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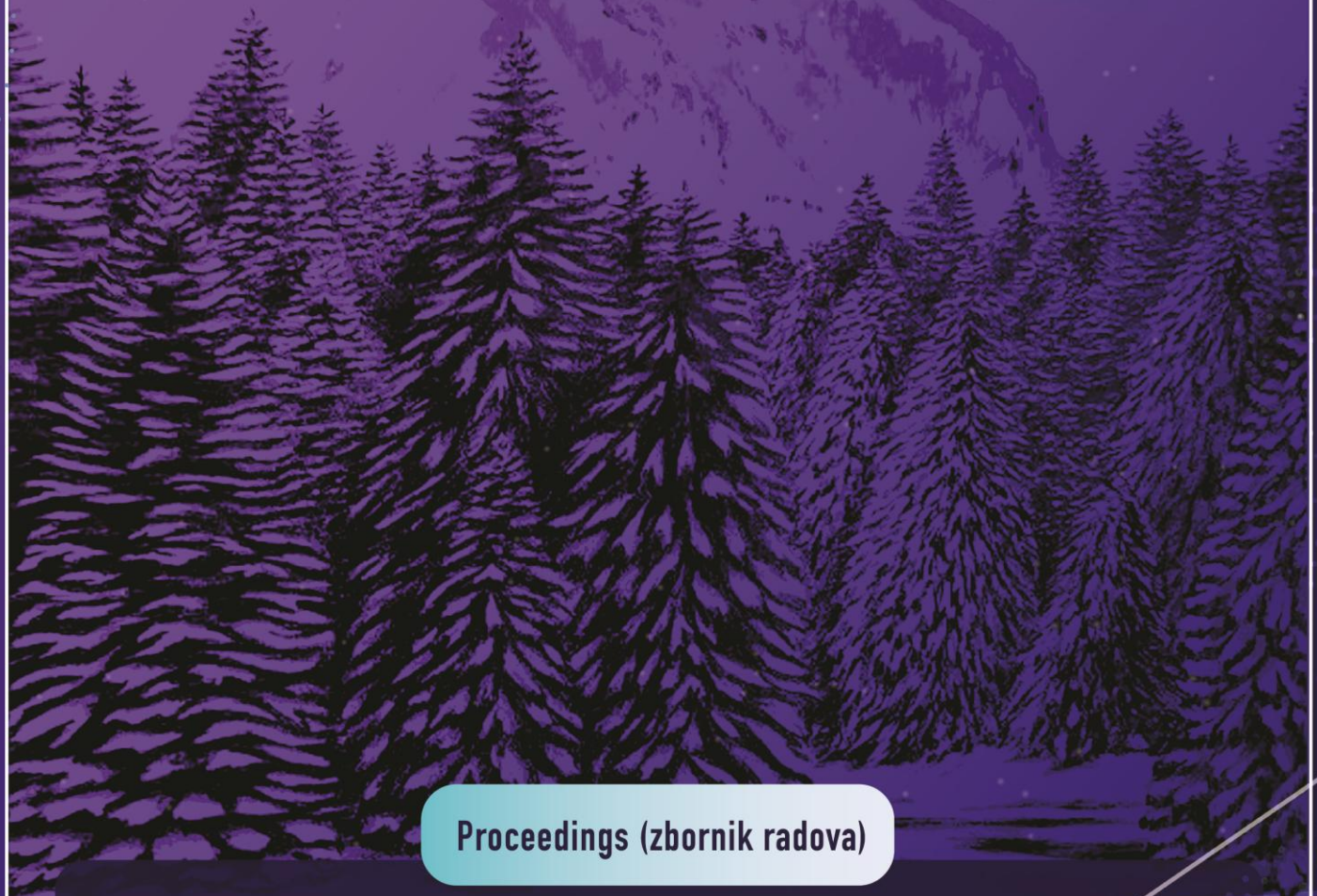

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P R E D G O V O R

Dragi učesnici i čitaoci,

Pred vama je zbornik radova prezentovanih na jubilarnoj XXX naučno-stručnoj konferenciji „INFORMACIONE TEHNOLOGIJE – sadašnjost i budućnost 2026“. Programski odbor, kroz proces anonimne međunarodne recenzije, odabrao je 87 radova, od kojih su 4 dostupna u cjelini, dok su preostala 83 predstavljeni sažecima koji se mogu pronaći u bazi IEEE Xplore. Zbornik takođe sadrži i sažetak predavanja po pozivu. Na konferenciji su učestvovali autori iz dvadesetak država i programski odbor izražava zahvalnost autorima koji su, kvalitetom svojih radova, doprinijeli ugledu konferencije prezentujući originalna dostignuća svojih istraživanja. Od ukupno 197 pristiglih radova, prihvaćeno je 44%, čime se potvrđuje rastuće interesovanje i stroga selekcija u cilju očuvanja kvaliteta konferencije.

Ovogodišnja konferencija ima poseban značaj jer obilježava tri decenije kontinuiranog rada i razvoja. Tokom 30 godina, konferencija „Informacione tehnologije“ izrasla je u međunarodno prepoznatu platformu za razmjenu znanja i inovacija u oblasti informaciono-komunikacionih tehnologija. Kontinuirano publikovanje radova u bazi IEEE Xplore potvrđuje njen naučni kredibilitet i međunarodnu vidljivost, dok rastuće interesovanje autora iz različitih dijelova svijeta svjedoči o njenom stabilnom razvoju i reputaciji.

Jubilej je obilježen Svečanom akademijom u Naučno-tehnološkom parku Crne Gore, gdje je naglašena vrijednost kontinuiteta u vremenu ubrzanih tehnoloških promjena i značaj povezivanja nauke, privrede i institucija. Time je još jednom potvrđena misija konferencije – da bude prostor susreta ideja, generacija i razvojnih inicijativa.

Radni dio konferencije, tradicionalno održan na Žabljaku, protekao je kroz paralelne sekcije u hibridnom formatu, omogućavajući aktivnu diskusiju i međunarodno učešće autora. Poseban fokus stavljen je na primjene superračunarstva (HPC) i vještačke inteligencije (AI) u okviru projekata EuroCC2 i EuroCC4SEE, uz prezentacije konkretnih rješenja, proof-of-concept projekata i B2B susrete usmjerene ka daljoj regionalnoj saradnji. Značajan doprinos konferenciji dali su i studenti master studija Univerziteta Crne Gore i Univerziteta Donja Gorica, čije je aktivno učešće u radionicama, sekcijama i projektnim prezentacijama dodatno osnažilo generacijsku dimenziju skupa i potvrdilo njegovu ulogu u oblikovanju budućih stručnjaka IT sektora.

U ambijentu Durmitora, gdje se trajnost prirode simbolično susreće sa dinamikom tehnoloških promjena, konferencija je još jednom potvrdila svoj identitet – spoj naučne ozbiljnosti, institucionalne saradnje i kolegijalne otvorenosti su ostale snažan podsticaj za nove istraživačke izazove i buduće susrete.

Sve detalje o ovom, prošlim i narednim skupovima možete naći na zvaničnoj web stranici konferencije www.it.ac.me.

Prof. dr Božo Krstajić

F O R E W O R D

Dear Participants and Readers,

Before you is the Proceedings of the jubilee 30th Scientific and Professional Conference "INFORMATION TECHNOLOGIES – Present and Future 2026". Through a process of anonymous international peer review, the Program Committee selected 87 papers, of which 4 are published in full, while the remaining 83 are presented as abstracts available in the IEEE Xplore database. The Proceedings also include the abstract of the invited lecture. Authors from around twenty countries participated in the Conference, and the Program Committee expresses its sincere appreciation to all contributors whose high-quality papers and original research achievements have enhanced the reputation of the Conference. Out of 197 submitted papers, 44% were accepted, confirming both the growing interest in the Conference and the rigorous selection process aimed at preserving its quality.

This year's Conference holds special significance as it marks three decades of continuous work and development. Over the past 30 years, the "Information Technologies" Conference has grown into an internationally recognized platform for the exchange of knowledge and innovation in the field of information and communication technologies. The continuous publication of papers in the IEEE Xplore database confirms its scientific credibility and international visibility, while the increasing interest of authors from different parts of the world testifies to its steady development and established reputation.

The jubilee was commemorated by a Ceremonial Academy held at the Science and Technology Park of Montenegro, where the importance of continuity in times of rapid technological change was emphasized, as well as the value of connecting academia, industry, and institutions. Once again, the Conference reaffirmed its mission as a meeting point for ideas, generations, and development initiatives.

The working part of the Conference, traditionally held in Žabljak, was organized through parallel sessions in a hybrid format, enabling active discussion and international participation of authors. Special focus was placed on the applications of High Performance Computing (HPC) and Artificial Intelligence (AI) within the framework of the EuroCC2 and EuroCC4SEE projects, including presentations of concrete solutions, proof-of-concept projects, and B2B meetings aimed at strengthening further regional cooperation. Master's students also made a significant contribution from the University of Montenegro and the University of Donja Gorica, whose active participation in workshops, sessions, and project presentations reinforced the intergenerational dimension of the Conference and confirmed its role in shaping future IT professionals.

In the setting of Durmitor, where the permanence of nature symbolically meets the dynamics of technological change, the Conference once again affirmed its identity — a blend of scientific rigor, institutional cooperation, and collegial openness, providing a strong incentive for new research challenges and future gatherings.

All details about this and previous conferences, as well as information about upcoming events, can be found on the official Conference website www.it.ac.me.

Prof. Božo Krstajić, PhD

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PREDAVANJA PO POZIVU
- Invited Lectures -

Digital Health Governance in Serbia: From Strategy to Implementation

Ilija D. Antović

This invited lecture presents the institutional, legal, and technological foundations of digital health governance in Serbia, with a particular focus on the establishment and development of the Republic Integrated Health Information System (RIZIS). RIZIS became a legal and strategic reality through the Law on Healthcare Documentation and Health Records, which assigned responsibility for its establishment, organization, management, and development to the Ministry of Health, with technical support provided by the Office for IT and eGovernment. Conceived as a highly ambitious national framework, RIZIS integrates healthcare data and services across healthcare institutions, private practices, military healthcare, public health institutes, health insurance bodies, the Medicines and Medical Devices Agency of Serbia, and a broad set of national registries.

The lecture highlights four key components that illustrate both the scope and the complexity of this transformation. The first is the Electronic Health Record, designed to consolidate mandatory medical documentation from heterogeneous local systems into a unified, chronologically structured view of medical events. This concept is intended to improve continuity of care, support faster and more efficient exercise of healthcare rights, provide patients with comprehensive access to their medical records, and enable healthcare professionals to use complete and contextually relevant data regardless of where they were originally generated. Because such data belong to the category of highly sensitive personal data, particular attention is given to the role of the Personal Health Identifier and the pseudonymization framework used to protect patient privacy while preserving operational usability.

The second part of the lecture addresses the Unified Healthcare Resource Registry, a central system intended to provide complete, accurate, and up-to-date national records on human resources, equipment, infrastructure, medicinal products, medical devices, and ICT resources in the Serbian healthcare system. Its strategic value lies not only in data integration, but also in enabling interactive visualization, real-time monitoring of system changes, and predictive resource management. Through this component, digital governance extends beyond documentation toward operational steering of the healthcare system, including early detection of workforce shortages, infrastructure bottlenecks, and equipment failures.

The third focus is the Registry of Genetic and Biomedical Data, which represents one of the most advanced and sensitive elements of Serbia's emerging digital health ecosystem. This registry encompasses sequencing data, metadata, research study information, sample and donor data, institutional and methodological information, processed outputs, and selected linked health data necessary for research. The lecture discusses the architecture of the corresponding national system, including the central registry platform, researcher and participant portals, interoperability mechanisms for data exchange between healthcare institutions and sequencing centers, and pseudonymization services integrated with the Personal Health Identifier framework. This part illustrates how digital health governance increasingly intersects with research governance, bioinformatics, and ethical data use.

Finally, the lecture examines the Registry of Medicines and Medical Devices, with particular reference to the long-term digital transformation of the Medicines and Medical Devices Agency of Serbia (ALIMS). Although often referred to in simplified form in legal texts, this domain in practice includes a broad ecosystem of specialized registries covering medicinal products for human and veterinary use, medical devices, clinical trials, import authorizations, and quality-control certificates. These services, many of which are already digitally available and partially exposed through public and governmental platforms, represent an important operational pillar of interoperability within RIZIS and of future integration through national health service infrastructure.

Overall, the lecture argues that digital health governance in Serbia is moving from normative and strategic design toward concrete implementation through interoperable platforms, registries, and data governance mechanisms. Serbia's experience demonstrates that successful digital transformation in healthcare requires not only legal and institutional commitment, but also carefully designed architectures for data integration, privacy protection, resource management, and cross-sector interoperability.

Teaching Object-Oriented Programming through OOP4FUN: Methodology and Results

Dušan Savić

Teaching object-oriented programming (OOP) in secondary education remains a challenging task, as many students perceive programming as complex and difficult to understand. This often results in a gap between the programming knowledge acquired in high school and the level of competencies expected by universities. The Erasmus+ project OOP4FUN – Object-Oriented Programming for Fun addresses this issue by developing innovative approaches and teaching resources aimed at improving the teaching and learning of OOP in secondary schools. This invited lecture presents the main ideas, methodology, and results of the OOP4FUN project. The project involved the analysis of open educational resources and existing teaching materials, as well as a review of relevant scientific literature in the field of programming education. Based on the identified limitations of current resources—such as the lack of holistic approaches and limited use of real-world problem identification—the project developed new teaching scenarios and guidelines for teachers. The lecture discusses key findings, innovative teaching methods, and practical recommendations for improving OOP education, with the goal of making programming more accessible, engaging, and effective for secondary school students.

AUTORSKI RADOVI
- Contributed Papers -

Promene u elektronskoj trgovini – odraz primene veštačke inteligencije i karakteristika savremenog potrošača

Sonja Vučenović, Nikola Macura, Marija Pavličević,
Univerzitet u Novom Sadu, Ekonomski fakultet u Subotici, Republika Srbija

***Sadržaj*— Predviđanje budućnosti elektronske trgovine nije jednostavan zadatak, jer tehnologija transformiše način na koji otkrivamo, kupujemo i komuniciramo sa proizvodima – od pametnijih alata za pretragu vođenih veštačkom inteligencijom do transparentnih lanaca snabdevanja i sve većeg uticaja društvenih medija. Ovaj rad predstavlja pregledni rad čiji je cilj analiza savremenih trendova i identifikovanje ključnih faktora koji oblikuju razvoj elektronske trgovine. Savremena maloprodaja prolazi kroz značajnu transformaciju pod uticajem elektronske trgovine, društvene trgovine i veštačke inteligencije. Potrošači sve više kombinuju online i offline interakcije u hibridnom, omnikanalnom iskustvu, koristeći digitalne platforme za istraživanje proizvoda i fizičke prodavnice za taktilni kontakt. Društvene mreže i korisnički generisan sadržaj olakšavaju otkrivanje proizvoda, dok sistemi vođeni veštačkom inteligencijom omogućavaju personalizaciju i efikasnu automatizaciju procesa kupovine. Iako digitalne tehnologije unapređuju korisničko iskustvo, fizički kontakt sa proizvodima i emocionalno zadovoljstvo ostaju ključni. Najuspešnije strategije integrišu digitalni i fizički svet, pružajući interaktivna i iskustvena rešenja koja zadovoljavaju savremene potrebe potrošača.**

I. UVOD

Elektronska trgovina predstavlja jednu od najdinamičnijih oblasti savremenog poslovanja, čiji se razvoj odvija pod snažnim uticajem tehnoloških inovacija i promena u ponašanju potrošača. Predviđanje budućih tokova njenog razvoja predstavlja složen zadatak, imajući u vidu brzinu i obim transformacija koje digitalne tehnologije unose u procese otkrivanja proizvoda, donošenja odluka o kupovini i interakcije između potrošača i učesnika u elektronskoj trgovini. Napredak u oblasti veštačke inteligencije, razvoj sistema plaćanja, unapređenje transparentnosti lanaca snabdevanja, kao i rastući značaj društvenih medija, značajno redefinišu postojeće poslovne modele u elektronskoj trgovini. U ovom preglednom radu obuhvatićene su promene koje prati savremena elektronska trgovina, koje nameću brojna pitanja:

Prof. dr Sonja Vučenović (autor za kontakte), Univerzitet u Novom Sadu, Ekonomski fakultet u Subotici, Segedinski put 9-11, 24000 Subotica, Srbija(e-mail: sonja.vucenovic@ef.uns.ac.rs).

Nikola Macura, MSc., Univerzitet u Novom Sadu, Ekonomski fakultet u Subotici, Segedinski put 9-11, 24000 Subotica, (e mail: nikola.macura@ef.uns.ac.rs).

Marija Pavličević (e mail: marija.pavlicevic@ef.uns.ac.rs).

- Na koji način primena veštačke inteligencije utiče na optimizaciju kupovnih procesa i personalizaciju ponude u elektronskoj trgovini?
- U kojoj meri potrošači prihvataju autonomno donošenje kupovnih odluka od strane sistema veštačke inteligencije?
- Kako razvoj veštačke inteligencije menja ulogu potrošača u procesu donošenja kupovnih odluka?
- Na koji način pomeranje sa transakcionog ka iskustvenom i interaktivnom modelu kupovine utiče na uspešnost elektronske trgovine?
- Kakvi se trendovi mogu očekivati u budućem razvoju elektronske trgovine u kontekstu primene veštačke inteligencije?
- Zašto je neophodno sistematsko proučavanjem budućeg razvoja elektronske trgovine?

Veštačka inteligencija već ima važnu ulogu u optimizaciji kupovnih procesa i personalizaciji ponude, dok se u narednom periodu očekuje njeno sve izraženije uključivanje u autonomno donošenje kupovnih odluka u ime potrošača. Paralelno sa tim, novi oblici digitalne kupovine, poput kupovine uživo, saradnje sa kreatorima sadržaja, doprinose sve većem preplitanju zabavnog sadržaja i elektronske trgovine. Ovi trendovi ukazuju na pomeranje fokusa sa isključivo transakcionog pristupa ka iskustvenom i interaktivnom modelu kupovine, što dodatno potvrđuje potrebu za sistematskim proučavanjem budućeg razvoja elektronske trgovine.

II. KLJUČNE PROMENE U ELEKTRONSKOJ TRGOVINI

Promene u oblasti elektronske trgovine u poslednjih pet godina pokazale su se kao izrazito dinamične i u velikoj meri nepredvidive. Kao i u većini savremenih privrednih i društvenih delatnosti, veštačka inteligencija (engl. Artificial Intelligence – AI) ima značajan uticaj na transformaciju okruženja elektronske trgovine. Trendovi u ovoj oblasti podjednako utiču na sve relevantne aktere, uključujući prodavce i potrošače, oblikujući njihove poslovne modele, kupovne navike i očekivanja. Tržište elektronske trgovine beleži kontinuiran rast, dok su naročito izražene promene uočene od početka pandemije COVID-19, kako u pogledu obima elektronske trgovine, tako i u ubrzanom razvoju i primeni novih digitalnih tehnologija. U tom kontekstu, nameće se pitanje da li bi elektronska trgovina ostvarila isti

stepen rasta i dinamike razvoja da nije došlo do globalne pandemije, odnosno u kojoj meri su vanredne okolnosti uticale na intenzitet i pravac njenog tehnološkog i tržišnog razvoja. Prema podacima globalnih istraživanja, svetska elektronska trgovina porasla je sa približno 4,25 triliona USD u 2020. na oko 6,9–7,5 triliona USD u 2025. godini, pokazujući kontinuirani rast online prodaje širom sveta [1, 2], a prema podacima Narodne banke Srbije (NBS), broj online kupovina u 2024. godini iznosio je 82,4 miliona, što je rast od 39,2 % u odnosu na 2023. godinu [3].

Od izbijanja pandemije COVID-19, poslovanje tradicionalnih maloprodajnih objekata bilo je u velikoj meri ograničeno ili značajno redukovano, usled čega su brojni maloprodavci strateški razvoj usmerili ka unapređenju postojećih elektronskih kanala prodaje. U tom kontekstu, rast elektronske trgovine bio je naročito izražen kod tzv. „klik i cigla“ (click-and-mortar) i multikanalnih maloprodavaca, koji su uspešno integrisali fizičke i digitalne prodajne kanale. Nasuprot tome, kod „čistih“ elektronskih maloprodavaca zabeležen je rast prodaje koji je u većoj meri pratio dinamiku karakterističnu za period pre pandemije.

Promene u svremenim uslovima se dešavaju postepeno, ali suštinski menjaju pravac razvoja koji ima dugoročan uticaj na elektronsku trgovinu. U domenu elektronske trgovine, promene predstavljaju ključne determinante tržišnih kretanja i mogu značajno doprineti unapređenju poslovnih performansi i rastu prodaje. Njihovo formiranje uslovljeno je različitim faktorima, uključujući tehnološki napredak, evoluciju potrošačkih preferencija i zahteva za većom praktičnošću, uticaj društvenih mreža, kao i sve izraženija etička i društveno odgovorna pitanja. Među savremenim trendovima elektronske trgovine posebno se izdvajaju primena virtuelne i proširene stvarnosti, intenzivan razvoj mobilne kupovine, razvoj elektronskih sistema plaćanja, kao i sve šira implementacija tehnologija za prepoznavanje glasa i slike, i slično. Poseban značaj ima primena veštačke inteligencije, kao i usvajanje principa etičkog, održivog i ekološki odgovornog poslovanja, koji postaju integralni deo strategija savremene elektronske trgovine.

Proširena stvarnost (engl. Augmented Reality – AR) i virtuelna stvarnost (engl. Virtual Reality – VR) postaju sve značajnije tehnologije u oblasti elektronske trgovine. Primena AR i VR tehnologija omogućava visok stepen interaktivnosti u procesu kupovine, uključujući prikaz proizvoda iz ugla od 360 stepeni, virtuelno razgledanje proizvoda u simuliranim izložbenim prostorima, kao i virtuelno isprobavanje odeće i drugih proizvoda. Ove tehnologije doprinose smanjenju neizvesnosti prilikom onlajn kupovine i povećanju zadovoljstva potrošača. Glavna barijera kupovine na Internetu, a to je nedostatak fizičkog kontakta sa proizvodom se prevazilazi na ovaj način. Istraživanja potvrđuju ovaj trend, na primer, studija iz 2025. ukazuje da AR i VR znatno poboljšavaju angažovanje potrošača i njihovo poverenje u procesu kupovine, omogućavajući personalizovane i imerzivne kupovne doživljaje [4].

Sve veći broj potrošača koristi pametne telefone i tablete kao primarne uređaje za pristup elektronskoj trgovini, umesto tradicionalnih laptop ili desktop računara, pri čemu se ovaj trend kontinuirano intenzivira. Prema podacima kompanije Statista, pametni telefoni su u drugom kvartalu 2025. godine generisali oko 69% ukupnih porudžbina u okviru onlajn kupovine na globalnom nivou [5]. Praćenje i prilagođavanje ovom trendu podrazumeva optimizaciju veb-sajtova i onlajn prodavnica kako bi se obezbedilo besprekorno, efikasno i korisnički prilagođeno iskustvo na mobilnim uređajima, što postaje ključni faktor konkurentnosti u savremenoj elektronskoj trgovini.

Veštačka inteligencija (AI) u elektronskoj trgovini funkcioniše kao virtualni personalizovani potrošač, omogućavajući preduzećima da unaprede iskustvo potrošača. S obzirom na širok uticaj AI tehnologija u različitim sektorima, nije iznenađujuće što se one sve češće primenjuju u digitalnoj maloprodaji radi optimizacije interakcije sa potrošačima. Korišćenjem AI, kompanije mogu predviđati obrasce ponašanja potrošača, identifikovati njihove kupovne navike i preporučivati dodatne proizvode u skladu sa individualnim izborima. Tokom procesa kupovine, AI sistemi prikupljaju podatke o prethodnim kupovinama, pregledanim proizvodima i preferencijama korisnika, koje se potom koriste za optimizaciju veb-sajtova i onlajn prodavnica, s ciljem povećanja angažovanja i konverzije korisnika.

III. KONTINUIRANI RAST UPOTREBE VEŠTAČKE INTELIGENCIJE U ELEKTRONSKOJ TRGOVINI

Veštačka inteligencija (AI) značajno transformiše elektronsku trgovinu, oblikuje budućnost maloprodaje i unapređuje angažovanje potrošača. Tokom poslednjih nekoliko godina, AI je postepeno transformisala onlajn maloprodaju, prelazeći od jednostavnih sistema za preporuke ka sofisticiranim rešenjima koja omogućavaju predviđanje ponašanja potrošača, optimizaciju upravljanja zalihama i pružanje personalizovanih iskustava kupovine u velikom obimu. Prema globalnim statistikama o razvoju elektronske trgovine, približno 85 % kompanija u ovom sektoru na svetskom nivou implementira AI tehnologije u cilju poboljšanja korisničkog iskustva i efikasnosti poslovnih operacija. [6].

Savremeni potrošači očekuju besprekorno i personalizovano iskustvo kupovine, što zahteva od preduzeća sposobnost brzog prilagođavanja i implementacije inovacija. Primena veštačke inteligencije u elektronskoj trgovini donosi brojne prednosti, uključujući povećanje angažovanja potrošača i mogućnosti rasta, ali istovremeno nameće i određene izazove. Iako AI omogućava neviđene mogućnosti za optimizaciju kupovnog procesa i personalizaciju ponude, njena primena zahteva kontinuirano prilagođavanje poslovnih modela, kao i značajna ulaganja u nove tehnologije i sisteme.

Veštačka inteligencija (AI) u elektronskoj trgovini omogućava automatizaciju rutinskih zadataka koji su ranije zahtevali ljudsku intervenciju i inteligenciju. Za svaku individualnu situaciju i potrošača, AI sistemi analiziraju prikupljene podatke, identifikuju obrasce ponašanja, donose

odluke i kontinuirano unapređuju svoje performanse kroz proces učenja. Za razliku od tradicionalnog softvera elektronske trgovine, koji funkcioniše prema unapred definisanim pravilima, AI se dinamički prilagođava promenljivim okolnostima i postaje sve efikasnija kako se učestalije koristi, čime se povećava njena sposobnost personalizacije i optimizacije procesa kupovine.

Algoritmi mašinskog učenja omogućavaju analizu velikih količina podataka o potrošačima radi identifikovanja obrazaca i predviđanja njihovog ponašanja, čime se maloprodajnim preduzećima u elektronskoj trgovini omogućava anticipiranje potreba potrošača pre nego što oni sami postanu svesni svojih zahteva. Tehnologije obrade prirodnog jezika (Natural Language Processing – NLP) omogućavaju funkcionisanje četbotova i glasovnih asistenata koji razumeju i odgovaraju na upite i interakcije potrošača na prirodniji i intuitivniji način. Sistemi za preporuke koriste podatke o pretragama i prethodnim kupovinama kako bi predložili relevantne proizvode, čime se povećava stopa konverzije i prosečna vrednost porudžbina. Integracija ovih tehnologija doprinosi stvaranju efikasnijeg i prilagodljivijeg iskustva kupovine, koje se individualizuje prema specifičnim preferencijama i ponašanju svakog korisnika.

Veštačka inteligencija omogućava primenu personalizacije u velikom obimu, analizirajući podatke sa različitih tačaka kontakta sa potrošačima. Informacije o istoriji pregledanja, prethodnim kupovinama, vremenu provedenom na pojedinim stranicama, pa čak i pokretima kursora, omogućavaju AI sistemima kreiranje sveobuhvatnih profila potrošača. Ovi profili služe kao osnova za pružanje visoko personalizovanih iskustava kupovine, prilagođenih individualnim potrebama i preferencijama potrošača. Paralelno, dinamičke strategije formiranja cena omogućavaju optimizaciju cena za pojedinačne potrošače na osnovu njihove percipirane osetljivosti na cene, prethodne kupovne istorije i aktuelnih tržišnih uslova, čime se povećava efikasnost prodajnih strategija i poboljšava ukupno korisničko iskustvo.

Posebna snaga personalizacije vođene veštačkom inteligencijom ogleda se u njenoj sposobnosti da funkcioniše bez potrebe za direktnim unosom podataka od strane potrošača. Za razliku od tradicionalnih sistema podešavanja preferencija, koji zahtevaju da korisnici ručno definišu svoja interesovanja, AI sistemi analiziraju prirodno ponašanje potrošača tokom procesa kupovine. Na osnovu ove analize, sistemi organski kreiraju precizne profile preferencija, omogućavajući pružanje visoko personalizovanih i relevantnih iskustava bez dodatnog angažovanja samih potrošača.

Savremeni potrošači očekuju trenutne i precizne odgovore u bilo kom trenutku, što predstavlja izazov za tradicionalne modele korisničke podrške. Četbotovi zasnovani na veštačkoj inteligenciji uspešno adresiraju ovaj izazov pružajući podršku 24/7, uz značajno smanjenje troškova rada. Virtuelni asistenti koriste generativnu veštačku inteligenciju za obradu rutinskih upita, upravljanje porudžbinama i rešavanje uobičajenih problema bez potrebe za ljudskom intervencijom, čime se unapređuje kvalitet korisničke usluge. Najsofisticiraniji četbotovi sposobni su da besprekorno proslede složene upite ljudskim agentima kada je to neophodno, pružajući sve relevantne informacije o potrošačima, uključujući prethodnu istoriju komunikacije, kako bi se osigurao kontinuitet i doslednost u pružanju podrške. Ova sinergija između veštačke inteligencije i ljudskog faktora omogućava stvaranje hibridnog sistema korisničke podrške koji kombinuje efikasnost automatizovanih procesa sa empatijom i prilagodljivošću ljudskog pristupa, čime se značajno unapređuje celokupno iskustvo potrošača i jača lojalnost potrošača.

Pretrage zasnovane na tekstu imaju ograničenja, naročito u slučaju vizuelno orijentisanih proizvoda. Tehnologija vizuelne pretrage premošćuje ovu prazninu omogućavajući potrošačima da otpremaju slike i u roku od nekoliko sekundi identifikuju vizuelno slične proizvode. Ova funkcionalnost menja način na koji potrošači otkrivaju proizvode, čineći proces pretraživanja intuitivnijim i bližim prirodnom iskustvu kupovine u fizičkim prodavnicama. Algoritmi za prepoznavanje stila analiziraju vizuelne karakteristike proizvoda, uključujući boju, uzorak i oblik, kako bi predložili komplementarne artikle u skladu sa estetskim preferencijama potrošača. Paralelno, alati za vizuelni merčandajzing automatski generišu atraktivne prikaze proizvoda koji se prilagođavaju individualnim obrascima pregledanja korisnika. Sistemi za prepoznavanje slika mogu čak identifikovati proizvode u objavama na društvenim mrežama, omogućavajući kreiranje sadržaja za kupovinu zasnovanog na materijalima koje generišu sami korisnici. Primena vizuelne veštačke inteligencije (AI) smanjuje kognitivno opterećenje potrošača, skraćuje put od inspiracije do kupovine i povećava prodaju u kategorijama u kojima vizuelni atributi predstavljaju ključni faktor donošenja odluka o kupovini.

Rast elektronske trgovine istovremeno je praćen i sve sofisticiranijim pokušajima prevara. Tradicionalni sistemi bezbednosti zasnovani na unapred definisanim pravilima često ne uspevaju da prate dinamičan razvoj pretnji, stvarajući napetost između očuvanja sigurnosti i održavanja pozitivnog korisničkog iskustva. U tom kontekstu, sistemi za detekciju prevara zasnovani na veštačkoj inteligenciji (AI) pružaju adaptivnije i efikasnije rešenje, koristeći algoritme mašinskog učenja za identifikaciju sumnjivih obrazaca, pri čemu se minimiziraju lažno pozitivni rezultati koji mogu frustrirati legitimne korisnike [7]. Ovi sistemi analiziraju stotine varijabli u delovima sekunde tokom transakcija kako bi otkrili anomalije koje mogu ukazivati na prevaru. Dodatno, tehnike analize mreže omogućavaju identifikaciju povezanosti između naloga, što može ukazivati na organizovane krugove prevara. Prema podacima iz globalnog izveštaja o prevarama u elektronskoj trgovini, više od 60 % maloprodajnih preduzeća širom sveta koja koriste AI sisteme za detekciju prevara prijavilo je smanjenje gubitaka od prevara za najmanje 30 % u periodu od godinu dana [8]. Ključna karakteristika ovih sistema je njihova sposobnost kontinuiranog učenja iz uspešnih i neuspelih pokušaja

prevara, čime se povećava njihova efikasnost u skladu sa evolucijom pretnji. Rezultat je sveobuhvatan pristup bezbednosti koji istovremeno štiti preduzeća i potrošače, a održava besprekorno i pouzdano iskustvo kupovine koje korisnici očekuju u digitalnom okruženju.

IV. Novi online potrošač - nove navike i novo iskustvo kupovine

Sistemi za otkrivanje proizvoda zasnovani na veštačkoj inteligenciji već značajno transformišu način na koji potrošači pregledaju, upoređuju i donose odluke o kupovini. Očekuje se da će vizuelna pretraga i dalje dobijati na značaju, budući da korisnici otpremaju fotografije proizvoda ili predmeta koje su primetili na društvenim mrežama i u roku od nekoliko sekundi dobijaju gotovo identična vizuelna podudaranja. Maloprodajna preduzeća koriste ove sisteme kako bi personalizovala iskustva potrošača u realnom vremenu, analizirajući obrasce pregledanja, individualne preferencije, pa čak i signale raspoloženja, kako bi precizno prilagodila preporuke i povećala relevantnost ponude za svakog korisnika.

Onlajn potrošači, posebno mlađe generacije, ne otkrivaju proizvode na isti način kao stariji korisnici, tražeći inspiraciju pretežno na društvenim mrežama. Generacija Z (18–28 godina) pokazuje visok interes za digitalnu i mobilnu kupovinu; u 2024. godini više od polovine pripadnika ove generacije kupovalo je proizvode direktno putem platformi društvenih mreža, dok 68 % otkriva nove proizvode na tim mrežama, a gotovo 60 % ih i kupuje. Gen Z primarno koristi pametne telefone i mobilne aplikacije kako bi istovremeno otkrivala proizvode, komunicirala s brendovima i završavala kupovinu bez napuštanja aplikacije, što ukazuje na prelazak sa tradicionalnih veb-pretraga na mobilno iskustvo kupovine. Ovi trendovi redefinišu obrasce online kupovine i ističu potrebu za strategijama digitalnog marketinga i optimizacijom korisničkog iskustva prilagođenih očekivanjima ove generacije [9, 10].

Ako se pretraga zasnovana na veštačkoj inteligenciji koristi da potrošačima pomogne da pronađu odgovarajući proizvod, modeli velikih jezika (LLM) postaju sredstvo koje im može omogućiti i da ga kupe bez direktnog ulaska na stranicu za plaćanje. Savremeni konverzacijski asistenti, uključujući varijante modela kao što su ChatGPT, mogu preporučivati proizvode, upoređivati njihove karakteristike i čak dovršiti kupovine u okviru jedinstvenog interfejsa, čime se tradicionalni tok kupovine transformiše u interaktivno i prirodno iskustvo. LLM-ovi ne samo da obogaćuju personalizaciju i real-time interakcije sa potrošačima, već i služe kao temelj sofisticiranih virtuelnih asistenata sposobnih za razumevanje i reagovanje na kompleksne korisničke upite u okviru elektronske trgovine [11].

Ova tehnološka promena otvara značajna pitanja o privatnosti podataka i saglasnosti korisnika, jer modeli velikih jezičkih struktura obrađuju opsežne lične i transakcione podatke, što može imati etičke i pravne implikacije ukoliko se ne primenjuju odgovarajući mehanizmi zaštite podataka i transparentnosti [12]. Kako AI sistemi preuzimaju uloge koje sežu izvan pomoćnih funkcija — pa sve do autonomnog obavljanja transakcija — postaje ključno razmatrati kako održati ljudsku vezu i poverenje u digitalne procese kupovine.

Društvene mreže su postale ključni digitalni trgovački centri, gde se otkrivanje proizvoda, angažovanje zajednice i kupovina odvijaju integrisano na jednoj platformi. Sadržaj koji generišu korisnici (user-generated content, UGC) značajno utiče na odluke o kupovini, jer potrošači više veruju autentičnim iskustvima drugih potrošača nego tradicionalnim kampanjama brendova. Recenzije i video raspakivanja proizvoda funkcionišu kao moderna forma usmene predaje i ostvaruju visoke stope konverzije, dok događaji kupovine uživo i saradnje sa kreatorima dodatno brišu granicu između zabave i transakcione kupovine. Ove prakse potvrđuju da društvena trgovina predstavlja centralni segment savremenog elektronskog tržišta, u kojem UGC i interaktivni sadržaj direktno oblikuju ponašanje potrošača i prodajne rezultate [13,14].

Zaključno, savremeni razvoj elektronske trgovine i integracija veštačke inteligencije ne predstavljaju opštu pretnju fizičkoj maloprodaji, već ističu evoluciju hibridnog, omnikanalnog modela kupovine u kojem potrošači fluidno kombinuju online i offline interakcije. Empirijska literatura ukazuje da potrošači sve češće koriste više kanala prilikom kupovine — istražuju proizvode na digitalnim platformama pre posete fizičkoj prodavnici i, obrnuto, pretražuju proizvode u prodavnici pre nego što ih kupe putem digitalnih kanala — što potvrđuje postojanje uzajamnog uticaja između digitalnih i fizičkih kanala u potrošačkom ponašanju. Integracija kanala omogućava potrošačima veću fleksibilnost i kvalitet iskustva, čime se poboljšava ukupna angažovanost i zadovoljstvo kupovina u omnikanalnom okruženju [15]. Istraživanja pokazuju da strategije koje obezbeđuju besprekornu sinhronizaciju između fizičkih i digitalnih tačaka kontakta imaju pozitivne efekte na percepciju potrošača i njihov dalji angažman u kupovini. Ovaj razvoj dodatno potvrđuje da, iako algoritmi i digitalne tehnologije mogu unaprediti preciznost preporuka i efikasnost procesa kupovine, oni ne mogu u potpunosti zameniti emotivnu i taktilnu vrednost neposrednog kontakta sa proizvodima koju i dalje traži značajan deo potrošača.

V. Zaključak

Savremena elektronska trgovina prolazi kroz transformaciju pod uticajem tehnološkog napretka, promena potrošačkih preferencija i primene veštačke inteligencije, što omogućava personalizaciju kupovine, optimizaciju procesa i automatizaciju zadataka. Pandemija COVID-19 je dodatno ubrzala rast online kanala, posebno kod hibridnih maloprodajnih modela koji integrišu fizičke i digitalne kanale. Najuspešnije strategije kombinuju digitalno i fizičko iskustvo, koristeći društvene mreže i AI alate za predviđanje preferencija i interaktivnu personalizaciju, dok taktilna vrednost proizvoda i dalje ostaje ključna za značajan deo

potrošača. Ovakav omnikanalni pristup postaje ključni preduslov za konkurentnost i održiv rast u savremenoj maloprodaji.

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Komparativna analiza performansi multimodalne generativne veštačke inteligencije u složenoj kliničko-radiološkoj dijagnostici

Milica Krčo, *Medicinski fakultet Novi Sad,* Nataša Krčo, *Imperial College London*, Marijana Basta Nikolić, *Medicinski fakultet Novi Sad,* Srđan Krčo, *DunavNET/Univerzitet Donja Gorica*

***Sadržaj* - Istraživanje poredi Gemini 3 Pro, Claude Opus 4.5 i GPT-5.2 na 20 kliničko-radioloških slučajeva, kroz dva eksperimenta, putem API sistema. Gemini 3 Pro ostvario je dijagnostičku tačnost od 90% u obe faze. Rezultati potvrđuju značajan potencijal veštačke inteligencije za integraciju u medicinsku praksu, uz i dalje neophodnu ljudsku superviziju.**

I. Uvod

Epoha moderne medicine, obeležena brojnim trijumfima, paradoksalno je dovela zdravstvene sisteme u stanje preopterećenost usled produženog životnog veka i istovremene drastične ekspanzije hroničnih oboljenja [1]. Nedovoljna brojnost zdravstvenog kadra, preopterećenost i konstantan pritisak, sve češće dovode do sindroma izgaranja kod zdravstvenih radnika, direktno utičući na kvalitet zdravstvene zaštite [2] [3]. U situaciji koja deluje kao *circulus vitiosus*, integracija veštačke inteligencije nudi potencijalno transformativno rešenje, evoluirajući od rane kompjuterski potpomognute dijagnostike (CAD) zasnovane na krutim pravilima, preko metoda dubokog učenja, koje su omogućile efikasnu analizu nestruktuiranih medicinskih podataka, sve do upotrebe savremenih modela multimodalne generativne veštačke inteligencije, koji poseduju sposobnost integrisanja heterogenih kliničkih podataka na način sličan ljudskom rezonovanju [4]. Multimodalna generativna veštačka inteligencija predstavlja vrhunac savremenog razvoja tehnologije koja, kroz sposobnost kreiranja originalnog sadržaja i istovremene obrade i sinteze različitih tipova informacija, pokazuje mogućnost integracije različitih medicinskih podataka, dijagnostičkog zaključivanja i generisanja sopstvenih nalaza [5]. Važno je naglasiti da veštačka inteligencija ne može zameniti holistički pristup, empatiju i kliničko iskustvo lekara, te da se njena uloga ogleda u tome da bude svojevrsni saradnik, „kopilot“, odnosno alat koji zdravstvenim radnicima, kroz smanjenje administrativnog opterećenja i pružanje interaktivne podrške u donošenju odluka, vraća dragoceno vreme neophodno za ostvarivanje pravog kontakta sa svojim pacijentima i pružanje individualizovane nege. Uprkos ogromnom potencijalu, primena veštačke inteligencije u medicini suočava se sa brojnim preprekama, od kojih se posebno izdvaja potencijalna pristrasnost modela koja proističe iz podataka koji neretko odražavaju dugogodišnje društvene nejednakosti [6]. Dodatni rizik predstavljaju tzv. halucinacije modela, odnosno generisanje izmišljenih informacija prikazanih kao pouzdanih, što nalaže da se ovi alati, barem za sada, ne mogu koristiti kao autonomna rešenja već kao sistemi kojima je neophodan nadzor stručnjaka. Takođe, prisutna je i zabrinutost da bi prekomerna automatizacija mogla oslabiti proces medicinskog obrazovanja i dovesti do gubitka ključnih dijagnostičkih veština. Problematiku dodatno usložnjava netransparentnost algoritama, odnosno fenomen „crne kutije“, mada savremeni generativni modeli nude značajan iskorak pružajući uvid u sam tok i logiku razmišljanja modela. Uz etička pitanja i bezbedno upravljanje podacima, implementaciju otežavaju i institucionalne prepreke poput nedovoljne digitalizacije i nedostatka jasnih pravnih okvira [7].

II. Cilj istraživanja

Cilj istraživanja je komparativna analiza performansi tri multimodalna modela generativne veštačke inteligencije: GPT-5.2, Gemini 3 Pro i Claude Opus 4.5 u pogledu dijagnostičke tačnosti, kvaliteta kliničkog rezonovanja i sposobnosti samostalne interpretacije radioloških snimaka u kontekstu složenih kliničko-radioloških slučajeva.

III. Materijal i metode

Istraživanje je sprovedeno tokom druge polovine decembra 2025-te godine, na 20 slučajeva izabranih iz serijala „Case Records of the Massachusetts General Hospital“ objavljenih u časopisu *The New England Journal of Medicine* [8]. Izbor ovog serijala zasnovan je na njegovoj doslednoj i standardizovanoj strukturi prikaza kliničkog sadržaja, što omogućava uporedivost uslova testiranja. Svi odabrani slučajevi uključuju najmanje jedan modalitet radiološke dijagnostike kardiorespiratornog sistema (RTG, CT, MRI, ehokardiografija), dok krajnje dijagnoze pokrivaju širok spektar patoloških entiteta različitih organskih sistema.

Milica Krčo, Medicinski fakultet u Novom Sadu, Hajduk Veljkova 3, 21000 Novi Sad, Srbija (autor za kontakte) (e-mail: krco.milica01@gmail.com).

Nataša Krčo, Imperial College London, Exhibition Rd, South Kensington, London SW7 2AZ, United Kingdom (natasakrco@gmail.com).

Marijana Basta Nikolić, Medicinski fakultet u Novom Sadu, Hajduk Veljkova 3, 21000 Novi Sad, Srbija (e-mail: marijana.basta-nikolic@mf.uns.ac.rs)

Srđan Krčo, Univerzitet Donja Gorica, Oktoih 1, Podgorica 81000, Crna Gora (e-mail: srdjan.krco@dunavnet.eu).

Ovakva heterogenost namerno je odabrana radi sveobuhvatnije procene sposobnosti modela. U uzorak su uključeni i slučajevi sa urednim radiološkim nalazima, što omogućava evaluaciju sklonosti modela ka izmišljanju nepostojećih patoloških nalaza. Testirani su modeli **Gemini 3 Pro** (objavljen 18. novembra 2025.), **Claude Opus 4.5** (24. novembra 2025.) i **GPT-5.2** (11. decembra 2025.).

A. Dizajn eksperimenta

Istraživanje je organizovano u dva eksperimenta. U prvom eksperimentu, modelima su prezentovani kompletni prikazi slučajeva (anamneza, nalaz fizikalnog pregleda, laboratorijski nalazi, itd.) zajedno sa originalnim opisom radiologa na pridruženim snimcima. Na osnovu ovih podataka, za svaki analizirani slučaj, model je formulisao dijagnostički zaključak uz obrazloženje načina integracije pojedinačnih nalaza. U drugom eksperimentu, iz prikaza slučaja uklonjen je opis radiologa, te su modeli morali samostalno da interpretiraju priložene radiološke snimke, generišu svoj radiološki nalaz i potom ga integrišu zajedno sa ostalim dostupnim podacima iz prikaza slučaja i formulišu dijagnostički zaključak kao i u prvom eksperimentu. Ovakav dizajn istraživanja omogućio je sveobuhvatnu procenu sposobnosti modela za kliničko rezonovanje, kao i njihove samostalnosti u analizi radioloških snimaka.

Specifičnost metodologije ogleda se u automatizovanom pozivanju modela putem API (Application Programming Interface) interfejsa kompanija Google, OpenAI i Anthropic, čime je osiguran nivo rigoroznosti generalno nedostupan konvencionalnom korisničkom pristupu. Primena API-ja omogućila je fiksiranje parametra temperature na 0,3, čime je eliminisana kreativna varijabilnost svojstvena web verzijama u korist konzistentnih i determinističkih rezultata neophodnih za naučnu validaciju [9]. U okviru istraživanja, vizuelni podaci su ekstrahovani iz PDF formata, što je dovelo do određenog gubitka rezolucije u poređenju sa originalnim DICOM fajlovima. Primenom API-ja za interakciju sa modelima, izbegnuta je potencijalna dalja redukcija kvaliteta koju često nameću veb interfejsi. Takođe, postavljena je tehnička osnova za buduću integraciju sa bolničkim informacionim sistemima i rad u punoj dijagnostičkoj rezoluciji. Arhitektura sistema implementirana je u Python okruženju, oslanjajući se na biblioteke *pypdf* za ekstrakciju teksta i *Pillow* za procesuiranje vizuelnih podataka putem Base64 enkodinga, dok je upravljanje testovima i razvoj korisničkog interfejsa realizovan kroz *Streamlit* biblioteku. Ovakvim pristupom omogućena je potpuna tehnička reprodukcija eksperimenta.

B. Struktura izlaza

Od modela je zahtevano da formulišu strukturirane odgovore koji obuhvataju tri međusobno povezane celine: informacije o pacijentu, radiološki podaci i dijagnostička procena. Dijagnostička procena predstavlja glavni deo odgovora koji je posle i evaluiran, a uključuje primarnu dijagnozu, pet diferencijalnih dijagnoza, ključne nalaze koji podržavaju dijagnozu, obrazloženje kliničkog rezonovanja, predlog potvrdnog testa i stepen sigurnosti modela u svoju primarnu dijagnozu (0-100%).

C. Evaluacija

Evaluaciju dobijenih odgovora sprovele su autorke rada, studentkinja završne godine medicine i specijalista radiologije, kroz sistematičnu komparaciju rezultata sa uspostavljenim zlatnim standardom. Zlatni standard je utemeljen na originalnim dijagnozama i obrazloženjima dijagnostičkog procesa iz referentnih izvora, uz neophodnu kritičku dopunu evaluatora zasnovanu na stručnom medicinskom znanju [8]. Proces je strukturiran kroz rigidnu kvantitativnu i kvalitativnu analizu, koje su poslužile kao osnov za definisanje specifičnih pokazatelja iz kojih su potom izvedene finalne mere uspeha za objektivan prikaz rezultata.

Kvantitativna analiza obuhvatila je tačnost primarne dijagnoze (*PrimaryCorrect*), prisustvo tačne dijagnoze među diferencijalnim dijagnozama u slučajevima netačne primarne (*GoldInDiff*), kliničku plauzibilnost netačnih primarnih dijagnoza (*PrimaryPlausible*), tačnost diferencijalnih dijagnoza (*DiffCorrect*) i analizu kalibracije modela. Kvalitativna analiza realizovana je putem rubrik metodologije bodovanja na trostepenoj skali (0-2), gde je ocena 2 definisana kao maksimalno postignuće ili potpuna usklađenost sa zlatnim standardom, dok ocena 0 označava najniži nivo performansi kod svih posmatranih parametara [10]. U prvoj fazi obuhvaćena je koherentnost kliničkog rezonovanja (*KCorrect*), dok je u drugoj fazi ocenjivana tačnost tehničke karakterizacije snimaka (*TechCorrect*), ispravnost identifikacije ključnih patologija (*FindingsCorrect*), kao i prisustvo lažno pozitivnih nalaza (*FindingsFalse*). Svi definisani parametri omogućili su transformaciju sirovih podataka u uporedive mere uspeha, pružajući jasan uvid u dijagnostičku konzistentnost i tehničku pouzdanost ispitivanih sistema.

IV. REZULTATI

A. Kvantitativna analiza

Tabela I prikazuje uporedne rezultate dijagnostičke tačnosti ispitivanih modela u oba eksperimenta. Gemini 3 Pro ostvario je najvišu tačnost primarne dijagnoze od 90% u obe faze, i stabilne performanse nezavisno od prisustva opisa radiologa. Claude Opus 4.5 ostvario je tačnost od 75% u prvoj fazi, pri čemu je u 100% slučajeva sa netačnom primarnom dijagnozom tačna dijagnoza ipak bila prisutna među diferencijalnim dijagnozama. U drugoj fazi zabeležen je pad na 65%, što se može objasniti lošijim učinkom u samostalnoj interpretaciji radioloških snimaka. GPT-5.2 zabeležio je najnižu stopu tačnosti (65% u prvoj i 55% u drugoj fazi), uz važnu napomenu da su sve netačne primarne dijagnoze bile klinički plauzibilne opcije. Nijedan model nije pokazao adekvatnu kalibraciju, s obzirom na to da se nivo prijavljene sigurnosti nije značajno razlikovao kod tačnih u odnosu na netačne dijagnoze, što sugeriše da se izražena sigurnost modela ne može smatrati pouzdanim indikatorom tačnosti.

B. *Kvalitativna analiza*

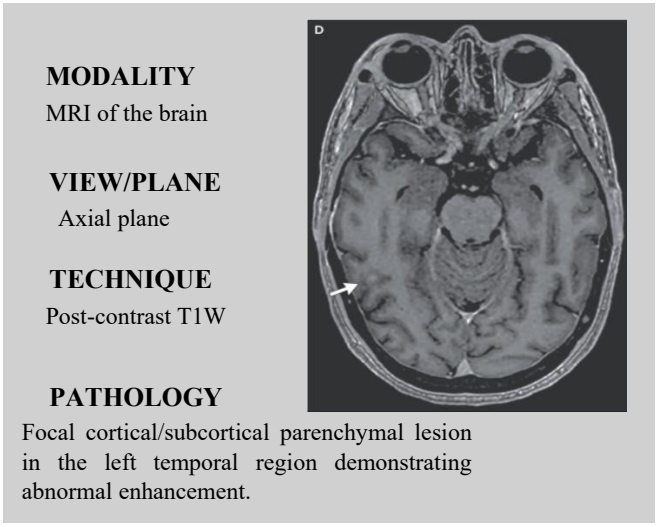
Analiza kliničkog rezonovanja u prvoj fazi istraživanja potvrdila je superiornost Gemini 3 Pro modela i u ovoj sferi, gde je demonstrirao izuzetno kliničko rezonovanje, zasnivajući svoja obrazloženja na preciznoj integraciji ključnih nalaza i jasnom razumevanju patofizioloških mehanizama i patogeneze samih oboljenja. Ovakav pristup rezultirao je maksimalnom ocenom (2) prema *KCorrect* kriterijumu u čak 95% slučajeva. Claude Opus 4.5 je takođe pokazao visok kvalitet kliničke argumentacije sa 85% uspešnosti, dok je učinak modela GPT-5.2 bio značajno niži, sa svega 65% odgovora koji zadovoljavaju najstrože kriterijume pokazatelja *KCorrect*. GPT-5.2 pokazao je tendenciju ka izrazito opreznom dijagnostičkom pristupu, često izbegavajući navođenje konkretne dijagnoze u korist opisnih formulacija. U pogledu samostalne interpretacije radioloških snimaka, Gemini 3 Pro ponovo je imao najbolje performanse, te je u 87% slučajeva tačno identifikovao sve ključne patološke nalaze i samim time pokazao visoku senzitivnost (*FindingsCorrect*), uz prisustvo lažno pozitivnih nalaza u 25% slučajeva. Claude Opus 4.5 pokazao je senzitivnost od 78%, uz veću sklonost ka lažno pozitivnim nalazima, u 67% slučajeva zabeleženo je navođenje patoloških promena koje nisu prisutne na snimcima (FindingsFalse=0/1). GPT-5.2 je, uprkos nižoj tačnosti identifikacije nalaza (60%), imao mali procenat lažno pozitivnih nalaza, u 25% slučajeva. Tačnost tehničke karakterizacije snimaka (modalitet radiološkog snimka, ravan snimanja, posebne karakteristike poput upotrebe kontrasta) bila je relativno ujednačena: Gemini 3 Pro 77%, Claude Opus 4.5 79%, GPT-5.2 60% sa najvišom ocenom.

TABELA I
UPOREDNI PRIKAZ REZULTATA ISPITIVANIH MODELA

Metrika	Gemini 3 Pro	Claude Opus 4.5	GPT-5.2
Faza 1 – Sa opisom radiologa			
Tačnost primarne dijagnoze	90%	***75%***	***65%***
GoldInDiff među netačnim primarnim dijagnozama	100%	100%	71%
PrimaryPlausible među netačnim primarnim dijagnozama	100%	100%	100%
Stepen sigurnosti kod tačne primarne dijagnoze	94%	84%	77%
Stepen sigurnosti kod netačne primarne dijagnoze	93%	82%	82%
Faza 2 – Samostalna interpretacija snimaka			
Tačnost primarne dijagnoze	90%	65%	55%
GoldInDiff među netačnim primarnim dijagnozama	87%	78%	68%
PrimaryPlausible među netačnim primarnim dijagnozama	50%	100%	100%
Stepen sigurnosti kod tačne primarne dijagnoze	94%	75%	79%
Stepen sigurnosti kod netačne primarne dijagnoze	93%	87%	78%

C. *Ilustrativni primer*

Sl. 1 prikazuje radiološki snimak i pripadajući izveštaj koji je generisao model GPT-5.2. Model je precizno identifikovao tehničke parametre snimanja i uspešno locirao samu patologiju bez prisustva lažno pozitivnih nalaza, uz jednu značajnu grešku. Naime, desnostrana temporalna patologija pogrešno je opisana kao lezija u levoj hemisferi. Ovaj uvid je visoko relevantan jer potvrđuje ranija zapažanja o poteškoćama GPT modela u prostornoj orijentaciji i preciznoj lateralizaciji na radiološkim snimcima.



Slika 1. MRI mozga i radiološki nalaz GPT-5.2 modela

V. DISKUSIJA

Sprovedena komparativna analiza ispituje najnovije verzije tri vodeća multimodalna modela kroz složene kliničko-radiološke slučajeve [8] koji predstavljaju realne dijagnostičke izazove, simulirajući realne dijagnostičke izazove umesto standardnih kviz-zadataka. Kroz dva eksperimenta procenjena je sposobnost modela da integrišu kliničke podatke sa nalazima, kao i da samostalno interpretiraju snimke. Pored kvantitativne evaluacije tačnosti, sprovedena je i kvalitativna analiza koja pruža uvid u dijagnostički proces i specifičan „tok misli“ modela.

Rezultati istraživanja pokazuju značajne razlike u performansama između ispitivanih modela. Gemini 3 Pro pokazao je odlične rezultate u oba eksperimenta, što sugeriše da već sada poseduje potencijal za primenu kao dijagnostičkog asistenta, naročito u domenima gde je multimodalna integracija podataka od ključnog značaja. Kod modela Claude Opus 4.5 ključan uvid predstavlja činjenica da je u svim slučajevima sa netačnom primarnom dijagnozom tačna dijagnoza ipak bila navedena među diferencijalnim dijagnozama. Ovaj nalaz ima izuzetnu

kliničku relevantnost za potencijalnu primenu modela kao dijagnostičkog asistenta, jer čak i kada model ne postavi tačnu primarnu dijagnozu, lekar bi na listi diferencijalnih dijagnoza uvek imao tačnu opciju za razmatranje. Kod modela GPT-5.2 su, uprkos najnižoj tačnosti, netačne primarne dijagnoze u 100% netačnih slučajeva bile klinički plauzibilne, što ukazuje da model nije nasumično pogađao, već da postoji solidna osnova, uz realan potencijal za dalju optimizaciju performansi.

Ključno ograničenje istraživanja predstavlja veličina uzorka od 20 slučajeva, što limitira statističku snagu zaključaka. Pri ovoj veličini uzorka, interval poverenja od 95% za tačnost od 90% iznosi približno ±13 procentnih poena. Stoga, uočene razlike između modela treba interpretirati kao preliminarne indikacije koje zahtevaju validaciju na većim uzorcima. Uprkos ovom ograničenju, odabrani slučajevi predstavljaju heterogen skup kompleksnih dijagnostičkih izazova, što pruža inicijalni uvid u komparativne performanse ispitivanih modela u realističnim kliničkim scenarijima.

Rezultati ovog istraživanja, a naročito visoke performanse modela Gemini 3 Pro, potvrđuju da savremeni multimodalni sistemi dostižu nivo koji ih čini relevantnim kandidatima za ulogu dijagnostičkih asistenata, ali istovremeno naglašavaju presudnu važnost interdisciplinarne saradnje, kako bi se izbegao razvoj rešenja koja su tehnički impresivna, ali klinički neprimenljiva. Put do šire kliničke implementacije ostaje zajednički poduhvat koji zahteva kontinuiran rad na pronalaženju balansa između tehnološkog progresa i humanih vrednosti medicine.

VI. Zaključak

Savremeni multimodalni generativni modeli pokazuju značajan potencijal za integraciju u medicinsku dijagnostiku. Gemini 3 Pro prednjači sa tačnošću od 90% i konzistentnim kvalitetom kliničkog rezonovanja. Claude Opus 4.5 pokazuje solidne rezultate uz ograničenje u vidu sklonosti ka halucinacijama pri interpretaciji radioloških snimaka. GPT-5.2, iako je dostigao najnižu tačnost, pokazuje obećavajuće rezultate. Ljudska supervizija ostaje neophodna, posebno imajući u vidu nedovoljnu pouzdanost prijavljenog stepena sigurnosti kao indikatora tačnosti dijagnoze. Buduća istraživanja trebalo bi da obuhvate nekoliko ključnih pravaca. Prvo, validacija na značajno većim uzorcima (n>100) neophodna je za postizanje adekvatne statističke relevantnosti i pouzdaniju kvantifikaciju razlika između modela. Drugo, multicentrična studija sa nezavisnim evaluatorima iz različitih kliničkih sredina omogućila bi procenu generalizabilnosti rezultata. Treće, evaluacija u realnom kliničkom okruženju, uz merenje uticaja na dijagnostičku efikasnost i ishode lečenja, predstavlja kritičan korak ka validaciji kliničke upotrebljivosti. Četvrto, razvoj i testiranje „*ensemble*" sistema koji simultano konsultuje više modela mogao bi kombinovati prednosti pojedinačnih sistema, na primer, visoku tačnost Gemini 3 Pro i pouzdanost diferencijalnih dijagnoza Claude Opus 4.5. Peto, istraživanje mehanizama za detekciju i redukciju halucinacija, posebno pri samostalnoj interpretaciji radioloških snimaka, ostaje prioritet za bezbednu kliničku implementaciju. Konačno, integracija sa DICOM formatom i bolničkim informacionim sistemima omogućila bi testiranje u punoj dijagnostičkoj rezoluciji, eliminišući ograničenja proistekla iz ekstrakcije slika iz PDF formata.

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Optimizacija lokacije i veličine otočnih prigušnica u elektroprenosnom sistemu Crne Gore

Hilmo Čindrak, Vladan Durković

***Sadržaj*—Cilj ovog rada je pronalazak optimalnog rješenja koje omogućava efikasno upravljanje naponskim prilikama u realnim uslovima rada prenosnog sistema, uz poštovanje tehničkih, ekonomskih i operativnih ograničenja sistema. Istraživanje će se realizovati kroz nekoliko faza koje obuhvataju prikupljanje, obradu i analizu istorijskih podataka, modelovanje elektroprenosne mreže, razvoj i implementaciju optimizacionog problema primjenom genetičkog algoritma, predlog rješenja i komparativnu analizu rješenja.**

I. Uvod

Tokom poslednjih dvadeset godina elektroprenosne mreže Zapadnog Balkana doživjele su značajan razvoj, posebno kada je riječ o internim i interkonektivnim prenosnim vodovima. Posebna pažnja bila je usmjerena ka razvoju 400kV i 110kV prenosnih vodova. Međutim, instalisani proizvodni kapaciteti i potrošnja energije nijesu pratili razvoj prenosne infrastrukture, što je dovelo do nedovoljne opterećenosti vodova, a samim tim i do porasta napona iznad dozvoljenih granica. Modernizacijom elektroenergetskih mreža i upotrebom obnovljivih izvora energije, optimalno korišćenje mreže postalo je izuzetno važno zbog visokih troškova izgradnje i razvoja sistema. Pored toga, problemi u elektroenergetskom sistemu kao što su odstupanje napona, naponska nestabilnost, gubici snage, podopterećenost ili preopterećenost vodova postali su jedno od glavnih pitanja u eksploataciji elektroenergetskih sistema [1].

Istraživanje je posebno značajno jer se odnosi na realni sistem elektroprenosnog sistema Crne Gore (CGES), u kojem su problemi prenapona prisutni u gotovo svim 400kV i 220kV čvorovima, naročito u čvorovima koji uključuju HVDC (High Voltage Direct Current) interkonekcije. Ovakvi elementi sistema su podložni brzim promjenama toka aktivne snage, što za posljedicu ima varijaciju napona. U tom kontekstu, optimizacija lokacije i veličine otočnih prigušnica predstavlja ključni korak u procesu unapređenja naponske stabilnosti, smanjenju gubitaka i povećanju energetske efikasnosti sistema.

Prva faza istraživanja obuhvata prikupljanje i obradu relevantnih podataka o naponskim prilikama u mreži CGES-a. Prikupljeni podaci su preuzeti iz upravljačkih sistema (SCADA) i internih baza CGES-a, za period od jula 2022. do jula 2025. godine u vremenskoj rezoluciji od jednog sata. Ključna faza istraživanja obuhvata razvoj genetičkog algoritma za optimizaciju lokacije i veličine otočne prigušnice radi minimizacije funkcije cilja koja je definisana kroz sumu kvadratnih odstupanja napona od referentnih vrijednosti i ukupne tehničke gubitke u sistemu, uz uvažavanje ograničenja sistema [2].

Rezultati optimizacije su verifikovani kroz simulacije u internim analitičkim alatima CGES-a (*Transmission Network Analyzer),* čime se omogućava poređenje stanja prije i poslije implementacije predloženog rješenja.

Pored tehničkog aspekta, istraživanje ima i strateški značaj za planiranje budućeg razvoja elektroenergetskog sistema Crne Gore, posebno u kontekstu povećane integracije obnovljivih izvora energije i razvoju regionalnih interkonekcija. Razvijeni model optimizacije i dobijeni rezultati mogu poslužiti kao alat za podršku odlučivanju u planiranju mreže, definisanju investicionih prioriteta i unapređenju politika upravljanja naponom.

Implementacija ovog istraživanja ima za cilj povećanje sigurnosti i pouzdanosti sistema, smanjenje tehničkih i ekonomskih gubitaka kao i omogućavanje integracije novih obnovljivih izvora električne energije i novih elemenata u sistemu.

II. Regulacija napona i reaktivnih snaga

Napon i frekvencija predstavljaju dva najznačajnija parametra stanja svakog elektroenergetskog sistema (EES). Ipak, među njima postoji razlika: frekvencija je globalni pokazatelj čija je stacionarna vrijednost ista u svim dijelovima EES-a koji rade sinhrono, pa se njena stabilnost može uspostaviti balansom proizvedene i utrošene aktivne energije na nivou sistema. Nasuprot tome, napon je lokalni pokazatelj i vezan je za pojedinačne čvorove prenosnih i distributivnih mreža. U normalnom radnom režimu svakog EES-a glavni cilj regulacije napona i reaktivnih snaga je održavanje napona unutar propisanih granica za sve čvorove u sistemu pomoću uspostavljanja ravnoteže između proizvedene i utrošene reaktivne energije. Regulacija napona u elektroenergetskom sistemu je ključna za pravilno funkcionisanje električne opreme, kako bi se spriječila oštećenja poput pregrijavanja generatora i motora, smanjili prenosni gubici i očuvala sposobnost sistema da izdrži i spriječi kolaps napona [3].

H. Čindrak – Crnogorski elektroprenosni sistem, Bulevar Svetog Petra Cetinjskog 18, 81000 Podgorica, Crna Gora (e-mail: hilmo.cindrak@cges.me)

V. Durković, Elektrotehnički fakultet u Podgorici, Univerzitet Crne Gore, Džordža Vašingtona bb, 81000 Podgorica, Crna Gora (e-mail: vladan.d@ucg.ac.me).

A. *Cilj regulacije napona i reaktivnih snaga*

Regulacija napona i reaktivnih snaga predstavlja jednu od pomoćnih sistemskih usluga koja se koristi za održavanje naponskog profila putem injektiranja reaktivne snage. Usluge regulacije reaktivne snage u prenosnoj mreži imaju važnu ulogu [4]:

- zadovoljavaju potrebe potrošača za reaktivnom snagom
- utiču na vrijednosti napona sabirnica
- smanjuju gubitke u mreži
- smanjuju opterećenje prenosne mreže
- obezbjeđuju dovoljne rezerve za sigurnost sistema u poremećenim stanjima.

Budući da se reaktivna snaga ne može prenositi na velike udaljenosti, regulacija napona mora se provoditi korištenjem posebnih uređaja raspoređenih po cijelom sistemu. To je u suprotnosti s kontrolom frekvencije koja zavisi od ukupnog bilansa aktivne snage sistema. Pravilan odabir i koordinacija opreme za kontrolu reaktivne snage i napona su među glavnim izazovima u procesu eksploatacije EES-a [5].

B. *Metode upravljanja naponom*

Rad elektroenergetskih sistema može se podijeliti na tri stanja: normalno, prethavarijsko i havarijsko. Sistem uobičajeno radi u normalnom stanju, ali prelazi u prethavarijsko stanje ako se procijeni da nije dovoljno otporan na poremećaje koji su uzeti u obzir prilikom projektovanja sistema. Zbog toga je organizaciona struktura regulacije napona i reaktivne snage podijeljena na tri nivoa:

- primarna regulacija
- sekundarna regulacija
- tercijarna regulacija

Primarna regulacija napona obezbjeđuje brzo održavanje napona generatora blizu referentne vrijednosti preko automatskog regulatora napona (AVR). Sekundarna regulacija djeluje u vremenskom okviru od nekoliko sekundi do minuta na nivou jednog dijela EES-a, s ciljem održavanja naponskog profila te regije i smanjenja tokova reaktivne snage. Tercijarna regulacija se odvija na nivou cijelog sistema i kroz optimalni tok snaga minimizira gubitke i raspoređuje rezerve u dužem vremenskom intervalu [6].

C. *Naponsko-reaktivni regulacioni resursi*

Proizvodne jedinice predstavljaju osnovno regulaciono sredstvo, zbog automatskog djelovanja na pobudu generatora kako bi održavali napone u dozvoljenim granicama. Međutim, za regulaciju napona na nivou cijelog sistema neophodno je koristiti dodatna regulaciona sredstva. Kompenzacija reaktivne energije jedan je od najefikasnijih načina upravljanja naponom. Kao osnovna podjela naponsko-reaktivnih regulacionih resursa izdvajaju se dvije grupe:

1. Sredstva za proizvodnju/apsorpciju reaktivnih snaga u mreži: sinhroni generatori/motori, otočni kondenzatori, otočne prigušnice, kablovi, podopterećeni dugi vodovi.
2. Sredstva za preraspodjelu tokova reaktivnih snaga u mreži: redni kondenzatori i reaktori i regulacioni transformatori

III. TRENUTNO STANJE PRENOSNOG SISTEMA CRNE GORE

Kao posljedica neuravnoteženog razvoja prenosne mreže sa razvojem potrošnje i proizvodnje električne energije, pojavljuje se situacija u kojoj naponski profili u mnogim čvornim tačkama sistema i u mnogim režimima sistema izlaze izvan propisanih granica, a koje prenosni sistem nije u stanju da kontroliše korišćenjem postojeće opreme. Prenaponi se najčešće javljaju u režimima sa nižom potrošnjom aktivne i reaktivne snage, kao i sa malim brojem generatora u pogonu koji imaju sposobnost da apsorbuju višak reaktivne snage. Dugotrajni prenaponi u stacionarnom stanju dovode do ubrzanog starenja opreme, a mogu izazvati i aktiviranje zaštitnih releja i na taj način isključiti trafostanicu ili dalekovod, potencijalno izazivajući široko rasprostranjen prekid u snabdijevanju potrošača električnom energijom. Posebna pažnja posvećena je analizi 400kV čvorova u sistemu, zbog dominantnog uticaja na stabilnost i kvalitet prenosa električne energije u cijelom sistemu.

A. *Istorijski podaci o 400kV čvorovima*

Za potrebe analize korišćeni su podaci iz SCADA sistema o naponima u 400 kV čvorovima (TS Lastva, TS Podgorica 2, TS Pljevlja 2, TS Ribarevine), prikupljeni u satnoj rezoluciji za period od jula 2022. godine do jula 2025. godine. Svaka godina je analizirana zasebno, a rezultati su predstavljeni kroz:

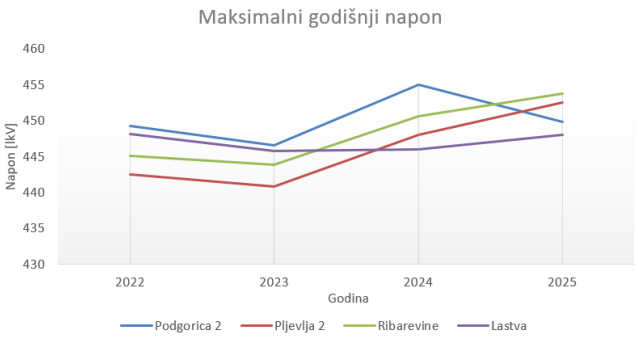
- godišnji izvještaj (maksimalne i prosječne vrijednosti napona za svaku trafostanicu na nivou godine),
- mjesečni izvještaj (mjesečne prosječne i maksimalne vrijednosti napona po trafostanici)
- izvještaj ekstremnih vrijednosti (identifikovani su tačan datum i sat kada je zabilježen najveći napon u svakom mjesecu za svaku trafostanicu).

Kroz godišnje i mjesečne statistike identifikovani su periodi najvećih oscilacija, kao i momenti ekstremnih vrijednosti koji potencijalno mogu biti od značaja za odabir kritičnih scenarija za analizu priključenja reaktora.

TS Lastva, iako je imala najniži prosječni napon tokom posmatranog perioda, pokazuje najizraženiji rast iz godine u godinu. Ostale trafostanice bilježe stabilnost u prvim godinama a u 2025. godini blagi rast. Ono što je karakteristično za sve trafostanice jeste da je prosječan napon (421 kV - 429 kV) za sve četiri godine izvan propisanih granica za 400 kV čvorove.

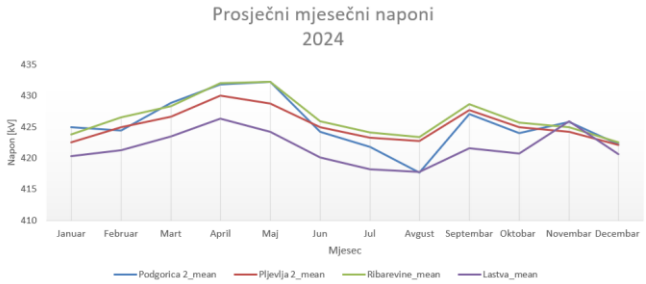
Posmatranjem maksimalnih vrijednosti napona na slici 1, izmjerenih u trafostanicama Podgorica 2, Pljevlja 2, Ribarevine i Lastva tokom četiri godine (od 2022. godine do 2025. godine), uočavaju se blage oscilacije maksimalnih vrijednosti napona sa značajnijim porastom u 2024. godini, gdje se ekstremne vrijednosti napona za sve trafostanice kreću od 445 kV do 455 kV.

Pri odabiru scenarija za analizu posebna pažnja je posvećena periodima u godini kada su zabilježene ekstremne ili netipične vrijednosti napona, kako u pogledu prosjeka, tako i u pogledu maksimalnih vrijednosti.



Slika 1. Maksimalni godišnji naponi po trafostanicama

Na slici 2. prikazani su prosječni mjesečni naponi za četiri trafostanice za 2024. godinu. Mjesečna analiza pokazala je da se najizraženije vrijednosti napona i naponske nestabilnosti javljaju u aprilu, maju, septembru i oktobru. Navedene mjesece u godini karakteriše nisko opterećenje mreže i povećan tranzit energije kroz sistem.



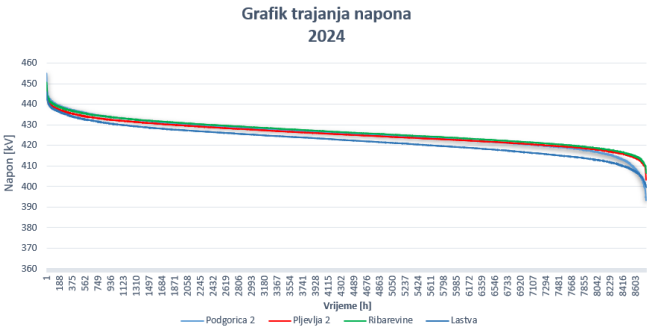
Slika 2. Prosječni mjesečni naponi po trafostanicama (2024)

Ono što je karakteristično za maksimalne mjesečne vrijednosti napona jeste da se javljaju u ranim jutarnjim časovima, tačnije u periodu od 3:00 h do 5:00 h. Od ukupno 144 mjesečnih ekstremnih vrijednosti napona, 58 ih je zabilježeno u 5:00 h, 41 vrijednost u 3:00 h i 32 vrijednosti u 4:00 h. S obzirom na to da su ekstremne vrijednosti ključne za tehničku analizu stabilnosti sistema i potencijalnog priključenja prigušnice, analiza se fokusira upravo na sate 3:00 h, 4:00 h i 5:00 h.

B. Analiza trajanja napona

Zavisnost napona od vremena prikazana je kroz krive trajanja napona na slici 3, omogućavajući na taj način uvid u učestalost i trajanje odstupanja napona od nominalnih vrijednosti. Ovaj prikaz značajan je za identifikaciju perioda naponskog stresa i procjenu blizine granica naponske stabilnosti. U tabeli I predstavljeno je procentualno odstupanje napona od dozvoljenih vrijednosti na nivou godine, s tim što su 2022. i 2025. godina djelimično obuhvaćene (3866 sati i 4213 sati respektivno). Prikazani rezultati ukazuju na izraženo odstupanje naponskog profila tokom analiziranog perioda.

Trafostanice Podgorica 2, Pljevlja 2 i Ribarevine u većem dijelu posmatranog perioda bilježe velike procente odstupanja, sa značajnijim padom u 2024. godini u odnosu na 2023. godinu, dok TS Lastva, sa druge strane, bilježi porast.



Slika 3. Grafik trajanja napona 2024. god.

Ovakvo ponašanje napona u TS Lastva može se direktno povezati sa karakteristikom HVDC postrojenja u njenoj blizini, gdje česte promjene toka aktivne snage imaju snažan uticaj na lokalne i sistemske napone.

TABELA I
PROCENTUALNO GODIŠNJE ODSTUPANJE NAPONA

	TS Podgorica 2	TS Pljevlja 2	TS Ribarevine	TS Lastva
2022. god.	87.40%	85.80%	89.90%	58.30%
2023. god.	86.80%	88.90%	89.60%	54.80%
2024. god.	77.70%	79.90%	85.70%	64.30%
2025. god.	93.10%	92.30%	94.20%	81.90%

IV. OPTIMIZACIJA PRIGUŠNICE U ELEKTROPRENOSNOM SISTEMU CRNE GORE

Cilj optimizacije genetičkim algoritmom jeste pronalazak optimalne lokacije i snage prigušnice kako bi naponski profil svih čvorova sistema bio unutar propisanih granica. Funkcija cilja definisana je kao kvadratno odstupanje napona od nominalne vrijednosti:

$$min\ F = \sum_{i}^{N} \sum_{t=1}^{24} \left(V_{i,t} - V_{nom}\right)^2 \qquad (1)$$

U procesu optimizacije korišćena je realna 400 kV mreža CGES-a koja je modelovana u softverskom alatu *Matlab* uz primjenu *Newton-Raphson* metode za proračun tokova snaga. Analiziran je scenario za 1. maj 2025. godine u 3:00 h. Zbog robusnosti rješenja pokrenuto je deset nezavisnih simulacija GA. Na osnovu višestrukih optimizacionih pokretanja, sa različitom veličinom populacije i različitom početnom populacijom, zaključeno je da je trafostanica Lastva najpogodnija lokacija za instalaciju otočne prigušnice, sa snagom 270 MVAr.

Kao najbolje rješenje za čvor Ribarevine izdvaja se prigušnica snage 220 MVAr, dok u čvoru Podgorica 2 najbolje rješenje je prigušnica snage 240 MVAr.

Rezultati optimizacije su verifikovani kroz simulacije u internim analitičkim alatima CGES-a (*Transmission Network Analyzer*).

Posebna pažnja posvećena je analizi 400kV čvorova zbog dominantnog uticaja na stabilnost i kvalitet prenosa električne energija.

Kao najbolje rješenje optimizacije izdvaja se čvor Lastva sa snagom od 270 MVAr. Ovo rješenje ima ujedno i najnižu vrijednost ciljne funkcije jer se njime postiže najmanje odstupanje napona. Drugo optimalno rješenje je čvor Ribarevine sa snagom oko 220 MVAr, dok je najbolje rješenje za čvor Podgorica 2 prigušnica snage oko 240 MVAr.

Sva tri slučaja biće analizirana u kombinaciji sa dalekovodom 400 kV Pljevlja 2 – Lastva, čiji se ulazak u pogon očekuje u prvom kvartalu 2026. godine. Pored toga, biće analiziran i slučaj priključenja druge žile HVDC kabla između Crne Gore i Italije, sa ukupnim kapacitetom od 1200MW.

A. Početno stanje sistema

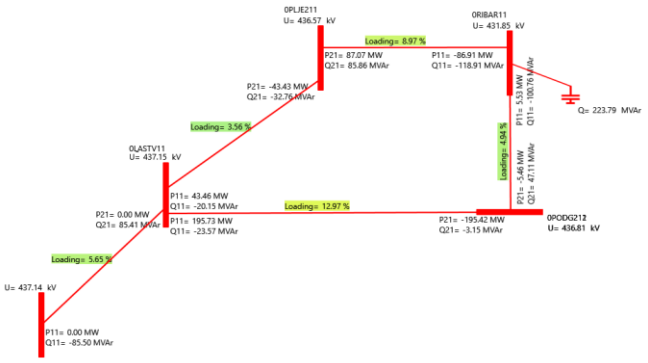
Analiza je sprovedena na realnom mrežnom modelu CGES-a za 1.maj 2025.god u 03:00 h. U analiziranom scenariju mreža je u normalnoj pogonskoj konfiguraciji sa svim elementima sistema pri čemu je uočljiva niska opterećenost 400 kV dalekovoda kao i povišeni naponi u svim čvorovima. Razmjene sa susjednim sistemima realizuju se isključivo preko AC interkonekcija, dok HVDC veza ME-IT ne učestvuje u razmjeni aktivne snage u analiziranom satu. U konvertorskom postrojenju Lastva u pogonu je prigušnica koja u ovom slučaju apsorbuje 85 MVAr reaktivne energije. Proizvodnja aktivne snage u sistemu je iznosila 46 MW, dok je potrošnja sistema bila 159 MW. Ukupan tranzit aktivne energije preko sistema je iznosio 330 MW, uz gubitke aktivne snage od 3.4 MW. Kvadratno odstupanje napona od nominalnih vrijednosti za posmatrane trafostanice iznosi 23.15 kV.

B. Analiza različitih scenarija

Trafostanica Lastva je veliko energetsko čvorište Crne Gore i predstavlja jednu od ključnih trafostanica kako u sistemu CGES-a tako i na Balkanu. Poseban značaj trafostanice ogleda se u njenoj ulozi u interkonekciji sa ostalim sistemima, posebno kroz pomorsku vezu između Crne Gore i Italije preko HVDC konekcije. S obzirom na osjetljivost HVDC konvertorskog postrojenja na česte promjene napone, posebna pažnja je usmjerena baš na ovu trafostanicu. Priključenjem prigušnice u TS Lastva napon u ovom čvoru opada sa 447 kV na 430 kV u odnosu na početno stanje sistema. Takođe, i naponi u ostalim čvorovima bilježe pad od 10 do 14 kV. Ukupni gubici aktivne snage u ovom slučaju iznose 3.4 MW.

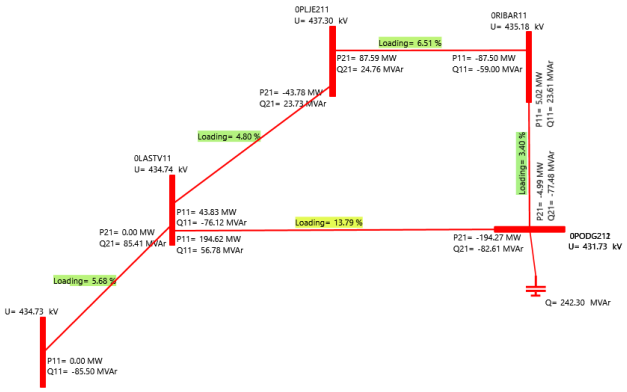
Implementacijom prigušnice u TS Ribarevine prikazanoj na slici 4, dolazi do pada napona u tom čvoru za 13 kV. Pored toga, naponi u ostalim čvorovima bilježe pad za oko 10 kV. Gubici aktivne snage u ovom slučaju iznose 3.3 MW.

Stanje sistema nakon ugradnje prigušnice u TS Podgorica 2 prikazano je na slici 5. U ovom slučaju napon u čvoru Podgorica 2 niži je za 16 kV, dok su naponi u ostalim čvorovima niži za oko 10 kV u odnosu na bazno stanje sistema, uz gubitke aktivne snage od 3.4 MW.



Slika 4. Stanje sistema – Shunt Ribarevine

Na osnovu rezultata prikazanih u Tabeli II može se zaključiti da instalacija prigušnica u posmatranim čvorovima sistema ima značajan uticaj na naponske prilike. Izgradnja 400kV voda Pljevlja 2 – Lastva dovodi do povećanja napona u svim čvorovima sistema. Ugradnja kompenzacionog elementa u TS Lastva ima snažan uticaj ne samo na taj čvor već i na ostale čvorove u sistemu. Ovakvo ponašanje napona ukazuje na to da je TS Lastva energetski jako čvorište i da promjene reaktivne snage u ovom čvoru imaju sistemski karakter. Otočna kompenzacija u TS Ribarevine uglavnom ima lokalni karakter, dok kompenzacija u TS Podgorica 2 ima najmanji ukupni uticaj na naponski profil sistema.

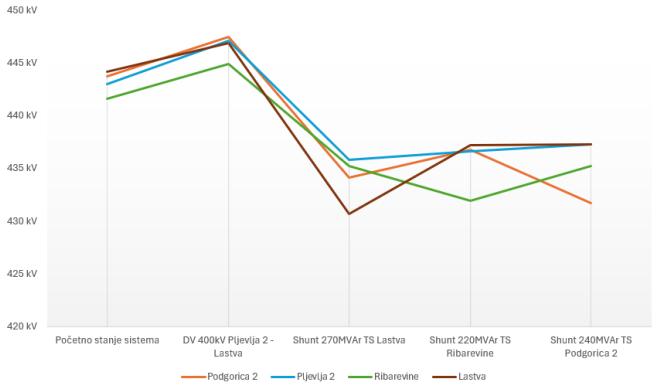


Slika 5. Stanje sistema – Shunt Podgorica 2

TABELA II
UTICAJ IMPLEMENTIRANIH RJEŠENJA NA NAPON

Element	Napon [kV]			
	Podgorica 2	Pljevlja 2	Ribarevine	Lastva
Početno stanje sistema	443.7	443	441.6	444.2
DV 400kV Pljevlja 2 - Lastva	447.5	447.1	444.9	446.9
Shunt 270MVAr TS Lastva	434.1	435.8	435.2	430.7
Shunt 220MVAr TS Ribarevine	436.8	436.6	431.9	437.2
Shunt 240MVAr TS Podgorica 2	431.7	437.3	435.2	437.3

Na slici 6. grafički je predstavljen uticaj implementiranih rješenja na napone u sistemu.



Slika 6. Grafički prikaz uticaja elemenata na napon

C. HVDC postrojenje Lastva

HVDC postrojenje Lastva predstavlja jedno od najvažnijih postojenja u regionu. Ova veza između Italije i Crne Gore omogućava stabilan uvoz i izvoz električne energije, dok istovremeno značajno utiče na naponske prilike u mreži CGES-a. Sa svojim ukupnim kapacitetom od 600 MW, ovo postrojenje je podložno čestim promjenama toka aktivne snage koji izazivaju fluktaciju napona u samoj TS, ali i u susjednim čvorovima sistema. Visoka osjetljivost postrojenja na promjene napona zahtijeva brzu i koordinisanu reakciju uređaja za regulaciju reaktivne snage i napona, kako bi se održala naponska stabilnost sistema.

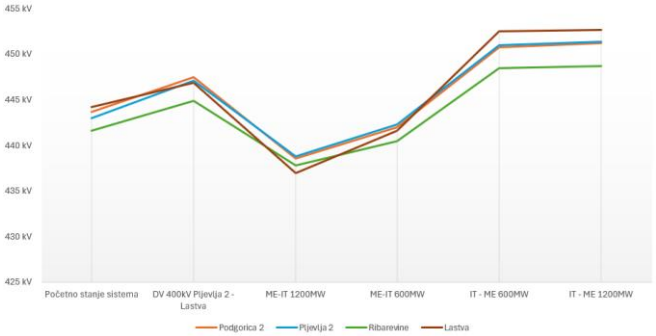
Na slici 7. predstavljen je uticaj toka aktivne snage HVDC kabla na naponske prilike u TS Lastva. Posmatran je period od 15. do 31. maja 2025. godine. Plavom bojom je označen tok aktivne snage u smjeru CG-IT u granicama od -600 MW do 600 MW, dok su vrijednosti napona označene crvenom bojom. Uočava se da se sa povećanjem izvoza aktivne snage [ME-IT] javlja pad napona u čvoru. Suprotno tome, u režimu povećanog uvoza aktivne snage dolazi do porasta napona.

Analizirani režimi obuhvataju:

- 1200 MW izvoza [ME-IT]
- 600 MW izvoza [ME-IT]
- 1200 MW uvoza [IT - ME]
- 600 MW uvoza [IT - ME]

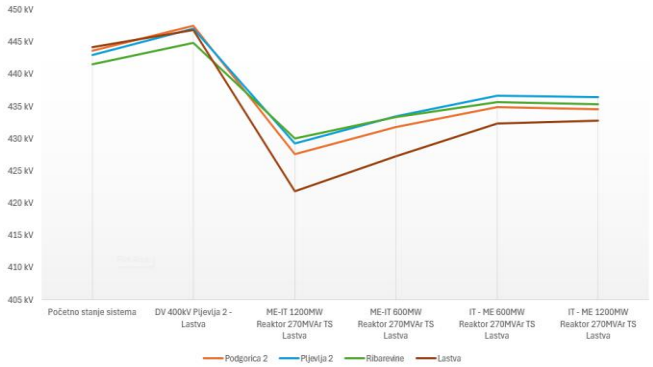
Na slici 8. predstavljeno je stanje napona u trafostanicama pri svim radnim režimima HVDC kabla. Iz ove analize može se zaključiti da tok aktivne snage na kablu ima jako izražen i sistemski uticaj na naponske prilike.

U slučaju pojačanog izvoza električne energije dolazi do pada napona u sistemu, pri čemu je pad najizraženiji u TS Lastva. Nasuprot tome, u režimima velikog uvoza dolazi do značajnijeg porasta napona, pa se može zaključiti da su ovi režimi kritični sa aspekta regulacije napona i da zahtijevaju adekvatnu i brzu regulaciju, naročito u TS Lastva.

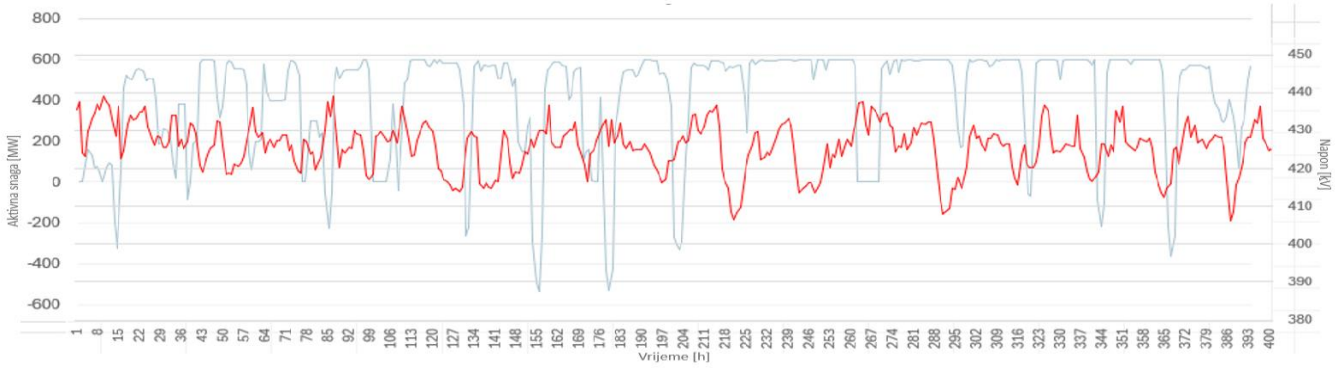


Slika 8. Uticaj HVDC kabla na napone

Priključenjem otočne prigušnice snage 270 MVAr u TS Lastva značajno se mijenja naponski odziv sistema na promjene toka snage na HVDC kablu. Sa slike 9. može se uočiti da prigušnica efikasno ograničava porast napona u slučaju uvoza električne energije, dok u slučaju izvoza od 1200 MW imamo najizraženiji pad napona u TS Lastva sa početnih 445 kV na 421 kV. Sličan trend pada napona primjetan je i u susjednim čvorovima koji se nalaze u neposrednoj blizini ove trafostanice.



Slika 9. Uticaj prigušnice u TS Lastva



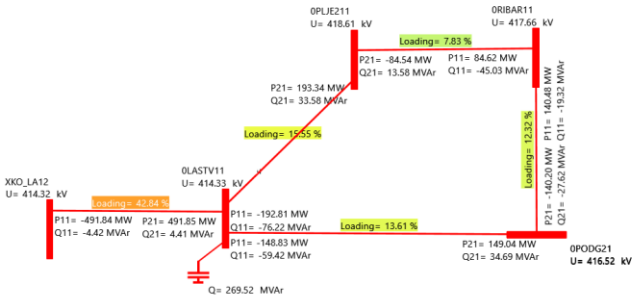
Slika 7. Uticaj toka aktivne snage HVDC kabla napone u TS Lasva

D. *Referentni model – analiza priključenja*

Analiza uticaja prigušnice u TS Lastva na naponske prilike u sistemu sprovedena je i na referentnom godišnjem modelu za jesen 2025. godine.

Odabrani referentni model karakterišu naponi koji su veoma bliski godišnjim prosječnim vrijednostima napona za posmatrani period. Na ovaj način omogućava se reprezentativna analiza uticaja prigušnice na stabilnost napona. Cilj analize na ovom modelu jeste da se kvantifikuje doprinos odabranog uređaja na naponske prilike u periodima koje ne karakterišu ekstremne vrijednosti napona.

Analizom priključenja prigušnice u trafostanici Lastva na referentnom modelu uočeno je sniženje napona u svim posmatranim čvorovima ispod gornje maksimalne dozvoljene vrijednosti. Stanje sistema nakon implementacije ovog rješenja prikazano je na slici 10.



Slika 10. Stanje sistema – referentni model

V. ZAKLJUČAK

Sprovedene analize naponskih prilika u mreži CGES-a pokazale su da HVDC kabl ima jako izražen uticaj na naponske prilike posebno na čvorove koji su u blizini ovog postrojenja. Uticaj ovog postrojenja posebno je izražen u periodima velikog uvoza energije iz Italije, kada dolazi do skoka napona. Analiza ukazuje da priključenje otočne prigušnice u TS Lastva ima najveći uticaj na napone u sistemu i da smanjuje ukupnu naponsku osjetljivost sistema na promjene toka aktivne snage na kablu, ali da njeno uključenje mora biti koordinisano sa režimom rada HVDC postrojenja kao i sa ostalim sredstvima za regulaciju napona kako bi se održala naponska stabilnost u sistemu.

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Transformacija predškolskog vaspitanja kroz IT: Od teorijskih okvira do praktične primjene

Armin Alibašić[1], Enela Bibić[2], Mina Mavrić[2]

***Sadržaj*—Ovaj rad istražuje ulogu i značaj informacionih tehnologija (IT) u vaspitno-obrazovnom radu s djecom predškolskog uzrasta. Cilj istraživanja je identifikovati prednosti i izazove integracije digitalnih alata, uz fokus na ulogu vaspitača i neophodnu stručnu podršku. Kroz analizu literature i empirijsku studiju, rad ispituje modalitete efikasne implementacije tehnologije u svrhu unapređenja kvaliteta predškolskog obrazovanja. Rezultati pružaju smjernice za praktičnu primjenu IT-a, doprinoseći boljem razumijevanju digitalne transformacije u ranom djetinjstvu.**

I. Uvod

Savremena paradigma predškolskog vaspitanja i obrazovanja suočava se sa izazovima digitalne transformacije, koja nalaže redefinisanje tradicionalnih pedagoških pristupa. Budući da su djeca rane dobi primarno okružena tehnološkim artefaktima, integracija informacionih tehnologija (IT) u vaspitno-obrazovni proces postaje ne samo mogućnost, već nužnost za razvoj rane digitalne pismenosti i kompetencija 21. vijeka.

Predmet ovog rada je analiza modaliteta i efikasnosti primjene IT alata u predškolskim ustanovama. Osnovni cilj istraživanja usmjeren je na identifikaciju korelacije između teorijskih postavki digitalne pedagogije i njihove praktične implementacije. Rad nastoji odgovoriti na ključna pitanja o prednostima digitalizacije u ranoj dobi, ali i o sistemskim izazovima koji prate ovaj proces.

Poseban istraživački fokus stavljen je na tri ključna aspekta:

1. Analiza pedagoškog potencijala: Ispitivanje na koji način IT alati doprinose interaktivnosti i individualizaciji učenja.
2. Uloga vaspitača: Evaluacija digitalnih kompetencija vaspitno-obrazovnog kadra kao primarnog faktora uspješne integracije tehnologije.
3. Institucionalna podrška: Identifikacija potreba za kontinuiranom obukom i infrastrukturnim unaprjeđenjem sistema.

[1] Fakultet za informacione sisteme i tehnologije, Univerzitet Donja Gorica, 81000 Podgorica, Crna Gora (e-mail: armin.alibasic@udg.edu.me).
[2] Departman za pedagoške i psihološke nauke, Univerzitet u Novom Pazaru, 11050 Novi Pazar, Srbija (e-mail: enela.bibic@gmail.com, mina.mavric@uninp.edu.rs).

Kombinujući teorijsku analizu i empirijske pokazatelje, rad nudi naučno utemeljene smjernice za optimizaciju vaspitno-obrazovnog rada. Rezultati istraživanja doprinose boljem razumijevanju uloge IT-a kao katalizatora kvaliteta u predškolskom obrazovanju, te pružaju osnovu za kreiranje budućih strategija profesionalnog razvoja vaspitača.

II. TEORIJSKI OKVIR

A. Informacione tehnologije i obrazovanje

Informacione tehnologije obuhvataju skup digitalnih uređaja, sistema i usluga koji omogućavaju prikupljanje, obradu, skladištenje i razmjenu informacija, uključujući računare, mreže, mobilne uređaje i različite softverske aplikacije. Razvoj IT od kraja 20. vijeka značajno je izmijenio način na koji ljudi komuniciraju, rade i uče, pa je obrazovanje postalo jedno od polja u kojem su promjene najvidljivije. Tradicionalni model škole kao glavnog izvora znanja suočen je sa konkurencijom različitih masovnih medija i online resursa, što utiče na očekivanja učenika i ulogu nastavnika [1].

B. Predškolske ustanove i digitalno okruženje

Predškolske ustanove imaju zadatak da djeci obezbijede sigurnu i podsticajnu sredinu za cjelovit razvoj, u kojoj će kroz igru, istraživanje i socijalnu interakciju sticati prva iskustva učenja. Pored brige o djetetu, predškolska ustanova ostvaruje i važnu funkciju saradnje sa porodicom, školom i širim društvenim okruženjem, pri čemu savremene komunikacione tehnologije mogu znatno olakšati ovu saradnju. Web-sajtovi vrtića, digitalni portfoliji i online komunikacioni kanali postaju sredstva informisanja, razmjene iskustava i uključivanja roditelja u vaspitno-obrazovni proces [2].

Uvođenje informacionih tehnologija u prostor predškolske ustanove mijenja i unutrašnju organizaciju rada, načine planiranja i dokumentovanja aktivnosti. Digitalni alati se koriste za pripremu materijala, planiranje aktivnosti, evaluaciju i dokumentovanje dječijeg napretka, ali i za same aktivnosti sa djecom. Time vrtić postaje dio šireg digitalnog ekosistema, a pitanje digitalne kulture ustanove dobija na značaju [3].

C. Integracija digitalnih tehnologija u predškolske programe

Savremeni programi predškolskog vaspitanja zasnovani su na ideji da je dijete aktivan učesnik u učenju, koje se odvija kroz igru, istraživanje i socijalnu interakciju sa vršnjacima i

odraslima. U tom kontekstu digitalne tehnologije posmatraju se kao dodatni resursi koji mogu obogatiti iskustva djece, a ne kao zamjena za tradicionalne oblike igre i neposrednu interakciju. U predškolskim programima mogu se koristiti interaktivne table za grupne aktivnosti, edukativne aplikacije za učenje slova i brojeva, programi za digitalno crtanje koji razvijaju finu motoriku, te početni setovi za robotiku koji podstiču logičko razmišljanje. Digitalne slikovnice, interaktivne priče, multimedijalne prezentacije i jednostavni edukativni programi mogu pomoći u motivisanju djece i vizuelizaciji apstraktnih pojmova [4].

Međutim, integracija IT u predškolske programe mora biti pažljivo planirana i usklađena sa preporukama o ograničenom vremenu pred ekranima za najmlađe uzraste. Tehnologija treba da bude uključena u kraćim, jasno strukturisanim aktivnostima, uz stalnu prisutnost i vođstvo vaspitača, koji je zadužen za to da sadržaji budu razvojno primjereni i bezbjedni. Na taj način može se postići ravnoteža između digitalnih i nedigitalnih iskustava, uz očuvanje igre kao osnovnog oblika učenja u predškolskom uzrastu [5].

D. Digitalna pismenost i uloga vaspitača

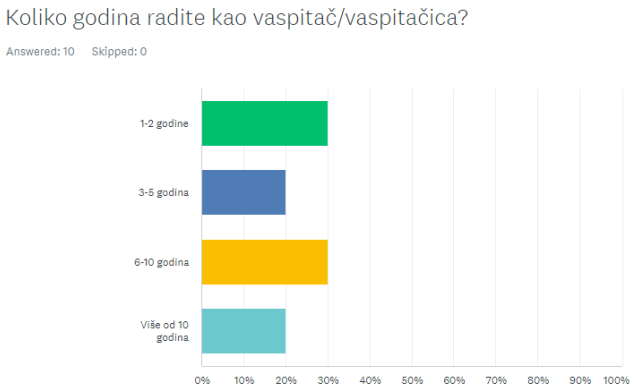
Digitalna pismenost podrazumijeva sposobnost promišljenog, odgovornog i kreativnog korišćenja digitalnih tehnologija u učenju, radu i svakodnevnom životu, uključujući pronalaženje, evaluaciju, kreiranje i razmjenu informacija. U predškolskom uzrastu ne radi se o složenim tehničkim vještinama, već o formiranju početnih navika i stavova prema tehnologiji kao sredstvu za učenje i komunikaciju. Rani razvoj digitalnih kompetencija djece snažno zavisi od digitalnih kompetencija odraslih, prije svega vaspitača i roditelja [6-7].

Evropski okviri digitalnih kompetencija, kao što su DigComp, DigCompEdu i DigCompOrg, naglašavaju da profesionalni razvoj nastavnika u oblasti digitalnih kompetencija predstavlja ključni uslov uspješne integracije IT u obrazovanje [8]. Uloga vaspitača pritom je višestruka: on planira i organizuje aktivnosti, bira digitalne resurse, procjenjuje njihovu primjerenost, prati reakcije djece i podržava njihovo iskustveno učenje. Bez obzira na stepen tehnološke opremljenosti, ljudski faktor ostaje presudan za kvalitet vaspitno-obrazovnog rada u digitalnom okruženju.

III. PODACI I METODOLOGIJA

Istraživanje predstavljeno u ovom radu ima za cilj da pruži empirijski uvid u to kako vaspitači u predškolskim ustanovama koriste informacione tehnologije, kako procjenjuju njihov uticaj na djecu i koje potrebe za stručnim usavršavanjem prepoznaju. U skladu sa ciljem, primijenjen je kvantitativni istraživački pristup zasnovan na anketiranju vaspitača.

Podaci su prikupljeni u martu 2024. godine putem online platforme SurveyMonkey[1], što je omogućilo jednostavnu distribuciju upitnika i anonimno učešće ispitanika. Uzorak čini deset vaspitača zaposlenih u različitim predškolskim ustanovama, sa radnim iskustvom u rasponu od jedne do preko deset godina. Učešće u istraživanju bilo je dobrovoljno i anonimno, uz poštovanje osnovnih etičkih principa, uključujući informisanost o svrsi istraživanja i mogućnost odustajanja.



Slika 1. Distribucija radnog iskustva ispitanika ankete

Kao instrument korišćen je strukturirani anketni upitnik zatvorenog tipa, sastavljen od pitanja koja se odnose na sociodemografske karakteristike vaspitača, iskustvo u radu, učestalost i načine korišćenja IT, procjenu uticaja tehnologije na djecu, prepoznate prednosti i rizike, kao i na potrebu za stručnim usavršavanjem u oblasti digitalnih kompetencija. Stavovi su mjereni petostepenom Likertovom skalom, od „u potpunosti se ne slažem“ do „u potpunosti se slažem“, što je omogućilo kvantitativnu analizu subjektivnih procjena.

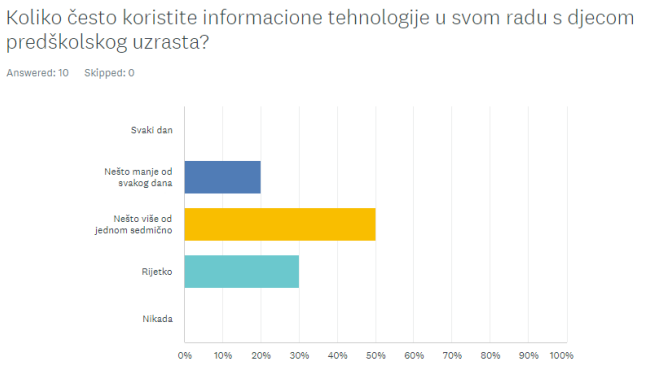
Nakon prikupljanja, podaci su obrađeni primjenom deskriptivne statistike. Urađen je izračun frekvencija i procentualne zastupljenosti odgovora, uz grupisanje rezultata u nekoliko tematskih cjelina: učestalost i vrste primjene IT, percipirani efekti na djecu, prednosti i izazovi, te potrebe za obukom vaspitača. Na osnovu ovih pokazatelja izvršena je evaluacija polaznih pretpostavki o značaju IT u predškolskom vaspitanju i ulozi digitalnih kompetencija vaspitača. Važno je istaći da uzorak od deset ispitanika predstavlja ograničenje koje onemogućava generalizaciju nalaza, te rezultati imaju eksplorativni karakter.

IV. REZULTATI I DISKUSIJA

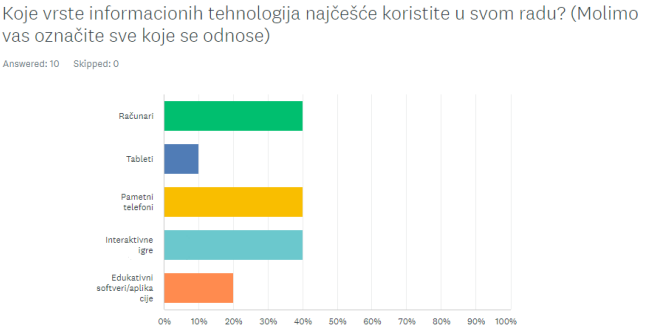
A. Učestalost i vrste primjene IT

Struktura uzorka pokazuje vaspitače različite dužine radnog iskustva (od godinu pa do više od 10 godina). Učestalost korišćenja IT u vaspitno-obrazovnom radu varira: nijedan ispitanik (0%) ne koristi tehnologiju svakodnevno, dvoje (20%) koristi IT gotovo svakodnevno, petoro (50%) nešto više od jednom sedmično, dok troje (30%) navodi da IT koristi rijetko. Ovi nalazi ukazuju da je tehnologija prisutna u većini vaspitnih praksi, ali da još uvijek nije integrisana kao sastavni dio svih aktivnosti.

[1] SurveyMonkey Analyze - Anketa za vaspitače



Slika 2. Učestalost korišćenja informacionih tehnologija u vaspitno-obrazovnom radu



Slika 3. Vrste IT u radu

Kada je riječ o vrstama tehnologija, ispitanici najčešće koriste računare (40%) i pametne telefone (40%), te interaktivne igre (40%). Tableti (10%) i edukativni softveri (20%) značajno su manje zastupljeni. Pod IT alatima u predškolskom kontekstu podrazumijevaju se hardverski uređaji (računari, tableti, pametni telefoni, interaktivne table) i softverska rješenja: edukativne aplikacije (npr. „Endless Alphabet“, „Kahoot“, „Bebilica Životinje“), programi za digitalno crtanje („Tux Paint“) i setovi za robotiku („Bee-Bot“). Očekivani doprinos ovih alata je individualizacija učenja i vizuelizacija apstraktnih pojmova, ali rezultati pokazuju da se u praksi uglavnom koriste opštenamjenski uređaji, dok potencijal namjenskih edukativnih alata nije dovoljno iskorišćen.

B. Percepcije efekata IT na djecu

Rezultati istraživanja pokazuju da većina vaspitača informacione tehnologije doživljava kao sredstvo koje može pozitivno uticati na motivaciju djece za učenje i na razvoj njihove kreativnosti. Šest od deset ispitanika (60%) ocjenjuje uticaj IT na motivaciju kao pozitivan, troje (30%) izražava negativan stav, a jedan (10%) zauzima neutralnu poziciju. Kod doprinosa razvoju kreativnosti, devet od deset ispitanika (90%) smatra da IT u određenoj mjeri podstiče kreativno izražavanje, dok jedan (10%) ne uočava takav efekat.

Sa druge strane, rezultati o uticaju IT na koncentraciju i pažnju djece ukazuju na podijeljene stavove: dvoje ispitanika (20%) smatra da IT uglavnom poboljšava koncentraciju, četvoro (40%) procjenjuje uticaj kao neutralan, dvoje (20%) da uglavnom smanjuje, a dvoje (20%) da znatno smanjuje sposobnost zadržavanja pažnje. Činjenica da 40% ispitanika percipira negativan uticaj sugeriše da efekti tehnologije zavise od načina i konteksta upotrebe – strukturisane aktivnosti uz vođstvo vaspitača nasuprot nestrukturisanom izlaganju digitalnim sadržajima.

TABELA I
Percipirani uticaj IT na različite aspekte razvoja djece predškolskog uzrasta (Likertova skala od 1-5)

Aspekt razvoja	1	2	3	4	5
Motivacija za učenje	-	30%	10%	60%	-
Kreativnost	10%	-	-	90%	-
Koncentracija/pažnja	20%	20%	40%	20%	-
Obuka vaspitača	-	-	20%	80%	-
Razvoj digitalnih vještina	-	-	-	80%	20%

TABELA II
Percepcija vaspitača o prednostima i izazovima upotrebe IT u predškolskom vaspitanju

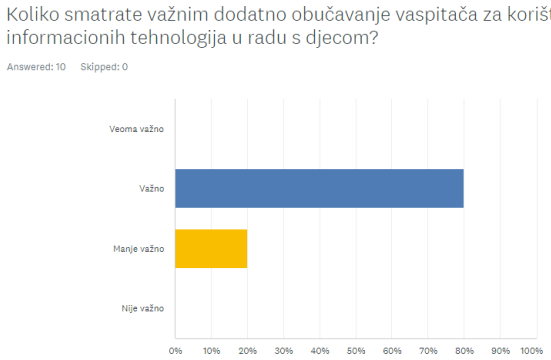
PREDNOSTI	Procenat (%)
Razvoj digitalnih vještina kod djece	80
Povećanje motivacije za učenje	20
Razvoj socijalnih vještina	0
Personalizovano učenje	0
Podrška djeci sa posebnim potrebama	0
IZAZOVI / RIZICI	**Procenat (%)**
Prekomjerna izloženost ekranima	50
Smanjene fizičke aktivnosti	40
Rizik od digitalne zavisnosti	10
Sigurnost i privatnost	0

Kao prednosti IT, ispitanici najčešće ističu razvoj digitalnih vještina (80%) i povećanje motivacije za učenje (20%). Ključni izazovi su prekomjerna izloženost ekranima (50%), smanjenje fizičke aktivnosti (40%) i rizik od digitalne zavisnosti (10%), dok se o digitalnoj bezbjednosti ne govori, što ukazuje na potrebu dodatne edukacije u ovom segmentu.

C. Potrebe za stručnim usavršavanjem i institucionalna podrška

Većina vaspitača koji su učestvovali u istraživanju smatra da je stručna obuka za korišćenje IT u radu sa djecom važna ili veoma važna. Ispitanici prepoznaju da nivo sopstvenih digitalnih kompetencija utiče na kvalitet planiranja, realizacije i evaluacije aktivnosti u kojima se koriste digitalne

tehnologije. Ovakvi nalazi u skladu su sa evropskim okvirima digitalnih kompetencija, koji naglašavaju da su kontinuirano usavršavanje nastavnika i institucionalna podrška ključni uslovi uspješne digitalne transformacije obrazovanja [8].



Slika 4. Stavovi vaspitača o važnosti obuke za korišćenje IT u radu sa djecom

Osam od deset ispitanika (80%) prepoznaje potrebu za stručnom obukom u oblasti digitalne pismenosti i pedagoški promišljene primjene IT u radu sa djecom.

Istovremeno, rezultati ukazuju da je potrebno jačati i institucionalne kapacitete, uključujući IT infrastrukturu, pristup odgovarajućim digitalnim resursima i sistemski pristup razvoju digitalne kulture predškolske ustanove. Bez odgovarajućih uslova rada, motivacije i podrške, individualni napori vaspitača mogu ostati ograničeni. Stoga je neophodno da predškolske ustanove planiraju digitalni razvoj na nivou institucije, u skladu sa savremenim pedagoškim i tehnološkim standardima.

V. Zaključak

Istraživanje potvrđuje da informacione tehnologije zauzimaju sve značajnije mjesto u predškolskom vaspitno-obrazovnom radu, ali da njihova primjena još nije u potpunosti integrisana u svakodnevnu praksu. Vaspitači najčešće koriste računare, pametne telefone i interaktivne igre, tehnologiju vide kao sredstvo za povećanje motivacije i razvoj digitalnih vještina, ali su svjesni rizika prekomjerne upotrebe ekrana.

Dobijeni rezultati sugerišu da je ključ uspješne integracije IT u pronalaženju ravnoteže između digitalnih i tradicionalnih aktivnosti, uz poštovanje razvojnih karakteristika djece. IT može doprinijeti kvalitetu rada pod uslovom da su aktivnosti pedagoški osmišljene, da se tehnologija koristi u kraćim intervalima i da uloga vaspitača ostane centralna. Preporučuje se razvoj sistematskih programa obuke zasnovanih na evropskim okvirima digitalnih kompetencija, unapređenje IT infrastrukture, kao i proširenje istraživanja na veći uzorak uz kombinaciju kvantitativnih i kvalitativnih metoda.

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An Algorithmic Approach to Workload-Aware Sprint Planning Using Integrated PERT and RACI Models

Yevheniia Kataieva, Daniela Paluchova, and Anton Korneta

Accurate sprint planning in agile software development is often hindered by uncertain task duration estimates and uneven workload distribution among team members. This paper proposes a workload-aware sprint planning approach that integrates the Program Evaluation and Review Technique (PERT) with a quantified Responsibility Assignment (RACI) model. Task durations are initially estimated using three-point PERT estimation and are subsequently adjusted based on team member workload and role-specific responsibility weights derived from the RACI matrix. The proposed algorithm dynamically corrects task durations in response to overload situations, enabling more realistic planning under capacity constraints. The approach is evaluated through deployment in a real software project over a single sprint, where the system is actively used by three product owners during sprint planning. The results indicate improved workload balance and more conservative and realistic duration estimates compared to traditional PERT-based planning.

Deep Transfer Learning Framework for Multi-Class Driver Behavioral States Recognition: A Computer Vision Approach

Deanne Cameren P. Evangelista

Driver behavior monitoring is essential for intelligent ransportation systems, as unsafe behaviors such as distraction, drowsiness, and mobile phone use significantly increase accident risk. This work presents a deep transfer learning–based computer vision framework for multi-class driver behavior recognition from in-cabin images, targeting four classes: neutral driving, distraction, microsleep, and cellphone use. A pretrained convolutional model is fine-tuned using an annotated dataset collected under diverse vehicles and lighting conditions, with preprocessing and data augmentation applied to improve robustness. Performance is evaluated using mAP@50, mAP@50–95, precision–recall, F1–confidence analysis, and confusion matrices. The proposed framework achieves high accuracy and strong generalization, with an overall mAP@50 of 0.992 and mAP@50–95 of 0.978, demonstrating minimal class confusion and reliable confidence calibration.

Automatic Classification of "Gross Negligence" in Serbian Court Decisions Using TF-IDF and Windowing

Dušan Kuzmanović, Ana Đilas

This paper presents an interpretable, resource- efficient baseline for detecting a concrete legal standard in Serbian judicial reasoning: whether a court decision affirms gross negligence or explicitly negates it. Using a small, expert-labeled corpus of decisions, we compare three input representations under leave-one-out evaluation: (i) manually extracted "gold" paragraphs, (ii) whole-document reasoning blocks, and (iii) window-based processing with document-level aggregation. Across experiments, the gold-paragraph setting achieves the highest performance, while the full-reasoning baseline outperforms the windowing approach on the current dataset. Windowing remains useful as an evidence-localizing representation that can support auditability and error analysis, even when it does not improve accuracy. The study is positioned as a pilot methodology and an engineering blueprint suitable for data-constrained e-Justice analytics.

Enhancing Physical Layer Security through Cooperation in Wireless Networks

Jovana Božović, Enis Kočan, Member, IEEE

Physical Layer Security (PLS) provides a promising complementary approach to cryptographic methods for protecting wireless communications from eavesdropping. This paper investigates secrecy enhancement through cooperative relaying and jamming in a wireless network with two legitimate users, one eavesdropper, and five potential relay nodes operating in amplify-and-forward mode. Three relay– jammer selection strategies are considered: random relay and jammer selection, best-SNR (signal-to-noise ratio) relay with random jammer selection, and best-SNR relay with a jammer chosen based on the strongest channel toward the eavesdropper. The secrecy performance of these strategies are evaluated in terms of secrecy rate and secrecy outage probability. The results demonstrate that intelligent relay and jammer selection can significantly improve PLS compared to random selection, highlighting the benefits of cooperation in secure wireless systems.

Quantum-Classical Weighted Clique Detection for Microservice Deployment in Cloud Systems

Seda Nur GÜNGÖR, Mehmet KARAKÖSE Senior Member, IEEE

The widespread adoption of microservice architectures in large-scale cloud systems introduces challenges related to the optimal deployment of service components and the optimization of inter-service communication. This study proposes a quantum–classical hybrid approach to address this problem, which can be considered an NP-hard problem at large scale, with the aim of achieving an optimal deployment of microservices that exhibit intensive interactions. In the proposed method, microservice interactions are modeled as a weighted graph and transferred to a quantum environment for the purpose of maximum clique detection. Modeling the problem using a weighted graph, where microservice interaction parameters such as latency, communication frequency, and data volume are evaluated as composite edge weights, enables the deployment problem to be grounded in system-oriented criteria and treated as a multi-dimensional optimization task. In this study, all valid clique structures are correctly identified, thereby enabling optimization strategies to be executed within the quantum computing environment.

Multi Perspective Effect Analysis of Quantum Computing in the Rise of Artificial Intelligence

Seda Nur GÜNGÖR, Mehmet KARAKÖSE Senior Member, IEEE

The rapid evolution of artificial intelligence (AI) and quantum computing (QC) is fostering a research landscape in which these two technologies increasingly shape each other across multiple technical layers. This study provides an overview of ten representative categories, including quantum- enhanced machine learning, quantum optimization for AI models, quantum encoding, hybrid quantum–classical architectures, quantum-inspired models for AI, AI-assisted quantum circuit optimization, AI-driven variational parameter tuning, AI-assisted quantum hardware calibration, and AI-driven quantum architecture search. It approaches QC–AI interactions within a conceptual model framework that organizes these relationships across dimensions of directionality, layer, and modality. This framework aims to provide an integrative analytical basis that supports future methodological and system-level research.

An End-to-End Framework for Surgical Phase Recognition and Large Language Model-Based Decision Support in Medical Videos

Mehmet Mert Menevse and Mehmet Karakose Senior Member, IEEE

Automatic recognition of surgical workflow phases from laparoscopic videos is a key enabler for context-aware intraoperative assistance, surgical training, and safety monitoring. While recent deep learning approaches have achieved promising accuracy on benchmark datasets, most systems remain limited to isolated phase classification without providing actionable guidance or interpretability. In this paper, we propose an end-to-end framework that integrates EfficientNet-B0–based surgical phase recognition with large language model (LLM)–driven surgical next-step guidance. The system operates on individual laparoscopic frames and produces both phase predictions and structured, phase-aware recommendations through configurable behavioral profiles. Experiments conducted on the Cholec80 dataset demonstrate that EfficientNet-B0 achieves strong validation performance, with a validation accuracy of 85.87% and a weighted F1-score of 85.95%. Phase-wise analysis and confusion matrix evaluation reveal predictable ambiguities in early and transitional phases, while Grad-CAM visualizations provide interpretable evidence that the model attends to anatomically and procedurally relevant regions. A lightweight web-based prototype illustrates how visual predictions can be transformed into context-aware textual guidance. By unifying perception, explainability, and language-based reasoning within a single deployable pipeline, this work advances toward practical and interpretable surgical assistance systems for laparoscopic procedures.

How Online-Offline Integration Drives Adoption of Fashion Commerce Among Gen Z

Laurencia Lynn, Michael S. Reyvinda, Maria Angelina, and Yohannes Kurniawan

This study examines how physical experience and the integration of online and offline information shape the adoption of online-to-offline (O2O) fashion commerce among Generation Z consumers in the Jabodetabek region of Indonesia. Data were gathered through purposive sampling from 401 respondents who had recently used online-to-offline platforms. The proposed model was analysed using partial least squares structural equation modelling (PLS-SEM). The results indicate that physical experience enhances perceived benefits while simultaneously increasing perceived risk, as consumers become more aware of potential quality discrepancies during in-store evaluation. Furthermore, the integration of online and offline information provides consistent and accurate information throughout the purchasing process, thereby increasing perceived benefit and perceived usefulness. Perceived risk is found to negatively influence purchase intention, whereas perceived benefit positively affects perceived usefulness. Among all constructs, perceived usefulness exerts the strongest positive effect on purchase intention. In line with these results, Generation Z consumers actively compare prices across channels and choose the option that offers the greatest financial benefit because they are highly value-oriented and price-sensitive.

Data Trustee Framework in Logistics

Michael Koch, Jessica Chwalek, Benjamin Gaunitz, André Ludwig and Bogdan Franczyk

The transport sector includes data exchange across organizational boundaries. However, once uploaded, the data are under the control of existing platforms, which offer only limited usage and access controls for this data. For this purpose, the Transit data trustee platform was developed to enforce fine-grained usage control at the attribute level, supported by a dedicated access rights management service. The centrally stored data are only shared for the purposes of the data owner. Inside the platform, modules such as attribute- level usage control, central logging, geo-fencing, and a modular and multi-layered data trustee architecture ensure the proper use of the data.

Student Group Assignment Problem: Deterministic vs Heuristic Approach

Emin Šiljak

Student Group Assignment Problem represents a specific type of University Course Timetable Problem. The objective of the problem is to assign students to groups under several constraints, including group overlaps, room capacity, and related restrictions. This paper showcases that determinis- tic approach significantly outperforms its heuristic counterpart in terms of runtime. Although the heuristic approach also provides feasible solutions, their quality is highly dependent on the hyperparameters selected. These findings highlight the trade-off between solution efficiency and scalability for real- world application of the proposed solutions.

From Relational to Document-Based: How Database Selection Shapes Software Architecture in Distributed Systems

Amina Merić and Bećir Isaković

This study explores how the choice of database influences performance, modularity, and extensibility in monolithic and microservices software architectures. These software architectures are tested in combination with relational database MySQL and document-based database MongoDB. Apache JMeter is used for automated load testing. Relational databases consistently deliver better performance for structured transactions, while document-based solutions offer greater flexibility and extensibility in distributed systems. In addition, the analysis shows that the choice of database may have more effect on the total performance of a microservices architecture than the inherent overhead of the architecture itself. The findings highlight the critical trade-offs between performance and flexibility, emphasizing the importance of strategic database selection.

The Impact of Popularity Bias and Perceived Fairness on Intention to Use Recommender System in Indonesian E-commerce

Vaniecia C. Dewi and Nilo Legowo

This study examines factors influencing users' Behavioral Intention (BI) to use Artificial Intelligence (AI)- based recommender systems in Indonesian B2C e-commerce by integrating Popularity Bias (PB) and Perceived Fairness (PF) into the Technology Acceptance Model (TAM). The purpose of this study is to investigate how PB shapes PF and how fairness- related perceptions subsequently influence Trust (T), Perceived Usefulness (PU), and users' Behavioral Intention (BI) to use recommender systems. The proposed research model analyzes the relationships among these key behavioral factors, including Cognitive Absorption (CA). A quantitative survey was conducted with 400 active users of major Indonesian e- commerce platforms, and the data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The results show that PB affects PF, which plays a central role in shaping T, PU, and BI. CA enhances PU, while T and PU significantly drive users' BI to use recommender systems. These findings emphasize the importance of fairness-aware recommendation mechanisms and extend TAM in the context of AI-based recommender systems.

Development and application of digital risk database in higher education institutions

Vera Kapetanović, Igor Petrović, Ana Babović Mujović, Maja Krčum, Jelena Nikčević and Tatijana Dlabač

Institutions of higher education are exposed to different types of risks that can be internal, which the institution can directly influence, but also external, which it has no direct influence on. The lack of a systematic and integrated approach to risk management can significantly reduce the effectiveness of the educational process and negatively affect the overall functioning of the institution.

The aim of this paper is to present some identified risks in a higher education institution and to contribute to the development of an innovative approach to risk management through the application of a digitized risk database. The proposed approach is based on the use of a risk matrix and enables structured recording, assessment and monitoring of risks in accordance with the principles of the quality management system. The proposed model is a practical and easy-to-apply solution that, with appropriate adaptation, can be applied in other higher education institutions with the aim of improving the entire system of risk management, and thus the entire system of work and operations of the institution.

Hybrid Artificial Rabbits Optimization and Bat Algorithm for Global Optimization Problems

Mehmet Umut Salur, Gökhan Altun and Ilhan Aydın

Metaheuristic algorithms are widely used to solve complex global optimization problems. However, their performance depends heavily on maintaining an effective balance between exploration and exploitation. This study proposes a novel hybrid metaheuristic algorithm, termed AROBAT, by integrating the Artificial Rabbits Optimization (ARO) algorithm with the Bat Algorithm (BAT). This hybridisation strategy preserves the inherent exploration– exploitation transition mechanism of ARO while enhancing the stochastic search capability by incorporating the random-walk operator derived from BAT. To evaluate the effectiveness of this approach, extensive experiments were conducted using standard CEC benchmark functions, and the results were compared with those of the original ARO and BAT algorithms. The findings demonstrate that AROBAT consistently achieves superior or competitive performance across the majority of benchmark functions, indicating improved convergence speed and robustness. These results confirm that the proposed hybrid framework effectively alleviates premature convergence and stagnation in local optima, highlighting its potential as a reliable optimization tool for complex, high-dimensional problems.

Evaluating LLM-Generated Synthetic Datafor Fine-Tuning RoBERTa-base on SST-2 and MRPC

Ismar Kovacevic and Becir Isakovic

This paper benchmarks LLM-generated synthetic data for fine-tuning RoBERTa-base on two GLUE tasks (SST- 2 se iment classification and MRPC paraphrase detection) under a low-resource setting with 1,000 real training examples per task. Real-only, synthetic-only, and hybrid (1k real + 1k synthetic) regimes are compared using data from eleven contemporary LLMs. Results show that synthetic-only train- ing remains below real-only baselines, but hybrid training consistently improves performance: on SST-2, the best hybrid configuration nearly matches doubling the real data, while on MRPC gains are smaller but positive. LLM-generated text is most effective as a supplement rather than a replacement for human-labeled data.

Teaching Domain-Specific Languages with textX: A Hands-On Approach

Igor Dejanović, Milan Šović and Balša Šarenac

Domain-Specific Languages (DSLs) are a key abstraction mechanism in modern software engineering, yet teaching the underlying principles of language engineering remains a significant pedagogical challenge, often hampered by the steep learning curves of complex tools. This paper addresses the need for a practical, low-overhead framework that facilitates a hands-on learning experience. We present an experience report from a master's level course at the Faculty of Technical Sciences structured around textX, a Python library for building DSLs. The methodology leverages textX's online playground for rapid experimentation and its automated gram- mar visualization features to enhance student comprehension. Our findings indicate a high level of student engagement, demonstrated through a diverse portfolio of successful final projects. We conclude that a tool-centric, hands-on approach using a lightweight framework like textX is a highly effective method for teaching abstract language engineering concepts, successfully bridging the gap between theory and practical application.

A Comparative Study of Rule-Based and Machine Learning-Based Methods for Authentication Anomaly Detection

Lejla Muratović, Bećir Isaković

This research presents a comparative study of rule-based and machine learning-based approaches for detecting anomalous authentication activities. Rule-based detectors are evaluated against an unsupervised anomaly detector trained on normal user behavior, using the LANL dataset expanded with realistic synthetic attacks. Thresholds used by all detectors are calibrated on an evaluation set to meet fixed false-positive budgets. Results are reported using event-level and burst-level metrics. The results show that rule-based approaches perform strongly on high-rate attacks, while machine learning approaches are effective for low-rate, stealthy activity.

Bridging Knowledge Gaps in Internal Auditing and Cybersecurity: Transitioning from CAATTs to AI-Driven Solutions

Katarina Topolko Herceg

Within the rapidly advancing technological environment, the intersection of internal auditing and cybersecurity has become increasingly critical. By applying a literature review, this research critically evaluates established frameworks to identify existing knowledge gaps and establish a basis for further development. The paper focuses on the technological transition from traditional Computer-Assisted Audit Tools and Techniques (CAATTs) to modern Artificial Intelligence (AI)-driven internal auditing solutions. By analyzing recent academic literature (period 2021-2026), the study explores how AI enhances cyber threat detection within accounting information systems and identifies the primary challenges practitioners encounter during implementation. The findings aim to bridge the current gap in cybersecurity-related accounting literature and provide a theoretical foundation for redefining frameworks in the era of AI. Ultimately, this paper results in a synthesized theoretical foundation for future research. The identified future directions serve to guide both academics and practitioners in the evolving domain of automated auditing, providing a framework amidst the intensive development of AI technologies and the rapid digital transformation of the internal auditing.

Learning Graph Shift Operator for Directed Graphs

Đorđe Borozan, Isidora Stanković, Miloš Brajović

Directed graphs arise naturally in many real- world applications, yet most graph neural networks are de- signed for undirected settings. This paper proposes a graph neural network framework that jointly learns a direction- aware graph shift operator and network parameters, enabling expressive feature propagation while preserving edge direc- tionality. By maintaining separate learnable parameters for incoming and outgoing propagation, the framework allows the model to adaptively capture distinct directional roles of nodes and balance information flow across both directions. Experiments on benchmark directed datasets demonstrate con- sistent performance gains over existing baselines, particularly on homophilous directed graphs.

U-Net Based Retinal Blood Vessel Segmentation Systems Analysis

Marius I. G. Gaura, Mihaela L. Gordan

The purpose of this article is to present a comparison between two segmentation systems of the blood vessels in retinal images from CHASEDB1 dataset. The task of the systems is to correctly identify the pixels corresponding to blood vessels from the other structures in color eye fundus images. The first system analyzed in this article consists of a U- Net neural network applied on color images. Using an encoder, a bottleneck, a decoder and skip connections, the network is able generate binary masks corresponding to input images. The second system starts also with a U-Net architecture but also applies afterwards a morphological post-processing block to try to correct the segmentation errors of the U-Net architecture. Numerical results on the test set (accuracy, AUC, sensitivity, specificity and F1 score) show that both systems have good performance, but the morphological block from the second one makes it more efficient in identifying the blood vessels in the retinal images, by an increase of at least 2% in sensitivity. Furthermore, the proposed solution outperforms similar U- Net-based architectures in terms of sensitivity, which translates into a correct identification of the vascular structure, with fewer missed vessels.

Interpretable ML for Diabetes and Prediabetes Screening Using Self-Reported Health Indicators

Sanja Lazic, Stevan Cakic, Member, IEEE, Isidora Rubezic Lukic, Natasa Popovic, and Tomo Popovic, Senior Member, IEEE

Early identification of type 2 diabetes (T2D) and prediabetes enables timely interventions, yet screening often relies on self-reported data rather than laboratory testing. This work compares lightweight Machine Learning (ML) models: Logistic Regression (LR), Random Forest (RF), Extreme Gradient Boosting (XGBoost), Light Gradient Boosting Machine (LightGBM), and Multilayer Perceptron (MLP) trained on 21 self-reported indicators from the 2015 Behavioral Risk Factor Surveillance System (BRFSS) dataset for three- class classification (no diabetes, prediabetes, diabetes). We propose a screening-oriented evaluation where a probability threshold is selected to achieve a target sensitivity (recall) of 0.80. LightGBM achieves balanced accuracy of 0.52 and precision of 0.33 at the target sensitivity, with 38% of cases flagged. Tree SHapley Additive exPlanations (TreeSHAP) highlight general health status, age category, body mass index (BMI), and hypertension as dominant predictors. A FastAPI web application provides individual risk estimates and instance-level explanations. The pipeline demonstrates feasibility of interpretable, calibrated screening from non- laboratory data.

The usage of program generators in the development of JavaFX applications

Ivana S. Vukmirov, Miloš Ž. Milić, Ana D. Trujić, Siniša S. Vlajić

This paper examines the application of different program generators in the development of JavaFX applications with an emphasis on the automation of graphical user interface artifacts. For this purpose, the following generators are used: Telosys, OpenAPI and Luca. The main objective is to indicate parts of the software systems where there is a possibility of using program generators along with benefits provided with an emphasis on their comparison.

Comparison of Event-Driven and Batch Processing Architectures for Fraud Detection and User Profiling in Banking

Elma Midžić and Bećir Isaković

Banking systems nowadays handle millions of transactions every day, where speed matters most when the system must detect fraud. Traditional batch-processing systems introduce delays because data is being processed at scheduled intervals. Event-driven architecture handles each transaction at the moment it appears; therefore, the system can react almost immediately. This paper compares event-driven and batch- processing architectures using simulated banking transactions. The results show that event-driven processing significantly reduces latency and enables earlier fraud detection, while batch processing still works well for non-critical jobs, such as periodic user profiling.

Application of SILAB and Luča Generators in the Software Development Process

Sonja M. Vukojičić, Ana D. Trujić, Miloš Ž. Milić, and Siniša S. Vlajić

This paper presents an approach to automating software system development through the application of documentation and program generators. The fundamentals of model-driven software development are examined, with particular emphasis on the advantages and limitations of automation within this paradigm. Following an analysis of the SILAB and Luča generators, their practical utility is demonstrated in a case study aiming to identify opportunities for improving efficiency, performance, and productivity in the software development process.

Multi-Stage Instance Segmentation for Strawberry Ripeness Assessment Across Physiological Development Stages

Deanne Cameren P. Evangelista, Roselle P. Cimagala, Myriam C. Jumila-Polinar, Elaine M. Cepe, and Carla May C. Ceribo

Accurate assessment of strawberry ripeness is critical for optimizing harvest timing and supporting intelligent agricultural automation. This study proposes a YOLOv12- based instance segmentation and classification framework for fine-grained strawberry ripeness recognition across six physiologically defined stages: Green, White, Early-Turning, Turning, Late-Turning, and Red. A dataset of 592 field images containing 2,599 annotated strawberry instances was used for training and evaluation, with data augmentation applied to enhance appearance diversity. Experimental results demonstrate effective convergence and strong detection and classification performance across ripeness stages. Qualitative evaluations further indicate reliable instance localization and class discrimination under varying field conditions. These results highlight the feasibility of deep learning–based, fine- grained ripeness assessment, while recognizing the need for broader validation to establish robustness across diverse environments and acquisition settings.

Designing for Accessibility: A Systematic Literature Review on User Experience Research for Visually Impaired Users

Khadisha Reswara Hippy, Mohammad Genta Pramesti Linduaji, Fredy Jingga, Member, IEEE

This article presents a systematic literature review (SLR) aimed at enhancing User Interface (UI) and User Experience (UX) accessibility for visually impaired users. With approximately 2.2 billion people globally suffering from vision impairment, there is an urgent need to shift application design towards inclusivity. From an initial pool of 1,898 candidate studies, 33 were selected for in-depth analysis to address two key research questions. The study identifies key factors that significantly improve accessibility and examines the most common barriers persisting in current digital designs. These findings offer insights into the essential components and strategies necessary for creating truly accessible digital environments.

Domain Shift in Skin Lesion Classification: Quantifying the ISIC 2019 Generalization Gap

Raul A. Cardoș, Marius I. G. Gaură, and Mihaela L. Gordan

Deep learning models for skin lesion classification achieve high validation accuracy but fail on unseen clinical data due to domain shift. Using ISIC 2019 and ConvNeXt architecture, we demonstrate balanced accuracy dropping 30+ percentage points from validation to test set. Comparing image- only versus metadata-augmented models, we show clinical metadata provides domain-invariant signals improving test robustness. Our analysis quantifies this generalization gap and demonstrates metadata's regularization effect against visual domain shifts.

Exploring Attention States through Unsupervised EEG Analysis

Sam Tsui, Dejan Babic, and Tomo Popovic, Member, IEEE

Declining attention spans in young adults highlight the need for automated cognitive state monitoring. This study investigates whether unsupervised learning can detect attention states from EEG signals without labeled data. Using a dataset of 34 participants, power spectral density and time-domain features were extracted from 14-channel EEG recordings, then applied three clustering algorithms: K-Means, Gaussian Mixture Models (GMM), and Agglomerative Clustering. K-Means achieved 64.5% accuracy in separating attentive and non-attentive states, outperforming GMM and Agglomerative methods. Results demonstrate that attention- related neural patterns are detectable through unsupervised approaches, offering an alternative to supervised and reinforcement learning methods for real-time cognitive monitoring applications.

Factors Influencing Generation Z's Intention to Use Generative AI: An Acceptance and Threat Avoidance Perspective in Indonesia

Juan Vaughn Verdene Parengkuan and Elfindah Princes

This preliminary research examines the determinants of Generation Z's intention to use GenAI by integrating the Unified Theory of Acceptance and Use of Technology (UTAUT) and Technology Threat Avoidance Theory (TTAT), along with trust and perceived risk constructs. Empirical evidence was obtained through the dissemination of an online survey spread through social media channels, yielding 100 valid responses, and analyzed using Structural Equation Modeling (SEM). The results show that effort expectancy and facilitating conditions significantly increase usage intention, while performance expectancy and perceived avoidability strengthen trust. However, performance expectancy does not directly influence intention. Perceived risk is not a significant predictor of trust, and neither social influence nor trust directly affects intention. In contrast, perceived threat shows an unexpected positive association with trust. These findings highlight the dominant role of usability and supportive resources over social or purely psychological factors in shaping generative AI adoption.

Predicting Teaching Quality Using Student Performance Data and Behavioral Metrics

Vanness Jackson, Edwin Tjandraatmadja, and Charles Bernando

Ensuring teaching quality is a priority in higher education, yet traditional evaluations often rely heavily on subjective surveys. This study aims to predict teaching evaluation outcomes (Low, Medium, High) using student performance and behavioral metrics. The dataset comprises 1,650 student-lecturer interaction records from a publicly available dataset. To determine the most effective modeling approach, this study benchmarks a Generalized Linear Model (GLM) against a Random Forest classifier. The GLM significantly outperformed the ensemble method, achieving an overall accuracy of 97.39% and a perfect recall (100%) for the minority 'High' quality class. Feature importance analysis revealed that traditional academic metrics—specifically Exam Scores and Self-Assessment are the strongest predictors, indicating a linear relationship between student achievement and perceived teaching quality. Conversely, digital interaction logs showed minimal predictive power.

Graph-Based Image Classification Using Superpixels and Non-Parametric Learning

Zeljko Bolević, Isidora Stanković, Miloš Brajović

This paper studies image classification using graph neural networks, where images are represented as graphs obtained from superpixel segmentation. First, images are con- verted into region-adjacency graphs using the Simple Linear Iterative Clustering (SLIC) superpixel method. Then, graph- level classification is performed using Graph Attention Net- works (GAT) and Graph Isomorphism Networks (GIN). In addition to standard supervised training with a parametric classifier, we evaluate an alternative two-stage approach in which a non-negative kernel classifier is applied on graph embeddings. Experimental results show that the nonparametric classifier consistently outperforms the supervised approach for both architectures, with especially significant improvements observed for GAT.

Transfer Learning-Based Computer Vision Modeling Framework for Lumbar Vertebrae Localization in Sagittal Radiographs

Roselle P. Cimagala

Accurate localization of lumbar vertebrae in sagittal radiographs is a fundamental prerequisite for quantitative spine analysis, yet manual annotation is labor- intensive and prone to inter-observer variability. This study presents a transfer learning–based computer vision framework for automated lumbar vertebrae localization in sagittal lumbar spine X-ray images. The dataset comprises radiographs from a proprietary cohort of Honduran patients with spondylolisthesis and the publicly available BUU-LSPINE dataset, restricted to sagittal views. Vertebrae from L3 to S1 were annotated using bounding boxes to enable supervised vertebral localization. The proposed model leverages pretrained feature representations and multi-scale detection to robustly capture vertebral structures under varying anatomical presentations and imaging conditions. Experimental results demonstrate stable convergence and strong localization performance across the evaluated datasets, with qualitative analyses confirming anatomically consistent vertebral detection. As validation was limited to the available data sources and acquisition settings, further evaluation on larger and more diverse cohorts is necessary to establish broader robustness and generalizability. The findings support the feasibility of automated lumbar vertebral localization and provide a foundation for subsequent quantitative spine analysis.

Transfer Learning-Based Computer Vision Framework for Automated Detection and Localization of Lung Ultrasound Vertical Artifacts

Myriam C. Jumila-Polinar

Lung ultrasound (LUS) is widely used for pulmonary assessment due to its portability, safety, and real- time imaging capability, with vertical artifacts (B-lines) serving as key indicators of lung pathology. However, manual identification of these artifacts is operator-dependent and subject to inter-observer variability. This study presents a transfer learning–based computer vision framework for automated detection and localization of LUS vertical artifacts using clinically acquired ultrasound images. The dataset consists of polygon-annotated LUS images collected from patients with pulmonary diseases at national referral hospitals, enabling detailed spatial modeling of artifact morphology. The proposed approach leverages multi-scale feature extraction to capture the elongated and directionally consistent characteristics of vertical artifacts. Experimental results demonstrate stable convergence and strong detection performance within the evaluated dataset, with qualitative analyses confirming accurate localization on unseen samples. These findings illustrate the feasibility of applying deep learning–based methods to LUS artifact analysis and motivate further validation across more diverse clinical settings.

A Curriculum-Grounded AI Tutoring System

Sara Đurović, Sara Kovačević, Marko Lasica, Boban Uskoković, Adna Softić, Amra Džuho, Almir Badnjević

This paper presents TutorMe, an AI-assisted e- learning chatbot platform designed to support students with lesson explanations, question answering, quiz generation, and learning-material navigation using curriculum-aligned, digitized resources. TutorMe is implemented as a modular web application integrated with a domain-restricted knowledge base built from structured PDF learning materials. The contribution is engineering-focused: we describe a reproducible design for a knowledge-base-grounded tutoring assistant, document key configuration choices (prompting strategy, retrieval behavior, and platform settings), and report a pilot offline evaluation using a rubric for manual assessment of correctness and groundedness. In an internal test set of 120 questions spanning biology, chemistry, physics, and mathematics at three difficulty levels, manual review showed that 80.0% of answers were fully correct. Biology exhibited the lowest accuracy (60%) due to terminology imprecisions, while mathematics achieved 93.3%. We discuss limitations including hallucination risk, curriculum drift, privacy, and the need for teacher oversight, and outline steps toward deployment-grade validation.

Optimizing Microservices Performance with AI-Driven Load Balancing

Ahmed Alic, and Becir Isakovic

Microservices systems often face performance issues when workloads fluctuate, and services degrade over time. Traditional load balancing methods such as Round Robin or Latency-Aware routing do not adapt to changing conditions, which can lead to higher latency and increased error rates. This paper evaluates adaptive decision-making algorithms for request routing, including Deep Q-Network (DQN), Upper Confidence Bound (UCB), Thompson Sampling, and traditional heuristics. Experiments were executed on a production-scale cloud environment (Runpod, 16 vCPUs, 128 GB RAM) for 4 hours per algorithm with 50 concurrent users, generating more than 600,000 requests per experiment. Results show that contextual bandit algorithms significantly outperform deep reinforcement learning. UCB achieved a 0.097% error rate and a median latency of 220 ms, compared to DQN which produced an 11.32% error rate and instability during training. Latency-Aware routing performed well but could not match the adaptability of contextual bandits. These findings demonstrate that simpler learning algorithms such as UCB and Thompson Sampling provide faster adaptation, lower error rates, and better stability than deep RL approaches in microservices routing tasks.

Design and Implementation of a RAG Chatbot System for Scientific Research Institutes

Igor Radulović, Jovana Mitrić, Katarina Kovijanić, Mija Ljuka, Nejra Merdović,
Madžida Hundur Hiyari, Almir Badnjević, Member, IEEE

This paper presents the design and implementation of a prototype chatbot system based on the Retrieval-Augmented Generation (RAG) architecture, applied in a scientific research institute to improve knowledge access. The system combines semantic search over a vector knowledge base with response generation using large language models, enabling contextually relevant institutional information. A case study was conducted to evaluate the prototype in a real-world environment. Results indicate improved factual grounding compared to an LLM-only baseline within the evaluated dataset, although the evaluation was limited to a small set of queries and a single institutional document collection.

An Intelligent Troubleshooting Support System for Incident Resolution in Telecommunication Networks

Anastasiia Dmytrus, Michal Greguš, Jr., Mykola Brych, and Marian Seliuchenko

Modern telecommunication networks are increasingly complex, distributed, and knowledge-intensive, making manual problem resolution time-consuming and inefficient. Engineers often rely on fragmented documentation and heterogeneous information sources, leading to prolonged resolution times and limited reuse of operational knowledge. This paper presents a demonstrative study of an Intelligent Troubleshooting Support System (ITSS) designed to improve problem-solving efficiency in distributed telecommunication environments. The system integrates a structured knowledge base with Retrieval-Augmented Generation architecture and Large Language Models to enable semantic search, guided root cause analysis, and automated documentation. A proof-of- concept implementation was developed and evaluated in a controlled simulator-based environment using predefined network fault scenarios. Experimental results demonstrate that the ITSS significantly reduces time spent on knowledge- intensive troubleshooting stages. The findings indicate that ITSS substantially enhances operational efficiency while preserving human control over technical decision-making.

OctaKnee: A Smart Knee Health Monitoring System

Prajwal Gupta, Kushi Prahalad Patil, Pranathi Shivakumar, Prateek G. Aekbote, and
Dr. Sudhamani M. J.

Continuous knee-health assessment traditionally relies on episodic clinical visits and subjective reporting, of- fering limited visibility into day-to-day gait variability. This work presents OctaKnee, a low-cost IoT-ML system for real-time gait monitoring using a 6-axis inertial sensor and cloud-based signal processing. Time and frequency domain features such as RMS impact load and dominant cadence frequency are extracted to characterize gait biomechanics. Six machine-learning models were evaluated to identify an efficient classifier for lightweight deployments. While k-Nearest Neighbors achieved the highest accuracy (83.8%), it incurred high inference latency (33.38 s/sample). Logistic Regression provided the best accuracy-efficiency balance, delivering 80.6% accuracy with only 2.43 s/sample (13 times faster than k-NN and 31 times faster than Random Forest). This model forms OctaKnee's functional gait-state classification engine, classify- ing gait into Healthy, Recovery, or Impaired states. To move be- yond snapshot analysis, OctaKnee incorporates a Longitudinal Insight Generator that detects deviations from a rolling five- session baseline, enabling automated trend assessment. These insights are translated into patient-friendly explanations via an LLM (Llama-3-70B), providing interpretable, context-aware feedback. The results demonstrate that OctaKnee achieves accurate, ultra-low-latency functional state classification and trend analysis, supporting continuous monitoring in pilot-scale deployments for remote rehabilitation.

Online Consensus Control of Discrete-Time Leader-Follower Multi-Agent Systems with Unknown Disturbances

Luka Martinović, Žarko Zečević, Božo Krstajić

Online control methods have recently emerged as a powerful framework for regulation and tracking under unknown, potentially adversarial disturbances, but have been developed primarily for single agent systems. This paper ex- tends these methods to the leader-following consensus problem of discrete-time linear multi-agent systems. Since the leader state is not globally available, a distributed observer is employed to estimate it using local infor tion exchange. Based on this estimate and local state measurements, three novel online consensus protocols are proposed that augment a stabiliz- ing feedback term with an online disturbance compensation component, updated via online gradient descent. Numerical simulations demonstrate effective disturbance rejection and successful leader-following consensus under both constant and time-varying disturbance scenarios.

Computationally Efficient Laplacian CL-colME

Nikola Stankovic, Student Member, IEEE

Decentralized collaborative mean estimation (colME) is a fundamental task in heterogeneous networks. Its graph-based variants B-colME and C-colME achieve high scalability of the problem. This paper evaluates the consensus- based C-colME framework, which relies on doubly stochastic averaging matrices to ensure convergence to the oracle solution. We propose CL-colME, a novel variant utilizing Laplacian- based consensus to avoid the computationally expensive nor- malization processes. Simulation results show that the proposed CL-colME maintains the convergence behavior and accuracy of C-colME while improving computational efficiency.

AI-Based Pollen Detection for Montenegrin Honey Authenticity Verification

Andrea Milačić, Elvis Taruh, Nadja Raičević, Stevan Čakić, Member, IEEE, Sanja Savković, Aleksandra Martinović, and Tomo Popović, Senior Member, IEEE

Melissopalynology, the microscopic analysis of pollen in honey, remains the reference method for determining botanical origin, but it is highly time-consuming and strongly dependent on expert knowledge. The PollenTrace project addresses the need for faster, scalable analytical solutions by developing a large-scale pollen microscopy dataset and an AI- assisted detection pipeline. The project encompasses 1,100 biological samples (600 honey, 500 plant-source) collected over five years across Montenegro, from which a target dataset of over 33,000 high-resolution microscopy images is being constructed. Using standardized imaging protocols (Olympus BX43, ×400 magnification) and the Roboflow annotation platform, over 150 images have been annotated to date, with 600 targeted by project completion. For proof-of-concept validation, the initial subset of annotated images (expanded three times via augmentation) was used to train a YOLOv11 detection model, achieving 84% precision, 88% recall, 97% mAP@50, and 84% mAP@50-95 for chestnut pollen detection. These preliminary results demonstrate pipeline feasibility and establish a foundation for comprehensive model development as annotation coverage expands.

From Aerial Imagery to Label-Conditioned Disaster Reports

Zeynep Karaca, Ilhan Aydın

This study proposes a hybrid approach for disaster damage detection and automated explanatory reporting using the LADI-v2 dataset, which comprises aerial imagery. The system is structured upon a two-stage architecture: in the first stage, a ResNet-18 model trained to identify 12 distinct damage categories exhibited high classification performance with an F1 score of 81.88%. In the second stage, Qwen2-VL and BLIP-2 Vision-Language Models (VLMs) were optimized through LoRA-based fine-tuning to translate detected findings into natural language. Performance analyses revealed that the BLIP-2 model outperformed in fidelity to reference texts and key concept extraction, achieving scores of 53.29 in sacreBLEU and 71.03 in ROUGE-1. Conversely, the Qwen2-VL model excelled in semantic flexibility and grammatical richness with a METEOR score of 0.81. Findings indicate that BLIP-2 excels in high-precision reporting, whereas Qwen2-VL provides superior contextual depth. This framework demonstrates significant potential as a rapid, interpretable, and collaborative decision-support tool for disaster management within experimental settings.

Hybrid Semantic and Graph-Based Analysis for News Consistency Detection

Zeynep Karaca, Ilhan Aydın, Duhan Harbi

The rapid propagation of online news, while facilitating access to information, has given rise to problems of misinformation and content inconsistency across different sources. This study proposes an AI-based system that automatically evaluates the contextual consistency and reliability of different online news articles reporting on the same event. The system collects news via web scraping, groups them by event, and applies preprocessing and extractive summarization. The summaries are encoded with SBERT, modeled as weighted graphs, and analyzed using PageRank and Z-score to compute a hybrid ConsistencyScore. Furthermore, the proposed hybrid method is applied to all core models used in the study, and the baseline and hybrid versions of each model are compared. The hybrid usage of the model yielded the highest accuracy, 94.55%. This study aims to systematically demonstrate the impact of widely used embedding- and graph- based models by integrating them into an explainable, weighted system architecture specifically tailored to the problem of news consistency.

A Transformer-Based Sentiment and Topic Analysis of Public Perception on Pertamina Gas Station Services

Matthew Wirasana Sulistyono and Tuga Mauritsius

Public perception of gas station service quality can be effectively analyzed through user-generated content on social media platforms such as Twitter/X. This study investigates transformer-based sentiment analysis to evaluate public sentiment toward gas station services using Indonesian Twitter data, which is characterized by informal language and class imbalance. IndoBERT and IndoBERTweet are fine-tuned and compared with random oversampling, class weighting, and back translation applied to address class imbalance. The results show that both models achieve comparable performance, while IndoBERTweet demonstrates more stable results and improved macro-averaged F1-scores, particularly when combined with back translation. BERTopic is further applied to sentiment predictions to identify dominant service-related themes across sentiment categories. Overall, the proposed framework effectively integrates sentiment classification, imbalance handling, and topic modeling to analyze public perceptions of gas station services from social media data.

The Role of Artificial Intelligence in the Process of Creating Teaching Materials

Jasmina Hasanović and Fatima Masić

Artificial Intelligence (AI) is becoming an important part of modern educational reforms, introducing innovative approaches and learning methods [2]. This study explores the application of artificial intelligence in the education system, examining whether a tool such as ChatGPT can generate pedagogically relevant and curriculum-aligned teaching materials. The research methodology is based on the analysis of the role of AI in education, focusing on the evaluation of the quality, accuracy, and pedagogical value of the content generated by ChatGPT-5. The study combines international research on the use of generative AI in schools with an analysis of materials created for teaching biology and mathematics in the sixth grade of primary school. The analysis included simple, detailed, and curriculum-aligned prompts to examine how different prompt types affect cognitive complexity, language clarity, and alignment with learning outcomes. The results show that all generated materials were factually accurate but differed in educational value. Tasks created using detailed and curriculum-aligned prompts demonstrated higher pedagogical relevance and contributed to deeper understanding and the development of critical thinking skills among students. The research confirms that thoughtful and responsible use of artificial intelligence can provide significant support to teachers in creating quality and educationally meaningful teaching materials.

Assessing Hallucination Risk in Accessible Image Captions

Rostyslav Zatserkovnyi, Zoriana Novosad, Roksoliana Zatserkovna

The recent advancement of large vision-language models (VLMs) has opened new possibilities for automatic image captioning, offering significant potential for improving web accessibility. However, these models are prone to hallucinations – generating descriptions of objects or details that are not actually present in the source images. Hallucinations represent a critical risk to visually impaired users who rely on these captions as their primary means of understanding visual content, which can lead to confusion and erode trust in assistive technology.

In this article, we present a comprehensive evaluation of four vision-language models on the POPE benchmark for hallucination detection, comparing frontier API-based models (Claude Sonnet 4.5 and Claude Haiku 4.5) against open-source models suitable for local deployment (Moondream 2B and Gemma 3 4B). Our evaluation spans 12,000 samples across all four models. Claude Sonnet 4.5 achieves state-of-the-art accuracy of 89.0% with an F1 score of 0.881, while Moondream 2B offers the lowest risk of hallucination at 1.7%. We find that local models exhibit a significant precision-recall tradeoff, achieving precision above 96% but recall of only approximately 50%. Analysis of error patterns reveals that “person” is the most commonly missed object category with 536 instances, and “cat” is the most frequently hallucinated object. We discuss the implications of these findings for accessibility applications.

A New BLIP based Natural Language Analysis Method for Crowd Images

Turan Goktug Altundogan, Selen Gürbüz, and Mehmet Karaköse, Member, IEEE

Automatic reporting of crowd density and spatial distribution is a significant problem for smart city and campus applications. This study presents a BLIP-based visual language model approach that can generate density reports in natural language from crowd images. In the proposed method, five synthetic descriptions encompassing the number of people, density level, and spatial distribution information for each image in the UCF-QNRF dataset are generated using a rule-based template structure. This structure provides linguistic diversity by using different sentence patterns that express the same quantitative information. The automatic reporting performance of the BLIP model trained with the generated synthetic descriptions was analyzed using ROUGE and CIDEr metrics, which are evaluation criteria suitable for text generation tasks. Experimental results show that the proposed approach can produce consistent and meaningful descriptions in crowd density reporting; achieving performance values of 47.79 for ROUGE-L and 44.1 for CIDEr.

Towards Role-Based Multi-Agent LLM Systems for Software Requirements Analysis

Novica M. Trifković, Ilija D. Antović

This paper presents a structured overview of recent research on the application of Large Language Models (LLMs) and multi-agent systems in software requirements analysis and introduces a conceptual, role-based multi-agent architecture for addressing identified limitations. The proposed approach emphasizes hierarchical supervision, collaboration between Large and Small Language Models, and structured cross-checking based on report comparison and uncertainty- aware arbitration to improve robustness and reliability. The contribution of this work is theoretical and exploratory, providing a foundation for future research on multi-agent LLM systems aimed at improving the software requirements analysis process.

Explaining User Intentions to Use AI-Generated Image Tools Through Trust, Risk, and Service Quality

Calvin Andrew Widjaja and Tanty Oktavia

This study examined the factors influencing users' behavioral intention to use AI-generated image (AIGI) tools in Indonesia by extending the Unified Theory of Acceptance and Use of Technology (UTAUT) through service quality, trust in AI, and perceived risk. We conducted a quantitative analysis of six variables based on survey data from 100 Indonesian AIGI users: service quality, trust in AI, perceived risk, performance expectancy, effort expectancy, and behavioral intention. Moreover, it has been examined that performance expectancy and effort expectancy significantly affect behavioral intention, signaling that perceived ease of use and usefulness continue to be key determinants of behavioral intention. Level of service quality has a major influence on effort expectancy; however, it does not directly impact performance expectancy. AI trust increases performance expectancy and decreases perceived risk whereas perceived risk reduces behavioral intention, while it does not impact performance expectancy. These results contribute to demonstrating how usability, trust, and risk mitigation can positively reinforce AIGI adoption.

Determinants of Merchant Satisfaction and Continuance Intention toward an InterActive QRIS Application: A Multi-Group Analysis of Traditional Markets and Shopping Malls

Joy S. Kotalewala, and Viany U. Tjhin

The widespread adoption of QRIS has facilitated the adoption of digital payment systems among merchants in Indonesia; however, supporting systems such as InterActive QRIS still face challenges related to service quality, transaction costs, and system performance. This study investigates the effects of system quality, service quality, perceived cost, and trust on merchant satisfaction and continuance intention toward the InterActive QRIS system, with satisfaction as a mediating variable. A quantitative approach was employed using survey data collected from 100 active InterActive QRIS entrepreneurs in the Greater Jakarta region. These data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM), supplemented by multiple group analyses comparing merchants operating in traditional markets and shopping malls. The results show that service quality and perceived costs have a significant effect on merchant satisfaction, while system quality and trust do not show a direct effect. Customer satisfaction significantly influences continuance intention and mediates the effects of service quality and perceived costs. An exploratory multi-group comparison was also performed to observe differences between traditional market and shopping mall merchants. The results indicate that service quality and perceived cost are key drivers of merchant satisfaction, which in turn strongly influences continuance intention. The findings highlight contextual variations in satisfaction drivers across retail environments and provide practical insights for digital payment service providers to improve merchant retention strategies.

A Novel 3D Line-of-Sight Guidance Law for Path Following of AUV Subject to Ocean Currents

Lazar Ašanin, Luka Martinović, Member, IEEE, Žarko Zečević, Member, IEEE

This paper presents an improved three- dimensional line-of-sight (LOS) guidance law for path following of underactuated autonomous underwater vehicles. The proposed approach employs a Luenberger observer to estimate body-frame velocities from position measurements, enabling direct computation of the crab angles. A corrected desired pitch angle formulation ensures convergence of the vertical-track error to zero without requiring zero horizontal crab angle or constant depth assumptions. Simulation results demonstrate improved performance compared to existing adaptive LOS methods.

Modeling User Intention in Mandatory Digital Systems: The Roles of Privacy, Security, and Trust

Jenifir March and Tanty Oktavia

The deployment of mandatory digital government systems has reshaped user interaction with public service technologies, particularly in environments involving continuous usage and sensitive personal data. This study examines user intention in a mandatory digital taxation system, namely the Core Tax Administration System (Coretax), by extending the Technology Acceptance Model with data privacy, digital security, trust, and digital literacy.

Data were collected from 404 individual taxpayers in Jakarta and analyzed using partial least squares structural equation modeling. The results show that data privacy and trust significantly strengthen digital security perceptions. Digital security has a significant positive effect on perceived usefulness but demonstrates a significant negative effect on perceived ease of use and intention to use. Consistent with technology acceptance theory, perceived usefulness remains a key determinant of user intention, while perceived ease of use shows a negative relationship with intention to use in the mandatory system context. Digital literacy also exhibits a significant negative relationship with intention to use, indicating more critical evaluations among digitally capable users in mandatory digital environments.

The findings highlight the importance of balancing privacy protection, security assurance, and usability considerations in the design of mandatory digital government platforms and contribute to understanding technology acceptance in compulsory environments.

Detecting DDPM-Manipulated Medical Images Using Contrastive Learning-based Pre-training

Turan Goktug Altundogan, Mehmet Karakose, Member, IEEE

Deep learning models can detect AI-generated images with high accuracy; however, classifying locally altered fake images is more difficult due to the low manipulation rate and the preservation of original patterns. This study proposes a novel CNN architecture for detecting images manipulated with tumor in-painting based on DDPM, which are difficult to distinguish by both the human eye and neural networks. The proposed architecture was trained with a two-stage training strategy that enhances performance, and a contrastive learning approach was used in the pre-training process. The default and two-stage training performances of the presented model were compared with pre-trained neural networks such as ResNet and MobileNet under the same conditions. In addition, comprehensive performance comparisons were carried out with existing deepfake production and manipulation detection methods in the literature. As a result of the evaluations, the proposed model demonstrated competitive performance, achieving an F1 score exceeding 99% under the evaluated DDPM-based manipulation setting.

Evaluation of the Models for Abstract Generation

Dragica S. Ljubisavljević, Milica J. Bačić, Dušan S. Savić, and Siniša S. Vlajić

This paper investigates the application of prompt engineering for scientific abstract generation using large language models. The study analyzes how different prompt formulations, ranging from general zero-shot prompts to domain-specific and structured instructions, influence the quality of generated abstracts. Two large language models are evaluated by comparing their generated outputs to the original human-written abstracts using standard reference-based metrics, including ROUGE-1, ROUGE-2, ROUGE-L, and BLEU. The experimental analysis demonstrates that increasingly specific and structured prompts lead to improved content coverage, coherence, and alignment with the reference abstracts, without any model fine-tuning. Furthermore, the results indicate consistent performance differences between the evaluated models, highlighting the combined impact of prompt design and model choice. These findings emphasize the effectiveness of structured prompt engineering as a practical approach for scientific abstract generation in zero-shot settings.

A Rule-Based Decision-Support Prototype for Digital Maturity Assessment

Dijar Mujalović, Nurudin Tivari, Lejla Gurbeta Pokvić, Sarah Spahić, Lemana Spahić, Almir Badnjević

Despite widespread discussion of digital transformation, many organizations struggle to assess their digital capability and define improvement priorities. We developed a transparent self-assessment tool, implemented as a Streamlit web application, based on 25 items grouped into five dimensions. Dimension averages are combined into a weighted overall score (1–5 scale) using explicit and visible scoring rules. The tool was evaluated through a single organizational case study (XL Labs) and a pilot expert review (N = 3), providing preliminary, non-generalizable evidence. In the case study, the organization achieved a score of 3.41/5.00, corresponding to the Intermediate maturity category, which remained stable under one-at-a-time sensitivity analysis (±0.20 per dimension).

Universal Structural-Semantic Model of Design Patterns

Sinisa Vlajic, Ana Trujic, Milos Milic, Dusan Savic, Ana Poledica

This paper introduces the Universal Structural– Semantic Model of Design Patterns (USSMDP), a minimal and formal framework that explicitly separates a pattern's structural skeleton from its semantic and behavioral specification. USSMDP represents structure using Basic Design Pattern Structure of the Solution (BDPSS) and captures semantic intent, responsibilities, and operational relations through Basic Design Pattern Semantic Module (BDPSM). This separation enables unambiguous specification of pattern participants and their roles while remaining independent of implementation details and modeling notation. The approach is demonstrated through full structural–semantic formalizations of three representative GoF patterns - Abstract Factory, Composite, and Observer-covering creation, composition, and behavioral dependency management, respectively. The results show that USSMDP provides concise, machine-readable yet human-interpretable pattern specifications, suitable for systematic analysis, education, and further automation.

AI-Driven Dynamic Microsegmentation for East-West Traffic in Cloud and Data Center Networks

Spas Georgiev, Monika Velkova and Kamelia Nikolova

Eastwest traffic in cloud and data center networkshas grown significantly due to microservices, containerization, and elastic workload scaling. While microsegmentation is a core component of Zero Trust architectures, existing approaches rely on static, manually defined policies that struggle to adapt to dynamic environments. This paper proposes an AI-driven dynamic microsegmentation framework that leverages machine learning to model workload communication behavior and automatically adapt segmentation policies based on observed eastwest traffic patterns. Network telemetry and workload metadata are analyzed to infer normal service interactions and identify anomalous behavior indicative of potential lateral movement. The inferred behavior is translated into fine-grained microsegmentation policies enforced through a software-defined policy engine with safeguards to prevent application disruption..

Heuristics for Mapping Structures from the Data Dictionary of Structural System Analysis to Graphical User Interface Data Controls

Kristina Jovanović, Tatjana Stojanović, Saša D. Lazarević, Ilija Antović and Dragica Ljubisavljević

This paper presents an initial step toward executable software specifications by defining a metamodel of the Data Dictionary of Structural System Analysis (SSA). Together with existing graphical user interface (GUI) data controls, the metamodel provides a formal basis for model- based GUI generation. Based on this foundation, we propose a set of heuristics for transforming Data Dictionary structures into corresponding GUI data controls.

The approach is demonstrated on an inventory document that is first analyzed and transformed into a Data Dictionary by a domain expert, after which the heuristics are applied to derive a GUI layout. The example indicates how executable specifications can support early requirement validation by enabling stakeholders to visualize expected data entry, constraints, and structure before implementation.

Multi-Criteria Evaluation of Mobile Navigation Applications for Non-SOLAS Vessels in Confined Coastal Waters

Ivan Mraković, Igor Stanovčić, Igor Petrović, Rino Bošnjak, Božo Krstajić IEEE Member

The increasing reliance on mobile navigation applications by non-SOLAS vessels introduces safety challenges in confined coastal waters, where traditional Aids to Navigation (AtoN) are increasingly complemented by virtual solutions (V-AtoN). This paper presents a structured multi-criteria evaluation of four commercial navigation applications and one locally developed solution, BokaSafe, using the Boka Bay as a case study. An expert-based SMARTER method combined with Rank Order Centroid (ROC) weighting was applied to ten evaluation criteria derived from established literature. Results indicate that while commercial applications perform well in general usability, they often lack critical V-AtoN integration and safety alerting capabilities. Applications incorporating context-aware and V-AtoN-related functionalities demonstrate measurable advantages in safety-critical categories; quantitatively, the locally developed BokaSafe achieved the highest aggregated score of 0.979, compared to 0.74 for the best-performing commercial application (ORCA).

Correction of the Eyring Reverberation Time Formula Using an Artificial Neural Network: A One-Solution Approach

Zoran N. Milivojević, Violeta Stojanović, Bojan Prlinčević and Dijana Kostić

The first part of this paper presents the classical Eyring formula used for estimating the reverberation time T60 of a room. An experimental study to assess T60 using the classical Eyring formula was performed. The Schroeder algorithm to estimate T60 from the Room Impulse Response (RIR) was also applied. The second part of the paper introduces a corrected Eyring formula obtained by multiplying the original Eyring formula by a correction coefficient kEyr, parameterized by the coefficients β, γ and δ. Using an Artificial Neural Network (ANN), the parameters β, γ, and δ were computed. An ANN training procedure on the dataset $\mathcal{DD}_{\text{train}}$, consisting of N = 25401 RIRs, was performed. The corrected Eyring formula to test on M = 10887 RIRs was then applied. The mean absolute error e and the mean squared error MSEEyr as evaluation metrics for reverberation time estimation were used. The experimental results with graphs and a table are presented. A detailed comparative analysis shows that the corrected Eyring formula improves the precision of reverberation time estimation by 51.38% compared to the classical Eyring formula was performed.

Cluster-Based Hybrid MAC Protocol for FANET with Massive MIMO in 5G and Beyond

Ece Tan, Sumaiya Sultana, A. F. M. Shahen Shah, Senior Member, IEEE,

Muhammet Ali Karabulut, Senior Member, IEEE, and Haci Ilhan, Senior Member, IEEE

Flying ad hoc networks (FANETs) composed of unmanned aerial vehicles (UAVs) provide flexible and infrastructure-independent connectivity in 5G and beyond. Recently, cluster-based FANET architectures have been proposed in disaster and emergency scenarios to support search and rescue operations. However, their performance is severely limited by high node density and contention-based medium access. In this paper, a cluster-based hybrid medium access control (MAC) protocol is proposed in which the cluster head is equipped with massive multiple-input multiple-output (mMIMO) capability. An algorithm is presented to explain the mMIMO-enabled hybrid MAC protocol for cluster-based FANET. The proposed MAC divides channel access into a contention-based control phase and a scheduled data phase, where the cluster head exploits mMIMO spatial multiplexing to serve multiple UAVs simultaneously. Analytical study is carried out. Simulation results are provided, which show that the proposed protocol performs better than the traditional single- antenna cluster-based system.

Scalable OFDMA-Based Multi-User Channel Access for FANETs in Disaster Scenarios

Sumaiya Sultana, A. F. M. Shahen Shah, Senior Member, IEEE,

Muhammet Ali Karabulut, Senior Member, IEEE, and Haci Ilhan, Senior Member, IEEE

Flying Ad Hoc Networks (FANETs), with its high mobility and dynamic topology, enables wireless communication between unmanned aerial vehicles (UAVs); this makes efficient channel access a major challenge. However, traditional single- user and conventional contention-based medium access control (MAC) protocol suffer from extreme control overhead and un- successful backoff adaptation, which leads to high access delay and spoiled network performance under dense UAV deploy- ments. Regarding these issues, this paper proposes an orthog- onal frequency division multiple access (OFDMA)-based MAC protocol that jointly integrates multi-user request-to-send/clear- to-send (MU-RTS/CTS) signaling and an backoff mechanism with joint channel sensing. By authorizing aligned transmission on multiple frequency resource units and restricting excess contention and backoff expansion, the proposed model notably reduces control overhead while improving channel utilization and synchronization among UAVs. A transmission Opportunity- based analytical model is evolved to assess system throughput and delay under increasing network density and large-scale simulations are administered for authentication of performance. Simulation results show that the crucial upgrades throughput and reduces access delay compared to traditional FANET channel access, especially in dense UAV scenarios.

A Trustworthy RAG Approach for Healthcare and Health Tourism

Osman Furkan Kucuk, Eray Hanoglu, Onur Tokel, and Mehmet Karakose, Senior Member, IEEE

While health tourism requires accurate and verifiable information for international patients, generative models often suffer from hallucinations and weak source grounding. To address these limitations, we develop a specialized Retrieval-Augmented Generation (RAG) chatbot for healthcare support and health tourism assistance. The system is built on a curated knowledge base of 268,119 validated question–answer pairs spanning 12 specialized domains, and employs hybrid dense–sparse retrieval with BGE-M3 on Qdrant, orchestrated by LangGraph and powered by Qwen3-14B for response generation. In a preliminary evaluation with 80 test queries, the system achieved 93.5% overall intent accuracy, with an average response time of 65.8 s and 43.2 s time-to-first-token (TTFT), indicating reliable intent routing and responsive streaming behavior across heterogeneous user scenarios.

Appraisal and Emotional Factors in Social Media Engagement with AI-Generated Content in Java Island

Divya Asri Febrianty, Gusti Putri Khadila and Anderes Gui

This Study aims to investigate the factors that influence users' willingness to engage and interact with AI generated content (AIGC) on social media by adopting and extending Artificial Intelligence Device Use Acceptance (AIDUA) framework. As exposure to AIGC on social media platforms increases, it is important to understand how users conduct cognitive and emotional evaluations of such content. This study posits Social Influence (SOI), Hedonic Motivation (HM), Anthropomorphism (ANT), and Perceived Risk (PER) as primary appraisal stage, factors that shape Performance Expectancy (PE) and Effort Expectancy (EE) in the secondary appraisal stage, which in turn influence emotion (EM) and ultimately lead to willingness to use AIGC (WUA) as an outcome. Data were collected through a questionnaire survey of social media users in Java, Indonesia, who were exposed to AI generated content (AIGC), and the data will be analyzed using PLS-SEM to examine its role in shaping users' cognitive evaluations. Performance expectancy has a significant effect on Emotion, and Emotion is a key factor in encouraging users' willingness to use and interact with AIGC on social media. These findings confirm that the acceptance of AIGC is not only determined by rational considerations, but also by users' emotional responses.

Design and Implementation of a Real-Time RAG-Based Customer Relationship Management System Using Event-Driven Knowledge Updates and Vector Embeddings

Ivan Mijić, Bećir Isaković

Production CRM systems increasingly use large language models, yet typical Retrieval-Augmented Generation (RAG) implementations suffer from knowledge staleness due to 5–10 min batch processing cycles. This paper presents a streaming RAG architecture for business CRM applications that provides real-time knowledge updates with average document-to-query propagation latency of 3.1 s and strong retrieval quality. The event-driven system uses Apache Kafka for document ingestion, Rust microservices for embedding generation, PostgreSQL with pgvector for vector storage, and GPT-4 for response generation. On 62 insurance policy documents from 20 users and 102 test queries, mean document- to-query propagation latency was 3.1 s, 75–150× faster than batch processing, with retrieval quality metrics of Precision@5 = 0.398, MRR = 0.938, and NDCG@10 = 0.942 consistent with values reported in prior literature. Additional load testing with simulated users verified production-grade performance stability (P95 latency < 10.33 s), suggesting that streaming designs may mitigate the knowledge-currency vs. system performance trade-off in production CRM applications.

Leveraging Large Language Models for Automated Domain Model Construction

Tatjana D. Stojanović, Kristina S. Jovanović, Saša D. Lazarević

Domain models are fundamental artifact in software engineering. Errors made during their construction can be difficult to correct in later development stages. Domain models are derived from software requirements, which are most often expressed as unstructured textual descriptions. Domain model construction is still usually done manually, which makes their quality depend from knowledge and experience of the modeler. While rule-based system for automation of domain model construction have shown their ability to extract concept, their usability is limited due to lack of contextual understanding and semantic ambiguity. Large language models provide advanced contextual understanding and reasoning, but lack consistency, determinism and formal constraints. Hence, here is presented approach for construction of domain model by combining LLMs for their contextual understanding with the stability of heuristics. This paper introduces TEXTER, a framework that enables automated construction of formal, executable domain models from informal textual requirements.

Leveraging Outcome Metrics to Design Educational Hackathon: Setups for Sustainable Student Projects

Ana B. Miličević, Zorica M. Bogdanović and Tatjana D. Stojanović

The paper develops a conceptual metric framework for the design of sustainable educational hackathons in ICT higher education, grounded in a case study of a Web3 hackathon at the Faculty of Organizational Sciences (FON). The framework integrates a set of students, faculty, and institution-level indices that quantify knowledge, skills, motivation, professional development, and post-hackathon support. The methodology includes secondary analysis of combined quantitative and qualitative data from three waves of surveys and interviews with participants, mentors and organisers. The results show growth in knowledge and stable motivation, but low project continuity and a limited number of support structures, indicating a gap between the pedagogical potential and the existing ecosystem. The proposed set of metrics provides a basis for institutional self-evaluation and for redesigning hackathons towards greater sustainability of results. Based on this, the paper provides recommendations for integrating "sustainability" into the design and planning of educational hackathons by defining a basic set of metrics for institutional self-evaluation and continuous improvement.

LLM Based Software Test Scenario Generation System from Bug Descriptions

Merve Yilmazer Gundem, Mehmet Karakose Senior Member, IEEE

Large, user-interactive software systems require extensive software testing for safe deployment. Manually generated test cases by software testers require extensive time and effort, and their scope remains limited. In this study, a system based on LLM is proposed for automatic test cases and test steps generation from bug descriptions. In the proposed system, bug descriptions were first collected from the Defects4J Dataset. Keywords relevant to the bug scope were extracted from the descriptions. Structured automatic prompts were generated from the extracted keywords. The generated prompts were fed into the LLM as input, and software test cases appropriate for the bugs were generated. The method was evaluated on actual bug descriptions by comparing it to a general (baseline) prompt. Experimental results show that the lengths of the generated scenarios are similar, but the proposed method increases the keyword match rate with error descriptions to an average of 89%. The findings reveal that keyword-driven prompts are effective in generating more reliable and error-specific test scenarios without requiring additional data.

Neural Network-Based Prediction of Inter-Area Mode Parameters from Bus Voltage Phasors

Lazar Šćekić, Danilo Planinić and Vesna Popović-Bugarin

This paper presents a data-driven approach for predicting inter-area oscillation mode frequency and damping ratio directly from bus voltage magnitudes and phase an- gles. Unlike most machine learning-based stability assessment methods that frame the problem as binary classification, the proposed approach addresses a regression task to estimate the exact numerical values of modal parameters, providing system operators with quantitative stability margins. A feedforward neural network is developed and benchmarked against Least Squares Boosting (LSBoost) and Extreme Gradient Boost- ing (XGBoost) algorithms. The training dataset is generated through Monte Carlo simulations of the Kundur two-area system, incorporating load demand variations, generation redis- patch, N-K contingencies, and measurement noise. Results on the test set show that the neural network achieves R^2 values of 0.9691 and 0.9690 for frequency and damping ratio prediction, respectively, with a mean absolute percentage error of 0.85% for frequency and 5.80% for damping ratio.

Performance Evaluation of Jakarta EE-Based Applications in Containerized Environments

Miljana Stanković, Miloš Milić, and Siniša Vlajić

This paper introduces software quality concepts related to performance and portability and evaluates the performance of Jakarta EE-based applications. For evaluation purposes, Spring Boot-based and Quarkus-based applications are developed and compared by applying performance metrics. Although the experiment was limited, the results indicate that natively compiled Quarkus-based application achieves better performance compared to Spring Boot-based application. On the other hand, Spring Boot-based application benefits from a more mature ecosystem and stability. The research suggests that framework selection should be guided by the specific requirements of the software system under development.

Deterministic SU(2) Dynamics and Geometric Ill-Conditioning of Inverse Seed Reconstruction

Bojana Tomašević Dražić, Miloš S. Dražić and Mladen Veinović

We analyze deterministic dynamics on the com- pact Lie group SU(2) and investigate the conditioning of inverse seed reconstruction under finite numerical precision. Although sensitivity to initial conditions is commonly associated with Lyapunov-type chaotic divergence, we show that a different mechanism governs inverse instability in this setting.

Using a fully specified deterministic seed update rule and an axis-angle parametrization of SU(2) transformations, we construct a numerical framework and quantify sensitivity via a phase-invariant spinor distance. For fixed iteration depth, the final error scales linearly with the initial seed perturbation, with a stable exponent $\beta \approx 1$, indicating locally Lipschitz forward behavior. In contrast, the temporal evolution of the error is intermittent, showing plateaus and sudden jumps, rather than the uniform exponential growth characteristic of classical Lyapunov divergence.

We show that the inverse instability in deterministic SU(2) dynamics is dominated by geometric effects, which arise from the non-commutativity and holonomy of successive rotations, leading to severe numerical ill-conditioning despite stable forward evolution.

A proposal of support for mobile network resilience during emergencies – Montenegro case study

Milan B. Radulović, Dražen V. Mugoša and Boris M. Jevrić

In this paper the idea of use of the broadcast operator transport network, as a shared redundancy network in case of unavailability of mobile operators transport networks due to catastrophic natural disasters such as earthquakes, floods, wildfires, landslides etc. is introduced and results of the case study of Montenegro are presented. In this case study transport network of broadcast operator is used to deliver the priority voice, SMS and (pure) data traffic, including Public Warning System traffic from mobile network operators to end-users in affected areas. The results of simulations have shown that a high level of availability of basic services can be preserved when electronic communications infrastructure of mobile network operators is severely damaged across Montenegro during such possible emergency situations.

PerfMLOps: Zero-Human in the Loop Performance Testing Framework

Sowmya Chintakindi and Bharath Kumar Maganti, Member, IEEE

In today's world of rapid releases and continuous delivery, keeping applications fast and stable under real-world load is harder than ever. Most teams still rely heavily on manual performance testing, writing JMeter scripts, executing the tests, digging through logs, and guessing potential bottlenecks. These tasks are time consuming, expensive, and allow problems to slip into production far too often. We built PerfMLOps, an end-to-end automated pipeline that starts when the Python API is deployed; the JMeter test is automatically initiated and collects metrics directly into BigQuery via Google Analytics. These metrics were used to train BigQuery ML models for anomaly detection and identifying root causes. After the initial setup, no human intervention is required. From what we've seen in simulations, this kind of setup can cut deployment cycles by around 75%, drop performance-related incidents dramatically (we saw up to 90% fewer in our tests), and help teams achieve the kind of elite DORA (DevOps Research and Assessment) metrics that top performers reach: frequent deploys, quick lead times, and low failure rates. Cost-wise, automation like this typically saves 70 to 80% of the effort normally spent on performance testing, based on industry reports from places like Capgemini/Sogeti and others.

Reducing Software's Carbon Footprint through Performance Testing

Sowmya Chintakindi, Member, IEEE

As technology continues to evolve, the demand for software usage and its reliability is rapidly growing. To meet this demand, the development of new software has also increased to support progress. These software systems need significant computational resources, such as CPU, memory, and network bandwidth. While performance testing is tradi- tionally done to ensure system reliability, its role in reducing environmental impact has received little attention. This paper presents an industrial experience study on how performance testing can be systematically leveraged to lower the carbon footprint of software applications. Appropriate performance optimizations not only improve the performance of systems but also make them environmentally friendly. Our results show that performance testing is not only a tool for software quality assurance but also an effective mechanism for advancing green software engineering. We emphasize that our approach estimates carbon emissions using first-order analytical models rather than direct hardware power measurements. The goal is comparative analysis (before vs. after optimization), not absolute carbon accounting. We also discuss lessons learned from these performance tests, provide quantitative evidence of carbon reduction, and propose a framework for integrating sustainability metrics into performance testing practices.

Ski-Day Patterns from RFID Lift Usage Data

Sandro Radovanović, Andrija Petrović, Miloš Jovanović, Boris Delibašić, and Milija Suknović

RFID-based access systems generate detailed records of skier lift usage, enabling large-scale analysis of skiing behaviour but posing challenges due to the sequential and unlabelled nature of the data. In this study, we analyse skier movement patterns on data collected at Mt. Kopaonik over six ski seasons, comprising more than 7.6 million gate passages across 22 ski lifts. Each skier day is modelled as a sequence of lift usages enriched with temporal information. We learn compact behavioural representations using a self- supervised Transformer-based contrastive learning framework that captures both spatial and temporal structure. The learned embeddings are clustered using k-means. The resulting ten clusters reveal distinct but overlapping skiing behaviours, including repetitive looping within central lift areas, extended exploratory ski days spanning multiple resort zones, short- duration sessions, and structured progression across elevations. This paper thus introduces a method for modeling complex spatio-temporal event data, and transformation to a representation where traditional analytics can be performed; and is also applied to a real-world dataset to produce descriptive analysis of skiing patterns.

Retrieval-Augmented Generation Chunking Strategies for Financial Document Analysis: A Systematic Literature Review

Ryan Agatha Nanda Widiiswa, Matthew Martianus Henry, Alyssa Imani, Bens Pardamean

Retrieval-Augmented Generation (RAG) is an important architecture for generative AI. In particular, the subtle processing of financial reports (which constitutes a key area of regulatory scrutiny for tax authorities and financial bank sectors) has been automated. The performance of any RAG, however, is ultimately determined by its document splitting policy. When traditional fixed-size text chunking approaches are applied to financial statements, which are semi-structured, mixed data type documents, they cause context fragmentation and semantic incoherence, resulting in major degradation in subsequent retrieval and generation. This review of the literature is a systematic investigation of the emergent importance of chunking strategies within the financial context. In line with PRISMA 2020, a total of 16 recent studies were integrated in this review to unravel the effects of different chunking approaches, ranging from naive text splitting to more complex, layout-aware parsing. Our analysis shows that Naive fixed-size chunking is the most common strategy, whereas structure-aware and semantic chunking approaches enhance precision up to 33.42%. We discuss known trade-offs of chunk size granularity, retrieval precision and recall, and identify architectural patterns for high- end structure-aware solutions. The results demonstrate a conclusive and essential convergence of the previously arbitrary chunking paradigm to semantic chunking that captures, if not the entirety, a significant portion of the relational and logical nature of the document.

Rule-Based Framework for Assessing Organizational Maturity in HPC Infrastructure Adoption

Matija Zuber, Dino Kalač, Emin Badžić, Ana Lalović, Sarah Spahić, Lejla Gurbeta Pokvić, Almir Badnjević

Assessing organizational readiness for high- performance computing (HPC) adoption requires evaluation beyond hardware benchmarking, encompassing workforce capabilities, software maturity, data interoperability, and regulatory compliance. This paper presents a modular, rule-based decision-support framework implemented in Python that evaluates HPC maturity across five integrated dimensions and generates a phased migration roadmap through a weighted scoring model and recommendation engine. The framework employs a formally defined aggregation formula with configurable dimension weights, and its outputs are validated through a basic sensitivity analysis demonstrating score stability under weight variation. Demonstrated on two simulated organizational profiles—a mid-sized research institute and a public administration body—the framework identified critical gaps in workforce readiness and governance compliance, highlighting the role of non-technical factors in HPC transition planning and the practical value of transparent, reproducible maturity assessment for early-stage decision-making.

Server-side Decryption of Secure Shell Traffic

Dinakar Emmanuel, Cheruku Manas Ram, and Gokul Kannan Sadasivam

The Secure Shell (SSH) protocol is a cornerstone of network security, providing confidentiality and integrity for remote administration and data transfer. While its encryption is critical for protecting data in transit, it creates an opaque environment for real-time security monitoring and forensic analysis. This paper introduces a novel methodology for the extraction of keys and the live decryption of SSH sessions by leveraging modern in-kernel observability technologies. Our approach utilizes the extended Berkeley Packet Filter (eBPF) and its high-level tracing language, bpftrace, to perform non-invasive, dynamic instrumentation of a running OpenSSH server process. We demonstrate a technique that attaches a user-level probe to the kex derive keys function, a critical stage in the SSH key exchange protocol where session keys are generated and stored in memory. By reading process memory at precise offsets, we successfully extract the encryption keys for both client-to-server and server-to-client data flows. These inter- cepted keys are then passed to a Python application which uses the PyShark library to capture the corresponding encrypted network packets and decrypt their payloads in real time. This work provides a practical framework for introspection into encrypted protocols, showcasing the power of eBPF as a tool for advanced security auditing and live forensics without altering the target applications source code or configuration.

The Information Revolution: What Drives Users to Trust and Adopt Generative AI as Information Source?

Eggan Ojwala Yatalana and Tanty Oktavia

The study identified the variables that influence information adoption and trust in GenAI as a source of information. The empirical study further highlighted the Information Adoption Model (IAM) with variables including information quality, information credibility, information usefulness, trust inclination, argument quality, and information adoption. Structural equation modeling (SEM) was used to analyze survey data from 204 GenAI users. The findings indicated that high-quality information is positively associated with information credibility, usefulness, and trust inclination. Argument quality had a considerable impact on trust inclination. Information credibility, usefulness, and trust inclination had a considerable effect on information adoption. But information usefulness did not significantly affect trust inclination. The results highlighted the importance of the formation and quality of argument structure, trustworthiness in content quality, and trust in AI-generated content in raising perceptions.

Factors Affecting the Intention to Adopt Blockchain Technology in Cryptocurrency in Indonesia

Brian Hartanto, Philipus Jason Presley, Simeon Batara Jakub, and Lay Christian, Member, IEEE

This study investigates regarding the factors influencing the intention to adopt the technology of blockchain in the context of cryptocurrency market in Indonesia. Grounded in the Unified Theory of Acceptance and Use of Technology (UTAUT) and extended with Perceived Risk (PR) and Financial Literacy (FL), the research develops an enterprise-level information model explaining user adoption behavior. A quantitative methodology was utilized, collecting data through an online questionnaire, distributed to blockchain users and cryptocurrency holders. A total of 302 valid responses were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) via SmartPLS software. The results indicate that Performance Expectancy (PE) and Financial Literacy (FL) significantly influence the Intention to Adopt Blockchain Technology (INT), while Perceived Risk (PR) negatively significantly influenced, on the other hand Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC) are not significant predictors. The finding highlights that internal cognitive and perceptual factors play a stronger role than external technical or social drivers. This research contributes to enterprise information system literature by offering empirical evidence from an emerging market, emphasizing the importance of user literacy and regulatory clarity in promoting blockchain adoption.

XCC: A Universal Communication Interface Composer for Heterogeneous Systems

Nikola Stojkov, Igor Dejanović

In modern embedded systems with an ever- increasing number of computing nodes, a central challenge is communication design: maintaining consistent, low-latency, and low-overhead data exchange across the system. In mixed- criticality systems based on asymmetric multiprocessing (AMP), communication design is often fragmented across code, configu- ration files, and abstract architectural diagrams. This becomes problematic as systems grow more complex and communication becomes more heterogeneous, especially when implementation spans multiple teams, platforms, and technologies. Further- more, architects and integrators frequently opt for dynamic communication mechanisms to accommodate late architectural changes without breaking the system, but this often incurs costs in increased latency, memory footprint, and runtime overhead.

This paper presents XCC (Universal Communication Com- poser), a lightweight communication composition mechanism based on a domain-specific language. XCC enables architects, integrators, and developers to design compile-time known com- munication interfaces and protocols systematically. It captures (i) architectural connectivity, (ii) interface contracts, and (iii) communication profiles within a single representation, which can then be used for validation and code generation.

The key contribution is a practical method for creating traceable, repeatable, and analyzable communication interfaces across heterogeneous platforms, while still permitting late architectural changes without system disruption.

On the Role of Aggregation Operators in Deployment of Federated Learning

Matea D. Lukić, Tamara D. Drobnjaković, Ana M. Poledica

Federated learning trains models across distributed clients without moving raw data, but its effectiveness depends on how the server aggregates client updates. We present an operator-centric overview of aggregation mechanisms, organized by the practical problems they are designed to handle. Within this view, we frame client selection and weighting as two sides of the same aggregation design space and summarize representative operator families. We then motivate interpretability-oriented and security-aware aggregation as increasingly important for real deployments, emphasizing that under privacy mechanisms, the server may not access per-client signals, limiting which interpretable solutions can be implemented.

Identification and Optimal Output Regulation of Linear Systems Using Integral Reinforcement Learning

Žarko Zečević, Luka Martinović and Božo Krstajić

This paper addresses the optimal output regula- tion problem for continuous-time linear systems with unknown dynamics and external disturbances. A data-driven approach based on integral reinforcement learning is employed to iden- tify the system matrices and the optimal state-feedback gain using measured input-state data. The feedforward control gain is subsequently obtained by solving the regulator equations based on the identified model, enabling reference tracking and disturbance rejection. Simulation results demonstrate the effectiveness of the proposed approach.