) i heuristike stope promene (ROC), detekciju sekvenci konstantnih vrednosti i generisanje logičkih maski validnih podataka, uz satne i dnevne sažetke kvaliteta. Objavljivanjem validiranog skupa podataka i standardizovanih QA izveštaja, rad doprinosi povećanju transparentnosti, uporedivosti i reproduktivnosti istraživanja zasnovanih na low-cost senzorima, posebno u kontekstu procene kvaliteta vazduha u stambenim uslovima.

Ključne reči: low-cost senzori, kvalitet vazduha, QA/QC validacija podataka, satno usrednjene vrednosti, unutrašnje i spoljašnje okruženje, skup podataka

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PROSTORNA ANALIZA MEDIJUMA ŽIVOTNE SREDINE GRADSKE OPŠTINE GROCKA

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Prema administrativno-teritorijalnoj podeli, opština Grocka zauzima površinu od 299,70 km2 i jedna je od 17 opština administrativnog područja Grada Beograda. Opština Grocka, kao suburbano područje, primer je prostora na kom se prepliću uticaji urbanih i ruralnih izvora zagađenja. Analiza je izvršena na osnovu kartografskog prikaza tematskih karata zagađenja vazduha, vode i zemljišta, kao i sintezne karte trenutnog stanja životne sredine. Razmatran je uticaj javnih dobara, dok individualni izvori zagađenja poput domaćinstava i individualnih ložišta nisu bili obuhvaćeni. Vizuelni sadržaji u vidu karata izrađeni su u besplatnom softveru QGIS. Digitalizacija je izvršena na osnovu georeferenciranja topografskih karata i digitalnih alata za kartiranje. Cilj rada

je uvid u stanje medijuma životne sredine i prostornu distribuciju zagađivača, što omogućava prostorno planiranje, preduzimanje preventivnih mera i mera upravljanja. Na osnovu rezultata, Deponija Vinča, saobraćajna infrastruktura i poljoprivredne aktivnosti identifikovane su kao dominantni izvori zagađenja svih medijuma životne sredine u ovoj opštini. Dodatno, Naplatna stanica Beograd kod Vrčina nije direktan izvor zagađenja, ali usled čestih i dugotrajnih zadržavanja vozila dolazi do lokalnog povećanja koncentracije zagađujućih materija.

Ključne reči: prostorna analiza, životna sredina, zagađivači, QGIS, kartiranje

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САВРЕМЕНИ МЕМБРАНСКИ ПРИСТУПИ У УПРАВЉАЊУ ТЕЧНИМ РАДИОАКТИВНИМ ОТПАДОМ

Кристина Павићевић, Даница Јовашевић, Маја Рајковић, Ивана Јелић, Марија Јанковић, Марија Шљивић-Ивановић

Примена радиоактивних материјала у индустрији, медицини, научноистраживачком раду, као и производњи електричне енергије у нуклеарним електранама поред значајне користи за човечанство има за последицу генерисање течног радиоактивног отпада. Као и сви други радиоактивни материјали, и радиоактивни отпад емитује јонизујуће зрачење које потенцијално представља опасност по здравље људи и животну средину. Ради безбедног испуштања у животну средину, течни радиоактивни отпад мора да испуњава врло строге критеријуме у погледу концентрације радиоактивних елемената. Конвенционалне технике обраде углавном захтевају велику количину енергије, или укључују додатну фазу која доводи до стварања секундарног отпада, попут муља из таложника, потрошених јоноизмењивачких смола, или отпадних вода насталих процесом њихове регенерације. Сви ови недостаци могу бити превазиђени применом мембранских метода сепарације. У складу са тиме, овај рад пружа свеобухватан преглед мембранских техника које су, захваљујући израженом потенцијалу за унапређење и оптимизацију процеса, присутне у свим сегментима нуклеарног горивног циклуса.

Кључне речи: течни радиоактивни отпад, мембранска филтрација, реверзна осмоза, изоловање радионуклида

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