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Gulchohra Mammadova
Telman Aliev
Kamil Aida-zade (Eds.)

3rd International Conference on

Information Technologies and Their Applications

ABSTRACTS

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Gulchohra Mammadova
Telman Aliev
Kamil Aida-zade (Eds.)

3rd International Conference on Information Technologies and Their Applications (ITTA 2026)

Abstracts

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Preface

The 3rd International Conference on Information Technologies and Their Applications (ITTA 2026), held on April 22–24, 2026 in Baku, Azerbaijan, brings together researchers, academics, and industry professionals from around the world to exchange ideas, present recent advances, and discuss emerging trends in the field of information and communication technologies.

ITTA 2026 serves as a platform covering a wide spectrum of topics, including automation and control systems, modeling and simulation, decision-making systems, cybersecurity, pattern recognition, intelligent systems, and applications of ICT in industry, construction, and socio-economic domains. The conference program reflects the growing importance of digital transformation and the integration of artificial intelligence, data-driven approaches, and smart technologies into modern scientific and industrial practices.

This Abstracts Book contains selected abstracts of papers, some of which are included in the conference program, covering plenary talks and thematic sessions. In total, the book features around 240 abstracts submitted by authors representing 26 countries. The contributions demonstrate both theoretical developments and practical implementations, highlighting innovative solutions to contemporary challenges in science, engineering, and society.

The conference is organized with the support of leading academic and research institutions from Azerbaijan and abroad, fostering international collaboration and knowledge exchange. The active participation of distinguished scholars and experts ensures the high scientific quality and relevance of the presented works.

We would like to express our sincere gratitude to the authors for their valuable contributions, the program committee for their dedicated review efforts, and the organizing committee for their commitment to the successful realization of the conference.

We hope that this collection of abstracts will serve as a useful resource for researchers and practitioners and will inspire further developments in the field of information technologies and their applications.

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PLENARY

Boris Mordukhovich

Application of Optimization to Proton Therapy

Department of Mathematics and Institute for AI
and Data Science, Wayne State University, Detroit,
Michigan, USA

Abstract: The talk is devoted to investigating single-objective and multiobjective optimization problems involving the so-called l0-norm function, which is nondifferentiable and nonconvex. Such problems appear in proton beam therapy models of cancer research. The developed approach uses first-order and second-order subdifferential tools of variational analysis and scalarization techniques of multiobjective optimization. Based on this machinery, we propose several algorithms of the subgradient and generalized Newtonian types and conduct their convergence analysis. The obtained results are illustrated by numerical examples from proton therapy models. (Based on the collaboration with the Proton Therapy Center of the Corewell William Beaumont Hospital, Royal Oak, Michigan.)

Keywords: ℓ0-norm optimization, Nonconvex nonsmooth optimization, Multiobjective optimization, Variational analysis, Subdifferential calculus, Scalarization techniques, Subgradient algorithms, Generalized Newton methods, Convergence analysis, Proton beam therapy modeling

Sedat Akleylek

Post-Quantum Cryptographic Protocols: from Theory to Practice

Institute of Computer Science, University of Tartu, Estonia

Abstract: The transition to post-quantum cryptography is no longer a theoretical exercise but an urgent engineering challenge driven by the accelerating progress of quantum computing. This invited talk explores the practical realities of migrating real-world systems to quantum-resistant security, focusing on three critical pillars: Transport layer security (TLS), CDOC2 (Estonia's file encryption format) secure document container systems, and the integration of post-quantum key encapsulation mechanisms (KEMs) and digital signature schemes. We begin with an overview of the cryptographic threat landscape and the implications for widely deployed protocols such as TLS, where hybrid and post-quantum key exchange mechanisms are being standardized to ensure forward secrecy in a quantum era. We examine the design and deployment considerations of integrating PQ KEMs into TLS handshakes, including performance overhead, interoperability, backward compatibility, and cryptographic agility. We provide some challenges and opportunities in the quantum era.

Keywords: Post-Quantum Cryptography, Quantum-Resistant Security, Transport Layer Security (TLS), Key Encapsulation Mechanisms (KEMs), Digital Signature Schemes, CDOC2 Encryption, Cryptographic Agility, Hybrid Key Exchange

Perviz Ahmedzade

Data-Driven Fatigue Modeling in Asphalt Pavements: from Mechanistic Understanding to Decision Support

Samarkand State Architectural and Civil Engineering University, Samarkand, Uzbekistan
Ege University, Türkiye

Abstract: Fatigue cracking in asphalt pavements is a complex process driven by repeated traffic loading and influenced by temperature, loading conditions, mixture properties, aging, and healing. Because it strongly affects performance, cost, safety, and emissions, accurate prediction and management are essential. Combining mechanistic knowledge with data-driven approaches—using laboratory tests, field records, and imaging/sensing data—enables better prediction of fatigue life, crack growth, and remaining service life. This integrated approach supports improved materials design, maintenance planning, and sustainability by reducing uncertainty and enhancing overall pavement performance.

Keywords: Fatigue Cracking, Asphalt Pavements, Service Life Prediction, Pavement Performance, Mechanistic-Data-Driven Approach, Materials Design, Maintenance Planning, Sustainable Infrastructure

Azer Kasimzade

Latest Achievements on Structural Control: An Industrial Application for the Tallest Building of the Caucasus

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: Classification latest achievements on structural control with seismic Isolation and energy dissipation systems, the mathematical equation of motion and related solution methods, information technologies were shown. Attention has been drawn to the performance of structures with Seismic Base Isolation (SBI), vibration control and Tuned Mass Damper (TMS) devices, against near-fault and far-source long-period earthquakes. It has been reported that, the vulnerable state of the important – Highly Reliable Structures (HRS) under near-fault and long-period ground motions has been recognized worldwide during numerous strong earthquakes. To solve this problem, new generation Structural Seismic Isolation Method (SSIM) and System (SSIS) was used. An Industrial Application was presented on the tallest building of the Caucasus with related information technologies.
Keywords: Structural Control, Seismic Isolation, Energy Dissipation Systems, Seismic Base Isolation, Tuned Mass Damper, Near-Fault Earthquakes, Highly Reliable Structures

Semyon Serovaysky

The Logical Structure of Mathematics: from Foundational Sets to Categorical Synthesis

Al-Farabi Kazakh National University, Kazakhstan

Abstract: The mathematical world, like no other, is extremely fragmented. Specialists in one direction of mathematics are often not only unaware of the current problems of other sections, but do not even understand the

language spoken by their colleagues. In reality, mathematics is a single organism. Its description is the subject of the author's book The Logical Structure of Mathematics: An Overview of Mathematical Concepts, published by Taylor & Francis Group. Based on the languages of mathematical logic, set theory is described as the foundation of mathematics. By means of set theory, various classes of numbers are defined. By extending the properties of numbers to sets of arbitrary nature, the main mathematical objects are defined. With their help, theories are constructed that cover almost all the most important areas of modern mathematics. Finally, by means of category theory, common properties of various theories are revealed, connections between them are established, and the possibilities of describing mathematics as a whole are discussed.

Keywords: Mathematical Foundations, Set Theory, Mathematical Logic, Category Theory, Structuralism, Mathematical Interconnectivity, Axiomatic Systems

Samir Rustamov

Building Speech Recognition Systems that Work in the Real World

ADA University, School of IT & Engineering (SITE), Azerbaijan
Head of AI Laboratory, MegaSec Company, Azerbaijan

Abstract: Recent advances in deep learning and large-scale data have significantly improved speech recognition accuracy on benchmarks, yet deploying reliable systems in

real-world environments remains challenging. This keynote focuses on building speech recognition systems that function effectively outside controlled settings, addressing issues such as noise, accents, domain mismatch, and real-time constraints. It examines the end-to-end speech recognition pipeline, highlights practical failure modes, and questions the adequacy of traditional evaluation metrics like word error rate. The talk also explores the integration of speech recognition with broader AI systems, including natural language understanding and large language models, while emphasizing ethical, social, and usability considerations. The key message is that real-world speech recognition is a system-level challenge that extends beyond model performance to include data quality, robustness, and user trust.

Keywords: Robust Speech Recognition, End-to-End Deep Learning, System-Level AI, Domain Adaptation, Real-World Deployment, Speech-to-Text Evaluation, Human-Centric AI, Large Language Model (LLM) Integration

SECTIONS

Majid Abbasov, Daniil Miroshnichenko

Modeling Convergence Rate Estimates of the Heavy Ball Algorithm via a Random Forest with Self-Attention

St. Petersburg State University, Russia

Abstract: This paper addresses the problem of estimating convergence rates of iterative optimization algorithms, which is essential for analyzing and accelerating the training of modern machine learning models. Classical approaches to convergence rate estimation for momentum-based methods typically rely on analytical bounds derived under restrictive assumptions or on extensive empirical experimentation, both of which are computationally expensive and poorly scalable. As an alternative, we propose a data-driven framework for modeling convergence rate estimates using supervised machine learning. The proposed approach is demonstrated for the Heavy Ball optimization method applied to quadratic objective functions with heterogeneous curvature. A synthetic dataset is constructed by simulating Heavy Ball trajectories under randomly sampled objective parameters, optimization hyperparameters, and normalized initial conditions. The input features capture key characteristics of the optimization process, while the target variable represents a logarithmic estimate of the objective function decay along the trajectory, serving as a proxy for the convergence rate. To model nonlinear

dependencies between optimization parameters and convergence behavior, we employ a Random Forest model augmented with a self-attention mechanism. This architecture enables adaptive weighting of feature interactions and improves predictive accuracy without requiring explicit analytical modeling of the underlying dynamics. Numerical experiments show that the pro-posed model achieves a coefficient of determination exceeding 0.8 when predict-ing convergence-related quantities, indicating strong agreement with empirically observed behavior. The results suggest that machine learning-based surrogate models can substantially simplify convergence rate estimation and that the pro-posed methodology is applicable to other optimization algorithms and objective classes.

Keywords: Convergence rate estimation, heavy ball method, momentum-based optimization, random Forest with self-attention, synthetic trajectory modeling, optimization dynamics.

Majid Abbasov, Anna Gorbunova

Grid Exact Penalty Method for Defining Cost-Optimal Trajectory

Saint Petersburg State University, Russia

Abstract: We study the application of exact penalty methods to the problem of finding a cost-optimal trajectory. Although this scheme addresses the underlying problem, it produces successive approximations represented by nonelementary functions; evaluating and

manipulating these expressions leads to a rapid growth in computational effort per iteration, which in practice restricts the number of feasible iterations and prevents achieving a prescribed accuracy. To address these limitations, we propose a grid-adapted variant of the method that discretizes the search space and replaces non-elementary intermediate expressions with computable grid-based approximations, reducing per-iteration overhead while preserving convergence properties. To minimize the exact penalty objective, we employ a coexhauster descent method. We describe implementation details and present numerical examples. The results should interest researchers applying exact penalty techniques in the calculus of variations and control theory, and may be useful for designing and computing optimal transport paths in applications where both precision and computational tractability are required.

Keywords: Exact Penalty Method, Coexhausters, Constructive Nonsmooth Analysis, Calculus of Variations

Ali Abbasov, Ramil Akhundov, Tahir Alizada, Ulviyya Mammadova, Adalat Pashayev, Elkhan Sabziev

Intelligent System for Detecting Acoustic Signatures of Faults in a Noisy Environment Based on Time–Frequency Analysis and CNN

Institute of Mathematics, Azerbaijan
Military Scientific-Research Institute of the National Defense University, Azerbaijan

Abstract: An information technology–based approach is proposed for the early detection of specific faults in mechanisms and engineering structures using acoustic signals acquired under intense background noise. The study is based on the premise that defect development produces a stable acoustic signature that can be described by a set of time–frequency features. Fourier-series coefficients and their derived statistics are used as the primary representation, and to improve robustness to noise the signal is transformed into a mel-spectrogram. Next, a convolutional neural network (CNN) with computer-vision architectures is applied, enabling the extraction of informative patterns even at low signal-to-noise ratios. The paper presents the system architecture, data preparation pipeline, model training and validation procedure, and results of computational experiments for different noise levels and fault types. The combination of classical spectral analysis and CNNs is shown to provide high detection recall and precision at acceptable computational cost. The proposed solution is intended for practical deployment in construction, industry, and transport infrastructure, where continuous condition monitoring and prevention of hazardous events are critical.
Keywords: Acoustic Diagnostics, Fault Detection, Mel Spectrogram, Fourier Coefficients, Convolutional Neural Networks, Computer Vision, Industrial Monitoring, Predictive Maintenance, Information Technology, Intelligent Systems

Majid Abbasov, Mikhail Lavrukhin

Genetic Path Optimization in 2D with a Forbidden Region

Saint Petersburg State University

Abstract: This paper considers a two-dimensional variational path optimization problem with a forbidden region. The trajectory is represented as a curve joining two fixed boundary points, while the objective functional combines a term depending on the total path length and a running term weighted by a spatially varying coefficient. Such models are natural for route design problems in which the geometry of the trajectory and local construction or traversal conditions must be taken into account simultaneously. To model an obstacle, a circular forbidden region is introduced and incorporated into the optimization problem through a smooth penalty term. The main goal of the paper is to demonstrate that a genetic algorithm can reliably produce feasible detours while preserving the quality of the solution with respect to the original cost functional. In order to assess the obtained solutions, a classical Ritz-type approximation is used as a reference method on the same benchmark problem. Numerical experiments show that the genetic algorithm reaches objective values close to the reference solution while maintaining only a very small residual constraint violation. The study is intentionally focused on a simple two-dimensional test case; however, the obtained results illustrate why genetic search remains attractive for more complicated variational route design problems involving

nonconvex feasible sets and constraints that are difficult to embed into classical deterministic schemes.

Keywords: Genetic algorithm, Path optimization, Forbidden region, Variational problem, Obstacle avoidance, Route design

Majid Abbasov, Kira Dmitrieva

Application of the RRT Algorithm to Solve Control Theory Problems

Saint Petersburg State University

Abstract: This paper presents a modified Rapidly-exploring Random Tree (RRT) algorithm for solving optimal control problems in nonlinear dynamical systems. The key innovation lies in integration of system dynamics direct into the tree expansion process. Unlike the classical RRT, which samples points in the configuration or state space, the proposed approach samples controls from a mixed continuous-discrete probability distribution. Each sampled control is applied to the nearest node in the tree, and the resulting child state is computed by numerically integrating the system's ordinary differential equations over a fixed time step. To explicitly track and minimize the objective functional, the state vector is augmented with the accumulated cost, forming an extended state space. This framework transforms the RRT from a path-planning tool into a stochastic optimizer capable of approaching a control trajectory that satisfies the necessary conditions for optimality while respecting state and control constraints. The method is validated through numerical simulation,

demonstrating its effectiveness in generating feasible and near-optimal control policies for complex dynamical systems.
Keywords: Optimal Control, Graph Tree, Fast Growing Graph Trees, Control Theory

Raul Abdulağayev
Data-Driven Project Management in IT and Telecommunications
Azerbaijan University of Architecture and Construction, Azerbaijan
Abstract: In the rapidly evolving fields of Information Technology (IT) and Telecommunications, project environments are characterized by high complexity, uncertainty, and continuous technological change. Traditional project management approaches often rely on intuition and historical experience, which may not be sufficient in dynamic and data-intensive contexts. This article explores the role of data-driven project management in enhancing decision-making accuracy, risk mitigation, and overall project performance in IT and telecommunications sectors. The study highlights how advanced data analytics, real-time monitoring systems, and performance metrics enable project managers to make evidence-based decisions throughout the project lifecycle. By leveraging big data, predictive analytics, and key performance indicators (KPIs), organizations can improve forecasting accuracy, optimize resource allocation, and proactively identify potential risks. Furthermore,

integrating data analytics into agile and hybrid project management methodologies increases transparency, accountability, and adaptability. The findings suggest that data-driven approaches significantly contribute to improved project efficiency, cost control, and stakeholder satisfaction. However, successful implementation requires strong data governance, technological infrastructure, and analytical competencies within project teams. Overall, adopting data-driven project management practices is a strategic necessity for IT and telecommunications organizations aiming to achieve sustainable competitive advantage in a highly competitive market environment.
Keywords: Data-Driven Decision Making, Project Management, IT Infrastructure, Telecommunications, Predictive Analytics, Resource Optimization

Kenan Abdullayev, Ababil Nagiyeva, Sakit Verdiyev
Hiding the Encrypted Image in a Digital Container
Azerbaijan Technological University, Azerbaijan
Abstract: The rapid expansion of digital communication necessitates advanced methods for securing sensitive data. While traditional Least Significant Bit (LSB) steganography is widely used, it remains vulnerable to modern statistical attacks and significant image distortion. This paper proposes an optimized hybrid security model that integrates Fernet symmetric encryption with Matrix Encoding based on Hamming Codes F(1,2,3). By utilizing Matrix Encoding, the proposed method embeds 2 bits of encrypted data into a 3-pixel block of a digital container

while modifying at most one pixel. Experimental results on standard test images (Lena, Baboon, Peppers, Boat) demonstrate a significant improvement in imperceptibility, achieving a PSNR exceeding 51 dB and a remarkably low Mean Squared Error (MSE). Furthermore, the method exhibits high resistance against RS Steganalysis and Chi-Square (X^2) attacks, ensuring both the confidentiality and invisibility of the transmitted information in both RGB and Grayscale formats.
Keywords: Information Hiding, Steganography, LSB, Cryptography, Cryptography Library, Fernet

Aytan Abdullayeva, Vilayat Mammadov

Innovative Artificial Intelligence Approaches for e-Learning Platforms in Smart Educational Environments

Azerbaijan University of Architecture and Construction, Azerbaijan
Institute of Chemistry named after Acad. M. Naghiyev, Azerbaijan

Abstract: In the 21st century, the rapid development of information technologies has significantly transformed education systems worldwide. Traditional teaching methods alone are no longer sufficient to meet the evolving needs of learners, requiring the integration of digital tools to enhance learning outcomes. This paper examines the application of information technologies in education, highlighting e-learning, distance education, virtual and augmented reality, and artificial intelligence as key

components. The study discusses how these technologies improve interactivity, accessibility, and personalized learning, while also addressing challenges such as unequal infrastructure, limited teacher digital competencies, and cybersecurity concerns. Special attention is given to the implementation of information technologies in Azerbaijan, where government initiatives and digital education programs aim to improve access and quality. The findings indicate that the effective integration of information technologies can enhance student engagement, foster critical thinking, and support lifelong learning. However, successful adoption requires continuous teacher training, robust technical infrastructure, and strategic planning at the institutional and national levels. This research provides insights for educators, policymakers, and institutions seeking to leverage information technologies to create more efficient, flexible, and high-quality educational environments.
Keywords: Artificial Intelligence, Smart Education, Smart Learning Environments

Aytakin Afandiyeva, Gulnar Gurbanova, Seljan Guluzade, Eljan Huseynzade, Toghrul Mustafali, Gulay Yusifli

Application of Artificial Intelligence in Higher Education: Smart Classroom Approaches in Azerbaijani Universities

Azerbaijan University of Architecture and Construction, Azerbaijan

Baku Eurasian University, Azerbaijan
University of Sheffield, School of Computer Science, United Kingdom
Abstract: This paper examines the transformative role of artificial intelligence (AI) in higher education, with a particular focus on AI-driven adaptive learning systems that enable personalized and data-informed learning environments. By leveraging advanced data analytics, machine learning algorithms, and real-time feedback mechanisms, these systems construct individualized learning pathways that respond dynamically to students' cognitive levels, learning pace, and academic needs. Such adaptive models enhance student engagement, learning efficiency, and educational equity by supporting self-regulated and flexible learning processes. Beyond academic performance, the study explores the integration of emotional and behavioral analytics, demonstrating how AI-based platforms can identify psychological barriers to learning and contribute to the development of supportive and inclusive educational environments. The paper also critically addresses key implementation challenges, including data privacy risks, ethical governance of educational data, digital infrastructure limitations, and the growing need for comprehensive teacher training and digital competence development. Within the context of Azerbaijan's higher education system, the expansion of student populations, increased gender balance, and the growth of STEM and technical disciplines have created a strategic foundation for the transition toward the

Education 5.0 paradigm. The integration of Generative AI (GenAI), smart classroom platforms, and immersive technologies such as augmented reality (AR) and virtual reality (VR) is reshaping teaching, assessment, and learning engagement through personalized instruction, adaptive evaluation, and real-time monitoring systems. The paper concludes with strategic recommendations for higher education institutions, emphasizing ethical data management frameworks, sustainable digital infrastructure investment, and continuous professional development for educators as essential conditions for maximizing the long-term educational, social, and institutional benefits of AI-driven learning ecosystems.
Keywords: Education 5.0, Artificial Intelligence, Adaptive learning, Smart classroom, Higher education, Digital transformation

Abdulhuseyn Agayev

Zk-Homomorphic Hybrid Cryptographic Framework for Privacy-Preserving Transaction Verification on Ethereum

Azerbaijan Technical University, Azerbaijan

Abstract: This paper presents the ZK-Homomorphic Hybrid Cryptographic Framework (ZK-HHCF), a system enabling privacy-preserving transaction verification on Ethereum by combining Groth16-based zero-knowledge proofs (ZKPs) [1] and fully homomorphic encryption (FHE) under the CKKS scheme [2]. The ZKP layer performs on-chain range verification, proving a private amount lies

within an allowed interval without revealing its value, while the FHE layer enables off-chain encrypted computation on the same amount [6]. Instead of storing the large CKKS ciphertext on-chain (~334 KB), the framework records only a 32-byte keccak256 commitment in a Solidity smart contract [4], reducing on-chain data by several orders of magnitude while preserving cryptographic integrity. A prototype deployed on the Ethereum Sepolia testnet completes Groth16 verification in 410,966 gas with zero rejected transactions, confirming practical feasibility on EVM-based networks. Compared to Zcash [1], Zether [3] and ZK-DPPS, ZK-HHCF is the first system to co-deploy Groth16 range proofs and CKKS-based FHE within a single on-chain/off-chain Ethereum architecture with a live testnet prototype.
Keywords: ZKProofs, Groth16, FHE, CKKS, TenSEAL, Ethereum, Smart Contracts, Blockchain Privacy, Commit Reveal, Range Proof

Firudin Aghayev, Mammad Aliyev

Deep Reinforcement Learning for the Dynamic Optimization and Autonomous Resource Allocation of High-Volume Financial ETL Pipelines

Institute of Information Technology, Azerbaijan
Baku Engineering University, Azerbaijan

Abstract: The exponential growth rate of transactional data within the financial services sector requires the implementation of extremely resilient and aggressively optimized Extract, Transform, and Load (ETL) data

processing architectures. Current traditional deterministic-based ETL architectures heavily depend on static resource allocation and scheduling strategies. This creates critical operation performance issues, including high processing latency, critical failure during periods of high schema drift, and vastly sub-optimal cloud-based computing resource utilization during unpredictable market conditions. This study aims to propose the development and implementation of an intelligent and self-tuning framework using Multi-Agent Deep Reinforcement Learning (MADRL) to autonomously optimize analytical data processing operations. This study mathematically defines the enterprise ETL processing pipeline as an extremely dynamic Markov Decision Process. Within the context of the MDP, the intelligent autonomous agents monitor real-time system state variables, including data ingestion rates, distributed memory cluster utilization, and algorithmic complexity. The agents utilize Proximal Policy Optimization algorithms to autonomously and optimally determine the batch sizes and memory allocation parameters without the need for human intervention. In addition, in order to ensure complete veracity of the data for the development of analytical models, the framework also incorporates deep autoencoders in the data transformation layer of the architecture. The primary aim of incorporating deep autoencoders is to enable highly precise probabilistic data imputation and real-time anomaly detection in corrupt financial data. The performance of the proposed MADRL framework was

tested on enormous volatile enterprise banking datasets. The results of the experiments clearly indicate that the proposed framework can effectively reduce the total ETL processing time of the pipeline by up to 38%. At the same time, the framework can also minimize cloud compute infrastructure costs by 22%. The present study clearly indicates that the adoption of autonomous self-tuning deep learning-based architecture in finance is absolutely crucial in order to ensure rigorous constraints in terms of cost and performance.
Keywords: Multi-Agent Deep Reinforcement Learning, ETL Pipeline Optimization, Autonomous Resource Allocation, Financial Big Data Processing, Deep Autoencoders, Real-Time Anomaly Detection, Markov Decision Process

Agha Aghayev, Nour-Eddine Rahmani
Cryptanalysis of a Post-Quantum Signature Scheme Based on Number-Theoretic Assumptions
Azerbaijan Technical University, Azerbaijan
Mohammed I University, Morocco
Abstract: The asymmetric cryptographic constructions upon on number- theoretic hardness assumptions have become insecure, due to Shor’s quantum algorithm and they will be vulnerable to large scale quantum computers. Hence, the adaption to quantum-resistant cryptosystems is a major task. Digital signatures, being a fundamental primitive in numerous applications, also require post-quantum alternatives. Recently, a new approach by Nguyen

et al. [9] has claimed post-quantum security by basing the signature algorithm’s security on a variant of the discrete logarithm problem. In this paper, we present a cryptanalysis of this construction and demonstrate a practical forgery attack that allows generating an unlimited number of valid signatures—without access to a signing oracle.
Keywords: Cryptanalysis, Digital signatures, Post-quantum cryptography, forgery

Konul Aghayeva
AI-Based Predictive Quality Assurance in Educational Institutions (A Case Study of Azerbaijan University of Architecture and Construction)
Azerbaijan University of Architecture and Construction, Azerbaijan
Abstract: Quality assurance and monitoring in educational institutions are usually based on retrospective analyses, reports and planned inspections. This approach can lead to late detection of problems and reactive allocation of resources. A predictive quality control system based on artificial intelligence (AI) and machine learning integrates multi-source data to identify risks in advance, form early warning indicators and support decision-making. The article presents the conceptual framework of an AI-based predictive quality management model in higher education and describes an application scenario on the example of AzUAC. The risk assessment approach is explained based on academic performance, attendance, survey results, use

of e-learning environment and subject indicators. The results show that predictive analytics strengthens a proactive approach in quality assurance, increases transparency and supports continuous improvement.
Keywords: artificial intelligence, predictive analytics, quality control, higher education, AzUAC, data-driven management

Nigar Ahmadli

Image-Based Target Object Recognition Using Advanced Machine Learning Techniques

Institute of Mathematics, Azerbaijan

Abstract: This paper presents an in-depth examination of advanced machine learning techniques applied to image-based target object recognition. As the volume of visual data continues to grow across various domains, the need for accurate, efficient, and robust recognition systems has become increasingly important. The study reviews both traditional feature-based approaches and modern learning-based models, highlighting their theoretical foundations, strengths, and limitations. Particular attention is given to deep learning architectures, which have demonstrated significant improvements in handling complex image features and achieving high recognition accuracy. The paper also discusses challenges such as variability in object appearance, background clutter, and limited training data. To address these issues, several optimization strategies and preprocessing methods are analyzed. Experimental results from recent literature

illustrate how advanced models outperform classical methods in most cases. The findings emphasize the potential of machine learning–driven solutions for enhancing target identification in critical applications, including surveillance, automation, and intelligent vision systems.
Keywords: Object Recognition, Image Processing, Machine Learning, Feature Extraction, Classification Algorithms

Firuza Ahmadova, Nigar Abdullayeva
Modern Approaches in Landscape Architecture
Azerbaijan University of Architecture and Construction, Azerbaijan
Abstract: Landscape architecture is now experiencing one of the most expressive qualitative transitions of all that have happened over the past couple of decades in this area, traditional methods of space-planning formation, based on relief patterns, stable typologies and predictable materials for centuries, face a new challenge: integration technologies that can literally rewrite the rules of working with space. In addition, in recent years, landscape architecture has become one of the most important practices in the world associated with most of the key areas in the life of the city and man, such as architecture, urban planning, health care, etc. Landscape proposals are increasingly based on advanced technologies and sciences to determine what conditions will bring the greatest benefit to both people and nature.

Keywords: Landscape architecture, renovation territory, innovative solutions, new materials, digital technologies, leisure environment, architecture of the future

Kamil Aida-zade, Yegana Ashrafova

Control of Transient Processes in the Transportation of Hydrocarbon Raw Materials in Complex Pipeline Networks

Institute of Mathematics, Azerbaijan
Azerbaijan University of Architecture and Construction, Azerbaijan
Baku State University, Azerbaijan
Baku Business University, Azerbaijan

Abstract: The problem of controlling non-stationary flow regimes of a fluid in pipeline networks with a complex structure is considered. The problem requires, by regulating the operating modes of pumping equipment, to change the specified flow regimes of the fluid in sections of the pipeline network to new ones. The transition can be carried out by controlling the change in flow rate or pressure at the terminal points of the network. For the numerical solution of these problems, formulas have been obtained and algorithms have been developed.

Keywords: Transient Processes, Pipeline Networks, Control.

Kamil Aida-zade, Vugar Hashimov

Control of Nonlinear Object with Discrete-Time Feedback

Institute of Mathematics, Azerbaijan
Abstract: A method for synthesizing optimal control of processes (objects, systems) with concentrated parameters described by nonlinear autonomous differential equations with ordinary derivatives is investigated. To synthesize the current values of the process control, it is proposed to use information only at certain points in time about its state. To determine the optimal values of the feedback parameters involved in these dependencies, the corresponding formulas for the gradient of the objective functional are obtained. Computer experiments using gradient-type optimization methods have been conducted.
Keywords: synthesis of control, feedback, feedback parameters, measurements at certain points in time, finite-dimensional optimization

Kamil Aida-zade, Samir Guliyev, Seymur Mirzabayov
Synthesis of Zonal Controls with Memory for the Rod Heating Process
Azerbaijan University of Architecture and Construction, Azerbaijan
Azerbaijan State Oil and Industry University, Azerbaijan
French-Azerbaijani University (UFAZ), Azerbaijan
Abstract: This paper proposes a numerical approach for designing feedback controllers in distributed parameter systems, using a rod heating process as a case study. In this setup, the control inputs are the heating power levels of spatially localized heat sources along the rod. The controller uses feedback based on temperature readings at

selected sensor locations and employs a zonal control strategy extended to include memory. In the memory-based zonal approach, the control law at time t depends on both the current observed state and a previous state from time t-Δ, partitioning the augmented state space (current plus recent past) into discrete zones each associated with a fixed control value. Unlike continuously varying feedback laws, this zonal-with-memory strategy updates the control only when the combined state trajectory crosses a zone boundary, resulting in fewer adjustments. This discrete update policy reduces actuator wear and enhances robustness against uncertainties in the initial rod temperature and ambient conditions. The control design problem is transformed into a finite-dimensional optimization over the set of zonal control values. We derive explicit formulas for the gradient of the objective functional with respect to these control parameters, enabling efficient gradient-based numerical optimization. A conjugate gradient projection method is used to iteratively tune the zone control values. Numerical simulations illustrate the feasibility of the proposed memory-augmented zonal controller and its ability to approach the desired terminal temperature profile with acceptable computational cost. The results also suggest how the inclusion of delayed observations influences the closed-loop behavior, including switching frequency and control effort.
Keywords: zonal feedback control, memory-dependent control, distributed parameter systems, heat conduction process, gradient-based optimization, lumped sources

Anit Devrim Akdeniz, Tuna Bostanci, Sevgi Yigit-Sert
Fine-Tuning a Lightweight Language Model for Symptom-Based Disease Prediction: A Comparative Study Against Large Language Models
Ankara University, Türkiye
Abstract: Recent advancements in large language models (LLMs) have greatly enhanced the capabilities of conversational AI, but their effectiveness in highly specialized domains such as healthcare remains limited. In this paper, we investigate whether a lightweight language model optimized on a targeted medical dataset for symptom-based disease understanding can perform better larger general-purpose models. A subset of the MedQuAD dataset was processed and arranged in a structural instruction-based dataset by filtering on symptom-disease-related question-answer pairs. Symptom extraction was performed using Mistral-7B, with the addition of data augmentation through paraphrasing to improve dataset diversity and generalization. The final dataset was used to fine-tune GPT-2 using different training configurations. The fine-tuned model was evaluated compared to several state-of-the-art general-purpose LLMs such as GPT-4, LLaMA-3.1-405B-Instruct, and DeepSeek-V3 through evaluation metrics such as Accuracy, BLEU, ROUGE-L, and BERTScore. The experimental results indicate that domain-adapted GPT-2 model significantly outperforms these high-capacity models in symptom-based disease prediction, achieving 88% accuracy and strong semantic similarity scores.

Keywords: Large Language Models (LLMs), Fine-Tuning, Domain Adaptation, Symptom-Based Disease Prediction

Ramil Akhundov, Elshan Hashimov, Aziz Talibov, Islam Islamov, Bayram Ibrahimov, Kostiantyn Dergachov

A Finite Capacity Queueing Model for Information Flow Processing in a Logistics Support System

National Defense University, Azerbaijan
Azerbaijan Technical University, Azerbaijan
Institute of Mathematics, Azerbaijan
Baku Engineering University, Azerbaijan,
National Aerospace University "Kharkiv Aviation İnstitute", Ukraine

Abstract: This paper proposes a capacity constrained single server queueing model for quantitative assessment of information flow processing in a transportation logistics environment. Arrivals to the processing node are modeled as a Poisson process, while service times follow a general distribution. Finite buffer capacity is explicitly considered, so that blocking and loss events occur when the queue is full. The study introduces an integral effectiveness indicator that evaluates the processing function not only through throughput, but also through delay dynamics and loss probability, augmented by reliability and information security factors. Two traffic classes are distinguished: useful traffic and service traffic, characterized respectively by the useful flow arrival intensity and the service flow arrival intensity. The integral indicator combines effective

throughput with reliability and security coefficients and applies penalties for excessive delay and loss. An optimization formulation is developed to maximize the indicator under predefined admissible limits for mean delay and rejection probability. The resulting framework supports decision rules for selecting server capacity, buffer size, priority policy, and the depth of security procedures, particularly under critical load conditions. Scenario based parameter variation for arrival intensities, mean service time, and buffer capacity is used to delineate the feasible operating region and identify the optimal operating point. The approach is applicable to centralized logistics platforms and distributed processing nodes.
Keywords: Queueing system, Finite buffer, Blocking probability, Information flow processing, Logistics support system, Optimization

Aytaj Akparli, Nazrin Hajiyeva, Elshan Gurbanov

The Dual-Readiness Framework: Integrating Technical Agile Maturity and Interpersonal Collaboration Readiness for IT Project Success in Azerbaijan

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: Organisations in Azerbaijan increasingly adopt Agile methodologies, yet comparable levels of formal implementation consistently yield divergent project outcomes—a paradox that invites us to look beyond technical process fidelity toward the interpersonal fabric

within which those processes operate. Understanding whether technical and interpersonal readiness function as independent contributors or as interacting forces has direct implications for how transformation investments should be sequenced in post-Soviet organisational contexts where hierarchical norms persist alongside Agile adoption. To investigate this, a convergent mixed-methods design was employed, combining quantitative survey data from N=70 validated respondents across Finance, IT, Manufacturing, Startup, and Education sectors (collected December 2025–January 2026) with thematic analysis of open-ended responses, enabling triangulation across measurement modalities. The Dual-Readiness Framework (DRF) was proposed, integrating Technical Agile Maturity (TAM) and Interpersonal Collaboration Readiness (ICR) as joint predictors of IT project success. Hierarchical OLS regression with mean-centred predictors revealed that TAM independently predicts project success (β=.165, SE=.052, p=.002). ICR explained significant incremental variance beyond TAM (ΔR^2=.126, p<.001); its standardised coefficient (β=.183) was empirically indistinguishable from that of TAM. The combined model yielded R^2=.322 (f^2=.476)—a 64% gain over the TAM-only baseline. The interaction term did not reach significance (β=-.038, p=.397), pointing toward additive rather than synergistic dynamics; ICR range restriction (SD=0.528) limits the power of this test. Quadrant analysis identified four theoretically meaningful configurations; Optimal Agile teams (high on both dimensions) showed the highest mean performance (M=3.818, n=33). Concurrent investment in both capability dimensions is associated with superior outcomes.

Keywords: Agile Maturity, Interpersonal Collaboration, IT Project Success, Azerbaijan, Psychological Safety, Dual-Readiness Framework, Post-Soviet Transformation, Hierarchical Regression

Gennady Algashev, Ilya Lezin

Hybrid Pose Estimation Technology for Multi-Object Dynamic Scenes in Real-Time Based on Computer Vision Methods and Neural Keypoint Detection

Samara National Research University (Samara University), Russia

Abstract: This paper presents a hybrid information technology for real-time object pose estimation from a single RGB image, specifically designed to operate in dynamic multi-object scenes under conditions of partial visibility (occlusions). The proposed approach integrates state-of-the-art deep learning methods for object detection and semantic keypoint localization with a modified geometric Perspective-n-Point (PnP) algorithm. A key feature of the developed technology is the use of an automated synthetic data generation pipeline with controllable parameters for occlusions, lighting, and textures. This significantly reduces the need for expensive manual annotation and enhances model robustness against domain shift. To ensure robustness under partial visibility, a modification of the PnP algorithm is proposed, which

employs weighted filtering of keypoints based on confidence scores from the neural network model. Experimental studies on a dataset of synthetic and real images (Lego bricks) using YOLO and ViTPose architectures confirmed the technology's effectiveness: high reconstruction accuracy was achieved (IoU up to 0.94 under full visibility), stable operation was maintained with only 25% of the object's area visible, and performance reached up to 146 FPS for a single object class, meeting the stringent real-time requirements of robotics and augmented reality applications.

Keywords: Pose estimation, computer vision, keypoint detection, PnP, synthetic data, real-time, occlusion

Rafig Alibeyli, Tofig Aliyev, Kamil Cebiyev

Algorithmic and Computational Analysis of Two Fundamental Number Theory Formulas

Türkiye

Azerbaijan

Abstract: This paper presents two fundamental formulas in number theory with both theoretical significance and computational relevance. The first formula establishes a representation of every natural number through an infinite nested radical structure, providing a novel analytical perspective on number decomposition. The second formula introduces a method for expressing natural numbers n>1n > 1n>1 as products of non-periodic infinite decimal fractions, extending classical representations of irrational and non-repeating numbers. Beyond their mathematical

interest, these formulas demonstrate practical applicability in modern computational fields. Number theory serves as a foundation for cryptography, coding theory, data security, algorithm design, and computational complexity. The proposed representations contribute to the theoretical framework underlying encryption systems, numerical algorithms, and efficient data processing techniques. The results highlight the interdisciplinary role of number theory by connecting abstract mathematical structures with real-world computational and information security problems. These findings provide both theoretical insights and potential directions for algorithmic implementation in computer science and related disciplines. AMS Subject Classification: 11Axx, 11Yxx, 68Wxx.
Keywords: Number theory, Cryptography, Algorithms

Telman Aliev, Asif Rzaev, Gambar Guluev
Development of Technologies for Increasing the Oil/Water Ratio in Oil Extraction from Low-Producing Wells
Ministry of Science and Education of the Republic of Azerbaijan, Azerbaijan
Institute of Mathematics, Azerbaijan
Abstract: This article analyzes the process of oil recovery from low-producing wells at the final stage of production using mechanized methods (SRPU – sucker-rod pumping units, electric submersible pumps, etc.). The object of the analysis is the technical data and operating modes of wells at SOCAR's Bibiybetneft oil and gas production unit. The

results show that, on average, 95% of the fluid recovered from the well is reservoir water. This underscores the low efficiency of oil production at such fields and the fact that measures aimed at improving it are always relevant. In this regard, the problems and technologies for developing technologies and control systems to increase the oil-to-water ratio in the fluid recovered from the well are explored, based on the application of modern innovations to the existing technological system. To this end, a technology is proposed for continuous monitoring of the dynamic level during well operation using an ultrasonic level meter installed at the wellhead and for regulating the flow rate of reservoir fluid entering the well from the reservoir by adjusting the borehole pump capacity. Implementation options for this technology for SRPU wells using dynamogram devices are also considered. The concentration of water and oil in the total volume of fluid extracted from the wells is simultaneously determined based on this change, and a function of the concentration's dependence on well productivity is determined for selected wells. Options for using both automated group measuring units in the Trap type and laboratory analysis to determine the concentration of water and oil in the total volume of fluid extracted from the wells are considered. Well productivity optimization problem and its solution methods are explored.

Keywords: Reservoir pressure, water injection, sucker rod pumping units, electric submersible pumps, oil/water ratio, well flow rate, optimization

Elshad Aliyev

Deepfake - New Possibilities in Contemporary Artistic Creation or a Threat to Information Security

Azerbaijan Architecture and Construction University, Azerbaijan

Abstract: In the contemporary digital era, information and communication technologies are advancing at an unprecedented rate, transforming various spheres of human activity. Among these innovations, artificial intelligence (AI) and deepfake technology represent one of the most striking developments in the IT sector. Deepfake technology, based on AI-driven algorithms that generate or manipulate audiovisual content, has become an influential tool in artistic creation, including film, digital media, design, and television. Its potential to produce realistic synthetic media has revolutionized creative processes, offering new artistic possibilities while simultaneously raising ethical and informational concerns. Although deepfakes are frequently associated with deception and misinformation, their applications extend far beyond illegitimate use. They are actively employed in entertainment, advertising, education, and social awareness campaigns, where they serve innovative and socially beneficial purposes. However, the growing accessibility of this technology has also facilitated its mis-use in political propaganda, defamation, and pornography, creating new challenges for information security and public trust. The present research explores the dual nature of deepfake technology—as both a creative

instrument and a potential digital threat. It examines the implications of its integration into media production, the artistic opportunities it offers, and the ethical dilemmas it introduces in the digital communication landscape. Ultimately, the study underscores the necessity of establishing regulatory, technological, and educational frameworks to ensure the responsible and constructive application of deepfake technology in the global media environment.
Keywords: Deepfake, Artificial Intelligence, Artistic Creation, Digital Media, Audiovisual Content

Ilgar Aliyev, Maarif Yusifov, Aftandil Isayev
Intelligent Control of Emergency Modes in Multi-Line Gas Pipelines via the Integration of Digital Monitoring and Analytical Computation
Azerbaijan University of Architecture and Construction, Azerbaijan
Abstract: This paper presents a novel intelligent control methodology for the reliable and real-time management of emergency modes in multi-line parallel gas pipelines based on the integration of digital monitoring and analytical computation mechanisms. Unlike conventional approaches that rely solely on sensor-based supervision, the proposed system combines IoT-driven real-time data acquisition with gas-dynamic analytical decision-making, enabling robust discrimination between technological and emergency operating regimes. An analytical criterion for emergency identification is introduced using time-

dependent inlet and outlet pressure variations, followed by a simple yet effective analytical framework for leak localization without requiring additional sensing devices. Furthermore, an optimal control strategy is developed for determining the opening time of interconnecting pipeline valves, taking into account the dynamic characteristics of compressor stations, thereby ensuring system stabilization and protection of intact pipeline lines. The proposed methodology is formulated as a closed-loop intelligent control system fully compatible with SCADA and IoT platforms, significantly reducing gas losses, operational risks, and economic damage to consumers. The obtained results provide a strong scientific and practical basis for the digitalization of industrial gas transmission systems and the development of smart energy infrastructure within the Industry 4.0 paradigm.
Keywords: multi-line gas pipelines, intelligent control systems, IoT-based monitoring, SCADA integration, leak localization, analytical modeling, industrial digitalization, Industry 4.0, energy transmission systems, digital gas pipelines

Ali Aliyev, Shahla Gahramanova

From Product Lifecycle Management (PLM) to City-Scale Urban Digital Twins: Origins, Definitions, Reference Architectures, and Adoption Challenges – A Scoping Review

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: As human settlements and digital infrastructure co-evolve, cities are exploring urban digital twins as a means to integrate a wide variety of data and support decision-making and planning models into the urban planning footprint. Parallel advancements in the Internet of Things (IoT), Building Information Modelling (BIM), geospatial platforms, and computational processing power have improved the technical feasibility of such systems. However, the concept remains inconsistently defined, while system architectures and means of evaluation vary widely across fields. This paper traces how the digital twin concept evolved from Product Lifecycle Management (PLM) into urban applications and analyses the minimum criteria, common reference architecture layers, and the technical barriers that shape city-scale adoption practices. The review firstly explores definitional components, minimum functional criteria, and clarifies related categories such as digital models and digital shadows. We then conduct a scoping review of academic literature, standards and public frameworks, then compare reported implementations across key components, including data sensing/management, semantic modelling, simulation, analytics, visualization and governance. Based on the review, we identify recurring technical problems that limit the progress of this technology from becoming decision-making tools in the urban environment, such as weak system compatibility, limited validation, unclear operational responsibilities, disorganised data ownership, privacy and accountability requirements. The review

concludes with a classification framework and specification checklist, plus research directions to help support more feasible and scalable deployment of urban digital twins.
Keywords: Urban digital twin, Product Lifecycle Management (PLM), Decision-making, city-scale adoption, digital modelling, Urban planning

Chinar Aliyev, Agassi Melikov
Structured Conditional Histograms for Multi-Attribute Range Selectivity Estimation
Baku State University, Azerbaijan
Baku Engineering University, Azerbaijan
Abstract: Accurate estimation of multi-attribute range query selectivity is essential for cost-based query optimization in relational database systems. Despite extensive research, most practical optimizers still rely on the Attribute Value Independence (AVI) assumption, which ignores correlations among attributes and often produces large estimation errors on real-world data. Multidimensional histograms explicitly model attribute correlations but suffer from exponential space complexity and high maintenance cost, limiting their applicability in high-dimensional settings. In this paper, we propose Structured Conditional Histograms (SCH) for skewed OLAP workloads, a lightweight histogram-based framework that approximates conditional de-pendencies without constructing full multidimensional histograms. SCH selects a single pivot attribute, partitions its domain into histogram buckets, and augments each bucket with

compact conditional metadata for non-pivot attributes, including min/max envelopes, Top-k frequent values, and tail distinct counts. Range predicates are evaluated sequentially through conditional bucket refinement, yielding an approximation of joint selectivity via a conditional probability chain at the bucket level.
Keywords: Selectivity estimation, histograms, conditional probability, query optimization, correlated attributes, database statistics

Elbay Aliyev, Nizami Naghiyev, Sabina Aliyeva
Digital Transformation of Urban and Rural Settlement Systems in Azerbaijan
Azerbaijan University of Architecture and Construction, Azerbaijan
Abstract: This article presents a comprehensive analysis of the paradigmatic transition in the planning, design and management of urban and rural settlements in the Republic of Azerbaijan. The study was conducted in the context of the implementation of the "Great Return" state program in the liberated territories and "Azerbaijan 2030: National Priorities for Socio-Economic Development". The work synthesizes the historical urbanization theories of "group settlement systems" described in detail in archival urban planning documents with modern achievements of Industry 4.0 - Building Information Modeling (BIM), Geographic Information Systems (GIS), Digital Twins and Cyber-Physical Systems (CPS). Special attention is paid to the analysis of the "Smart Village" pilot project in the Agali

village of Zangilan region as a benchmark for post-conflict reconstruction. The article argues that the successful digital transformation of the Azerbaijani village requires not only the application of smart technologies, but also a deep integration of generative design with local (vernacular) architectural traditions. The research aims to develop a strategic roadmap for creating sustainable, culturally rooted, and economically viable rural communities. This approach can reverse the historical trend of "rural-urban" migration and ensure balanced territorial development.
Keywords: smart villages, smart cities, IT integrated architecture, Aghali village, Azerbaijan architecture

Adalat Aliyev, Asaf Aghayev, Konul Aghayeva

The Role of Information Technologies in Architecture and Construction and Their Contribution to the Sustainable Development of Cities and Regions of the Republic of Azerbaijan

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: Information technologies used in architecture and construction imply the application of digital data related to villages, cities, and regions of a country, covering all spheres of human activity within the social, economic, and environmental context. It is precisely digital data obtained through information technologies that makes it possible to plan architectural and construction activities in rural settlements, cities, and regions in such a way as to effectively meet human needs in all areas of life. Digital

information technologies play a key role in creating a unified model that brings together all participants in the architectural and construction process and prevents miscalculations and errors in architectural planning and in the design and construction of residential buildings, industrial facilities, and essential municipal support systems (water supply, sewage, electricity, transport communications, marketing services, social service facilities, waste-free waste collection and processing, etc.). At the same time, these technologies enable efficient monitoring of all types of resources that ensure human life support. Information and communication technologies, as a source of digital data required for architectural and construction projects, enable the solution of all tasks necessary for the construction of smart houses, villages, and cities. This highly complex system allows objective planning of the construction of buildings and industrial structures, as well as the required engineering communications, including the effective automated supervision of regulatory authorities and facilities. Thanks to information technologies, effective software is being developed in all areas of human activity, including residential and industrial design and construction. Software tools for architects and designers of construction projects have become widely used in all developed countries. Based on digital-data processing made possible by information technologies, modern data-processing methods are being developed that allow the implementation of architects' and designers' ideas and

transform them into models for effective management. Special attention should be given to the construction of IT infrastructure facilities in accordance with modern requirements and the specific nature of the work performed. As an example, one can consider Heydar Aliyev International Airport in Baku, which, according to the implemented project, is designed to serve approximately 5,000 passengers per hour (the design capacity of Terminal 1, fully commissioned in 1997, is 1,700 passengers per hour, and that of the newest Terminal 2 is 3,300 passengers per hour). As a rule, such facilities require the establishment of a powerful basic IT infrastructure, which includes: • a security system, including antivirus protection; • a video surveillance system covering all areas of passenger processing, cargo handling, and technical maintenance; • a video communication and telephone system; • a data processing center; • public address and fire suppression systems; • a structured cabling system; • a local area network for one thousand users; • e-mail services; • Internet access; • administration of database systems; • other specialized systems.
Keywords: information technologies, digital data, architecture, construction, design, models, supply control, communications, Dell Compellent Storage Center storage system, HPE ProLiant DL380 Gen10 server

Svetlana Allahverdiyeva, Vafa Jafarova
Noise in Big Cities and Methods of Combating It

Azebaijan University of Architecture and Construction, Azerbaijan
Abstract: One of the most widespread harmful factors of the urban environment is noise. Noise sources interfere with people's rest, causing dissatisfaction and irritation. When de-signing buildings and structures, architects must take into account the noise load on individual facilities as well as on the entire building complex. Noise protection can be implemented both at the source of noise generation and along its path of propagation. For the effective adoption of appropriate measures, it is necessary to know the noise characteristics of the sources. Noise maps make it possible to more rationally plan measures to combat noise of both urban-planning and administrative nature related to the organization of urban transport traffic. Transport, industrial, and domestic noise are considered as the main noise sources. The effectiveness of protecting buildings from sound waves increases with distance; moreover, the efficiency of protection is enhanced by greening the space located between the noise source and the receiver. Satisfactory protection results can be achieved when the green zone extends over more than 100 m. The construction of buildings with enclosed courtyard layouts in developments strictly parallel to the street should be considered an effective measure; however, such an arrangement affects the architectural and planning solution of the building. The main methods used to limit noise propagation include appropriate external and internal spatial planning, the installation of adequate sound

insulation for the enclosing structures of residential and public buildings, and related measures.

Keywords: Noise sources, noise load, transport noise, industrial noise, domestic noise, protection efficiency, sound insulation of enclosing structures

Okkes Tolga Altinoz

Redesigning the Particle Swarm Optimization Algorithm as a Reinforcement Learning Methodology

Ankara University, Türkiye

Abstract: Modern optimization algorithms consist of algorithms that have been developed, improved, and expanded for many problems, including extensive, stochastic, noise multi, many, bi-level, as well as traditional optimization problems. These relatively complex algorithms are based on traditional algorithms. These complex structures are increasingly being combined with learning-based methods. They can be used in conjunction with machine learning methods, particularly reinforcement learning, and are also used within these methods. These algorithms can be evolutionary algorithms or nature-inspired algorithms. Among nature-inspired algorithms, one of the most widely used is the Particle Swarm Optimization algorithm. The PSO algorithm is used in conjunction with machine learning algorithms, as well as for the problem-oriented application of these algorithms. In this study, however, the PSO algorithm will be redesigned as a reinforcement learning method, diering from these applications. Thus, innovation suggestions will be made

regarding the parameters and formulations of the algorithm according to their areas of use, its performance will be evaluated, and improvement suggestions will be presented.

Keywords: Particle Swarm Optimization, Reinforcement Learning, Learning-based Optimization, Machine Learning, Single-objective, Optimization

Okkes Tolga Altinoz

Reinforcement Learning for Linear Quadratic Regulation to Control Discrete-Time Balancing Experimental Set

Ankara University, Türkiye

Abstract: Model-free Reinforcement Learning (RL) is a machine learning architecture that can be eectively used for many applications including controlling dynamic systems without requiring model information. The agent can be designed and evaluated on controlling the discrete time control systems. Among many control laws optimal control methodologies are more suitable for this application of RL on control systems since they prefer objective functions which can be assessed as reward function. Among these control laws, the linear quadratic regulator (LQR) is an optimal controller that does not need a model. Instead of the Riccati Equation, Q learning based algorithms inside an agent preferred to control the discrete time dynamic system. In this research this methodology will be applied to the ball and beam balancing experimental system. The obtained controller with Rl agent and the

conventional LQR by solving the Riccati Equation will be compared with each other and their performances will be compared.
Keywords: Control Systems, Reinforcement Learning, Intelligence Control, Linear Quadratic Control, Balancing Experiment Set, Machine Learning

Ihsan Altun, Kerem Küçük, Halil Aydoğuş
Evaluating the Impact of Processor Isolation on Deterministic Behavior of Virtual PLC Solutions for Industrial Edge Platforms
Siemens A.S, Research and Development, Türkiye
Kocaeli University, Türkiye
Abstract: Virtual Programmable Logic Controllers (vPLCs) allow industrial control functions, visualization, data collection, and IT services to run together on IT-like virtualized production systems. Running multiple applications on shared hardware improves flexibility and reduces costs, but also creates resource conflicts in the virtualization layer that can harm the precise timing required by control tasks. This paper examines processor core isolation as a practical method to reduce timing variations (jitter) in SIMATIC Virtual PLC running on a Siemens Industrial Edge platform. We compare two setups: a vPLC with dedicated processor cores and a vPLC sharing cores with other applications. The evaluation uses eight carefully designed test scenarios that combine real-time communication, CPU-intensive tasks, and background network traffic. We measure timing precision using jitter

values from a cyclic interrupt block set to be triggered every 1 ms. Results show that processor core isolation reduces jitter significantly, with improvements ranging from 30.95% to 68.17% across all scenarios. Under the most demanding conditions, jitter drops from 1.176 ms without processor isolation to 0.501 ms with processor isolation. These findings demonstrate that processor isolation is an effective and practical technique to improve vPLC timing stability on shared industrial platforms.
Keywords: virtual PLC, industrial edge, determinism, real-time, jitter, CPU core isolation, processor isolation, virtualization, latency

Nubiyya Arif Gizi, Yegane Pashayeva, Nigar Gambarova, Samira Hasanova

Modeling and Application of an Expert System for Decision-Making in Viticulture Adapted to the Climate of Azerbaijan

Institute of Mathematics, Azerbaijan

Abstract: This article presents an information technology-oriented conceptual model of an expert system for decision-making in viticulture adapted to the climatic conditions of Azerbaijan. The study focuses on the formal representation of agronomic knowledge, integration of heterogeneous data, and development of an explainable decision-making mechanism. The system combines soil indicators (pH, salinity, humus), climate indicators (temperature, precipitation, humidity, frost risk), irrigation, and phytosanitary parameters within a unified

knowledge base and produces results through rule-based inference. From the perspective of information technology, the proposed approach addresses key challenges such as knowledge formalization, management of inter-rule conflicts, operation under incomplete and uncertain input data, adaptation to regional parameters, and scalable system architecture. The model integrates IF–THEN rules, a forward-chaining inference mechanism, an expert-weight-based reliability model, and an explanation module of the type “Why was this decision made?”. As a result, the system unifies land suitability assessment, variety selection, irrigation and fertilization planning, and disease risk forecasting on a single digital platform. The model reduces subjectivity in agricultural decision-making, strengthens data-driven management, and is justified as a practical, scalable scientific-applied solution for the digital transformation of viticulture in Azerbaijan.
Keywords: expert system, viticulture, decision-making, knowledge base, inference engine, IF–THEN rules, forward chaining, artificial intelligence (AI), digital agriculture

Nubiyya Arif Gizi, Ulviyya Goyushova, Atakishi Goyushov, Emin Babayev

Model-Based Sequential Restoration of Motion and Spatially Varying Defocus Blur in Digital Images

Institute of Mathematics, Azerbaijan

Abstract: Digital images frequently suffer from motion blur and spatially varying defocus blur, which significantly degrade visual quality and reduce the reliability of

subsequent image analysis tasks. Motion blur is typically modeled as a linear convolution resulting from relative camera–scene motion during exposure, whereas defocus blur is optically induced and spatially variant. Accurate restoration of these degradations remains a challenging problem in practical imaging conditions. This study proposes a model-based sequential restoration framework for the removal of known linear motion blur followed by adaptive compensation of space-variant defocus blur. Motion degradation is first addressed using channel-wise Wiener deconvolution to recover high-frequency components while preserving edge fidelity and chromatic consistency. Defocus regions are then identified through local variance estimation, enabling selective enhancement via an adaptive multi-level Unsharp Mask applied exclusively to blurred areas. A mild contrast refinement stage is incorporated to maintain natural visual perception and suppress over-enhancement artifacts. Experimental evaluation on real-world images captured under uncontrolled conditions demonstrates consistent performance gains, including an average PSNR improvement of approximately 5 dB, reduced MSE values, and increased SSIM indices across all test samples. The results indicate that the proposed adaptive space-variant deblurring strategy achieves robust and statistically significant image quality recovery, outperforming conventional non-adaptive restoration approaches in both quantitative metrics and perceptual assessment.

Keywords: Motion blur, Defocus blur, Image restoration, Wiener filter, PSF, Adaptive sharpening, SSIM

Ayşin Ceren Arslan, Merve Özkan, Kürşat Yıldız

Spatial Prediction and Safe Route Optimization of Autonomous Vehicle Accidents: Machine Learning and GIS-Based Integrated Approach

Gazi University, Türkiye
Ankara University, Türkiye

Abstract: This study aims to holistically model the occurrence of accidents, conflict risk and accident severity in order to increase traffic safety in autonomous vehicle systems. Traffic accidents, despite the advanced driving assistance systems, still remain an important problem. Therefore, the study proposes a multi-layered approach that models not only the existence of the event, but also its severity and temporal formation dynamics. Methodologically, Logistic Regression, XGBoost, Random Forest and Decision Tree models, which are classical machine learning algorithms, were applied as reference models first, and then the original PG-MTNet architecture based on physical meaningful feature separation was developed. This structure learns vehicle dynamics and environmental context through separate encoders and produces multiple outputs with a task-based gate mechanism. In order to model temporal dependencies, the architecture has been extended to PG-TMTNet structure and short- and long-term effects have been learned with LSTM-based encoders. Gradient blocking has been applied

to Decrement the gradient interaction between tasks. The findings obtained show that the proposed multitasking and temporal deep learning architectures offer a powerful, interpretable and extensible framework in traffic safety modeling.
Keywords: Autonomous Vehicle, Deep Learning, Machine Learning, GIS-Based Routing

Jamila Asadova, Valeriya Musayeva

Application of Machine Learning Technologies for Image Recognition and Process Optimization in Industrial Systems

Ministry of Science and Education of Azerbaijan, Azerbaijan
Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: This research investigates the integration of intelligent technologies, specifically Machine Learning (ML), within the industrial sector to enhance image recognition and optimize operational processes. The study successfully identifies effective methodologies for adapting modern algorithms to industrial environments. Key areas of focus include the development of models for visual defect detection, real-time image processing, and the integration of ML into SCADA systems. Furthermore, control strategies based on time-series analysis are proposed to improve decision-making accuracy. The efficacy of the proposed models was validated through a series of computational experiments using international benchmark datasets. The

results demonstrate that ML-based approaches significantly reduce human intervention, automate production workflows, and optimize quality control. By facilitating automated recognition and early error detection, these systems contribute to resource conservation and increased industrial productivity. This work provides a systematic synthesis of theoretical foundations and practical implementations of ML in modern industry.
Keywords: Machine Learning Image Recognition,
Industrial Automation SCADA Integration, Visual Defect
Detection Process Optimization

Jamila Asadova, Ali Talibov
Comparative Evaluation of Deep Learning Algorithms for Automobile License Plate Recognition
Azerbaijan University of Architecture and Construction, Azerbaijan
Baku State University, Azerbaijan
Abstract: This study presents a series of computational experiments designed to evaluate the efficacy of license plate recognition (LPR) algorithms implemented in the Python programming language. The research focuses on the development, adaptation, and benchmarking of contemporary deep learning frameworks, specifically Region-based Convolutional Neural Networks (RCNN) and You Only Look Once (YOLO) architectures. These models were rigorously tested against real-world datasets to ensure practical applicability. The experimental

methodology employed standardized testing protocols to ensure the objectivity and reproducibility of results. Key performance indicators (KPIs) investigated include recognition accuracy, inference speed, and robustness against environmental variables such as fluctuating lighting conditions and varying camera perspectives. Empirical results confirm the high efficiency of the selected deep learning models across diverse operational scenarios. A granular analysis of the experimental data identifies the specific technical strengths and limitations of each approach. These findings provide a foundational basis for the optimization of LPR systems and offer strategic recommendations for the further refinement of automated vehicle identification technologies.
Keywords: Deep Learning YOLO RCNN, License Plate Recognition, Computer Vision, Algorithm Optimization

Rena Asadova

Intelligent Method for Measuring the Delivery of an Electrocentrifugal Deep Well Pump in Oil Wells

Institute of Mathemetics, Azerbaijan

Abstract: The article proposes an intelligent method for measuring the flow rate of an electric centrifugal deep well pump (ECDWP) based on the integration of pressure data, the dynamic level of formation fluid, and the power consumption of the electric motor. The method is intended for use in intelligent oil production control systems and allows for more accurate and rapid determination of well flow rates without the use of cumbersome separation

measuring devices. An algorithm for calculating the flow rate of an electric centrifugal pump is presented, which takes into account changes in the density of the reservoir fluid and the current efficiency of the pump. An example of practical implementation and calculation results are given.
Keywords: intelligent measurement system, electric centrifugal pump, well flow rate, oil production, pressure sensors.

Jamila Asadova, Toghrul Suleymanov
Intelligent System Development Using Reinforcement Learning for Dynamic Difficulty Adjustment
Azerbaijan University of Architecture and Construction, Azerbaijan
Altinbash Cyprus University, Azerbaijan
Abstract: This paper investigates the implementation and efficacy of Dynamic Difficulty Adjustment (DDA) in interactive environments. The primary objective is to mitigate player attrition caused by boredom or frustration by maintaining an optimal challenge level. To achieve this, the study proposes an intelligent framework leveraging Machine Learning (ML) and Reinforcement Learning (RL) to monitor real-time behavioral metrics, including reaction latency and performance accuracy. The framework was validated using a computer simulation of the game Connect Four. Empirical results demonstrate that AI-assisted DDA significantly enhances player retention and satisfaction by facilitating a persistent "flow state." However, the findings also highlight a critical trade-off: the necessity of precise

calibration to avoid "over-adjustment," which can lead to perceptions of artificiality or unfairness. The study concludes that these adaptive intelligent systems hold significant potential for cross-industry applications, particularly within the domains of education and cybersecurity.
Keywords: Reinforcement Learning, Dynamic Difficulty Adjustment, Machine Learning, Adaptive Systems.

Yegana Ashrafova
Locating Pipeline Segments in Complex Networks with Leakages
Baku State Universtiy, Azerbaijan
Abstract: This study develops a computational framework for detecting potential leakage segments within complex hydraulic networks using discrete measurements of transient flow parameters. The leak identification problem is expressed as a parametric optimal control model characterized by hyperbolic partial differential equations, unknown initial conditions, and nonlocal boundary constraints. The numerical approach follows the general methodology outlined in earlier works, with modifications that account for measurement uncertainties and expanded network complexity. Gradient-based first-order optimization techniques are applied to minimize the deviation between observed and simulated flow regimes. The proposed method is evaluated through numerical experiments on a five-node pipeline configuration,

demonstrating robustness under varying leakage intensities and error levels.
Keywords: pipeline of complex structure, sections with potential leaks, fluid leaks, optimization techniques

Furkan Atban, Muhammed Yusuf Küçükkara, Cüneyt Bayılmış
Quantum Transfer Learning with Pretrained CNN Features for Multi-Class Medical Image Classification
Sakarya University of Applied Sciences, Türkiye
Sakarya University, Türkiye
Abstract: The automated classification of Optical Coherence Tomography (OCT) images is crucial for the early diagnosis of retinal diseases such as Choroidal Neovascularization (CNV), Diabetic Macular Edema (DME), and Drusen. While classical Deep Learning (DL) models achieve high performance, they often require massive computational resources. In this study, we propose a hybrid Quantum Transfer Learning (QTL) framework that combines a fine-tuned ResNet34 encoder with a Variational Quantum Circuit (VQC) for multi-class classification. Unlike standard approaches that utilize fixed feature extractors, we employ a partial fine-tuning strategy on the classical backbone to adapt high-level representations for OCT textures. Furthermore, the hyperparameters of the quantum circuit are optimized using Particle Swarm Optimization (PSO) to maximize classification accuracy. Experimental results on the OCT2017 dataset demonstrate that the proposed hybrid model achieves a competitive

accuracy of 89.38\% with a significantly reduced parameter space compared to fully classical counterparts. These findings validate the feasibility of hybrid quantum-classical models in medical imaging, offering a promising direction for parameter-efficient diagnostics in the Noisy Intermediate-Scale Quantum (NISQ) era.

Keywords: Quantum Transfer Learning, Medical Image Classification, Optical Coherence Tomography, Hybrid Neural Networks, Particle Swarm Optimization

Gokhan Aydin, Burak Aydin, Hakan Aydin, Sedat Gormus, Ibrahim Ugur Yılmaz

Trust-Aware Blackhole Detection and Fast Topology Recovery in RPL-Based 6TiSCH Networks

Karadeniz Technical University, Türkiye

Abstract: Industrial Internet of Things (IIoT) applications increasingly rely on 6TiSCH networks to provide deterministic latency, high reliability, and energy-efficient communication. However, the integration of RPL routing exposes 6TiSCH networks to routing attacks, among which the blackhole attack represents a particularly severe threat. In such attacks, malicious nodes advertise falsified routing metrics to attract traffic and subsequently drop data packets while remaining protocol-compliant. The problem becomes more challenging in dynamic industrial environments, where node mobility and frequent parent switching introduce packet losses that closely resemble malicious behavior. This paper proposes Tengri-6T, a trust-aware security framework designed to detect and mitigate

mobile blackhole attacks in RPL-based 6TiSCH networks. The framework employs a telemetry-driven trust model that jointly evaluates packet forwarding behavior and topology stability, enabling the differentiation of intentional packet drops from mobility-induced disruptions. A hybrid mitigation strategy is adopted, combining centralized trust evaluation at the 6TiSCH root with fast localized topology recovery to rapidly isolate detected attackers without triggering costly global RPL repairs. The effectiveness of Tengri-6T is evaluated through extensive simulations using Contiki-NG and the Cooja under grid and random topologies with mobile attackers. Experimental results demonstrate that Tengri-6T significantly improves packet delivery ratio compared to attacked RPL while maintaining moderate control packet overhead, confirming its practicality for dynamic industrial 6TiSCH deployments.
Keywords: Trust-based security, Blackhole attack, RPL routing, Mobility attack, 6TiSCH

Rustam Azimov, Chingiz Khalilov, Elshan Mustafayev, Ilgar Mahmudov

Enhancing the Reliability of Mass Examination Evaluation Through Integration of OMR and Handwritten Character Recognition

Institute of Mathematics, Azerbaijan
State Examination Center of the Republic of Azerbaijan, Azerbaijan

Abstract: Large-scale information systems increasingly rely on pattern recognition technologies. Ongoing advancements in image processing methodologies, combined with accessible open-source libraries, have made it possible to design effective solutions for a variety of practical tasks, among which is the automatic evaluation of examination answer sheets. A major challenge in these systems is the handling of incorrectly filled forms, particularly for open-ended questions. In many examination formats, students are required to provide answers both by marking predefined fields and by writing the answer in hand-written form. Discrepancies between these two representations may arise, leading to am-biguous or inconsistent responses. Therefore, a comparative analysis of these values is required in order to infer the answer intended by the examinee. In this work, a Convolutional Recurrent Neural Network (CRNN) with a bidirectional LSTM sequence modeling layer is employed as the core handwritten recognition module. A cross-validation framework is proposed that systematically compares the CRNN output against the corresponding OMR result for each digital field, enabling automatic detection of incorrectly filled forms and reducing the proportion of records requiring manual opera-tor review.
Keywords: information processing, intelligent system, evaluation of results, image processing, CRNN, OCR

Rustam Azimov, Ali Mehtizada

Effectiveness Analysis of Using Approaches Based on Morphological Operations for Cleaning Images from Natural Noise

Institute of Mathematics, Azerbaijan,
Baku Engineering University, Azerbaijan

Abstract: Image degradation caused by natural noise remains a fundamental problem in image processing, directly affecting the reliability of subsequent analysis and interpretation. This study investigates the effectiveness of image cleaning approaches based on morphological operations for removing natural noise while preserving essential structural features. A controlled experimental framework is designed using synthetically generated elementary images composed of simple geometric shapes such as circles and rectangles. These images provide a well-defined reference structure for quantitative evaluation. Random noise with varying characteristics is artificially introduced into the original images to simulate natural degradation. Several morphological-based image cleaning approaches are then applied with the aim of restoring the images to their original form. The performance of each approach is evaluated using standard image quality metrics, including Mean Squared Error (MSE) and Mean Absolute Error (MAE). Two primary comparisons are conducted: (i) between the original and noisy images to quantify the level of degradation, and (ii) between the cleaned and noisy images to assess the effectiveness of noise removal. The proposed quality adjustment test methodology enables an objective comparison of different

morphological strategies under identical conditions. Computer experiments demonstrate how specific morphological operations influence noise suppression and shape preservation. The results provide insights into the suitability of morphological approaches for image quality adjustment tasks and highlight their potential advantages and limitations in cleaning images affected by natural noise.
Keywords: image processing, image quality adjustment, morphological operations, quality adjustment test methodology, computer experiments

Rustam Azimov, Ioannis Faraslis
Computer Vision System for Analysis of Vegetative States of Plants using Multispectral Images from UAVs
Institute of Mathematics, Azerbaijan
University of Thessaly, Greece
Abstract: Intelligent computer systems based on remote sensing are widely used in many areas, including agriculture. Among the problem set for the development of such computer systems are monitoring of transport routes, determination of infrastructure objects (buildings, roads, etc.) for urban planning, determination of surface movements for geological scientific research studies, automated cartography for military intelligence, control of target objects, forecasting crop yields for agriculture, monitoring of weeds and pests, determination of diseased plants, etc. The approaches for a computer system for monitoring the health of cultivated areas are used in this study. The effectiveness of the approaches used in this

study is analyzed on the example of computer experiments conducted on multispectral data obtained from apple orchards using unmanned aerial vehicles. In the study, a segmentation model based on image instances was built for the identification of trees in multispectral images of apple orchards, and this model was used to identify tree segments in multispectral images of apple orchards. Then, a statistical approach was proposed for the identification of the vegetative health status of apple trees based on images consisting of vegetative indicators of the cultivated area. Using this approach, both the vegetative health status of individual tree segments and the overall health status of the plantation were identified.
Keywords: remote sensing, precise agriculture, machine learning, image segmentation, health state estimation

Arzu Babayeva, Yadigar Imamverdiyev
Advanced Hybrid Intelligent Control Strategies for Robotic Manipulators: A Critical Analysis
Azerbaijan Technical University, Azerbaijan
Abstract: Robotic manipulators are complex nonlinear dynamic systems operating under uncertainties, varying loads, and external disturbances, which complicates control tasks. This paper presents a review and analytical study of manipulator control methods, covering traditional, intelligent, and hybrid approaches. The fundamentals of mathematical modeling, including kinematics and dynamics based on the Lagrange equations, are presented to illustrate system complexity. Classical control methods

are analyzed with an assessment of their strengths and weaknesses, alongside intelligent approaches based on fuzzy logic, neural networks, and machine learning algorithms. Special attention is given to hybrid strategies that combine the stability of traditional methods with the adaptability of intelligent approaches, including an analytical evaluation of their stability, adaptability, and effectiveness. A conceptual hybrid control model for a robotic manipulator incorporating Reinforcement Learning (RL) is also proposed. Additionally, current development trends and open challenges in robotic manipulator control are discussed.
Keywords: Robotic Manipulators, Hybrid Control, Reinforcement Learning, Intelligent Control, Control Strategies

Firuza Badalova
Digital Management Platforms in Open and Closed Spaces
Azerbaijan University of Architecture and Construction, Azerbaijan
Abstract: Digital management platforms are widely used in the modern era. Smart management systems play an important role in the management of spaces. While the idea of remotely controlled open or closed environments seemed unbelievable several years ago, today we witness that we have become users of these platforms. The purpose of the article is to introduce smart management platforms used in the management of open and closed spaces, and to

explain their advantages and operating principles. At the same time, the article presents real application areas of smart platforms through examples. The article provides information about the advantages of digital management platforms, as well as the technologies and applications used. Digital management platforms in open spaces are widely applied in the management of urban infrastructure and the environment. This primarily includes the management of city services, traffic management, automated management of parking spaces, automation of street lighting, and similar applications. Digital management systems in closed spaces are mainly applied to optimize the internal spaces of buildings and offices. As a result, digital management systems optimize movement, increase comfort and safety, and improve energy efficiency. The use of digital management platforms has become an essential part of comfortable living in society
Keywords: digital management, management systems, mobile application, mobile platform, modern management systems, urban infrastructure

Ashraf Balametov, Tarana Isayeva, Tofiq Yaqublu
Application of Facts Devices to Increase Power System Voltage Stability
Azerbaijan Scientific-Research and Design-Prospecting Power Engineering Institute, Azerbaijan
Azerbaijan State Oil and Industry University, Azerbaijan
Abstract: The operating modes of the power system must be stable, and they must also be safe in the event of

potential unforeseen circumstances. Power systems operate closer to the limits of their stability. Maintaining the stable and safe operation of the power system is an important and complex problem. In recent years, great attention has been paid to voltage stability, and it is considered one of the main sources of unreliable operation of the power system. In the Unified Energy System (UES), voltage can drop below its normal value. Regions of the Unified Energy System (UES) connected by weak links and long lines have problems with voltage drop and are a source of stability disturbances due to higher loads. The application of Flexible AC Transmission System (FACTS) devices allows passive electrical networks to acquire active properties and enables flexible control of power system operating modes. FACTS devices allow increasing the transmission capacity of the electrical network. An improvement in damping low-frequency oscillations is proposed by placing a unified power flow controller in the power system. The effectiveness of the application was demonstrated on a test example of a heterogeneous network with voltages of 220, 330 and 500 kV. An automatic damping system is known as a means of improving the stability of power systems. Damping can be achieved using other devices specifically installed to improve stability. Power system instability results from loss of generator rotor synchronism due to insufficient damping torque for low-frequency oscillations.

Keywords: electric power system, nonlinear equations of steady state, convergence, existence, uniqueness of

solution enhancement of voltage stability, FACTS devices, STATCOM, unified power flow controller.

Ashraf Balametov, Gulnara Musakhanova, Afaq Salimova

Methods of Artificial Intelligence in Electric Power Engineering

Azerbaijan Scientific-Research and Design-Prospecting Power Engineering Institute, Azerbaijan

Abstract: Optimization of power system modes is a central ¬issue in the work of operational dispatch services. This article examines the application of Hopfield artificial neural networks to solving the problem of optimal load distribution between thermal power plants in the Azerbaijan Electric Power System. The power system is controlled by changing its state. The main control parameters are the active power of the generator equipment operating at the stations and its output. In a market economy , non - optimal operating conditions for thermal power plants can lead to significant economic damage not only to the power system but also to the national economy as a whole. Solving the optimization problem involves formulating an optimality criterion, adequately representing the object, i.e., constructing a mathematical model, and selecting a solution method. Among the most common approaches to formalizing its solution are the relative increment method, various modifications of gradient methods, and hybrid methods. With a large number of variables, their implementation is

significantly complicated by the need to solve high-dimensional nonlinear systems of equations. From this perspective, the use of artificial intelligence (AI) methods, in particular artificial neural networks (ANN), is promising. AI methods do not involve complex algorithmic calculations. The performance of the developed program was verified on a test circuit with three power plants using a Hopfield neural network and compared with the results of a numerical simulation method. Unlike existing approaches, this article utilized the dependence of active power losses on power plant generation in the form of a verbal description of an artificial neural network, derived from the results of multivariate power flow calculations

Keywords: Energy system, optimization, specific fuel consumption, relative gains, Hopfield neural networks

Tamara Bardadym, Aleksandr Lefterov, Oleksandr Fedosieiev

Problem of Knowledge Verification in the Era of Generative AI Development

V.M. Glushkov Institute of Cybernetics of the NASU, Ukraine

Abstract: The exponential growth of AI-generated content driven by Large Language Models (LLMs) has rendered traditional knowledge verification methods critically insufficient. This paper examines the core challenge of knowledge verification in intelligent digital platforms employing generative AI, analyzing why LLMs are architecturally predisposed to subjectivity and

hallucination. The study reviews three principal verification approaches – blockchain-based source tracking, Natural Language Processing (NLP) pipelines, and multimodal data verification – evaluating their capabilities and limitations. The paper further identifies key constraints of existing methods, including data bias, lack of contextual nuance, and susceptibility to adversarial manipulation, arguing that full automation of verification remains unattainable without human oversight. To address these limitations, the authors propose a set of platform-level approaches encompassing decentralized knowledge reputation systems, dynamic knowledge graphs, tiered verification architectures, and subject-oriented complementary algorithms. The findings suggest that effective knowledge verification requires a hybrid architecture integrating AI automation with expert consensus mechanisms, operating as a permanent, embedded function across the entire knowledge lifecycle of intelligent platforms.
Keywords: Knowledge Verification, Generative Artificial Intelligence, Large Language Model (LLM), Intelligent Digital Platform, Hybrid Verification

Suman Basak

Agentic Secure Software Development Lifecycle

Individual Researcher, United States

Abstract: The integration of artificial intelligence into the Software Development Lifecycle represents a paradigm shift in how enterprise applications are built, secured, and

deployed. This paper presents a comprehensive agentic architecture that automates the entire SSDLC pipeline—from JIRA ticket analysis and code generation to security scanning and deployment— using autonomous AI agents powered by Model Context Protocol (MCP). This article says about a production-ready implementation that achieved 87% reduction in manual development effort, 94% security vulnerability detection rate, and 65% faster time-to-deployment across 150+ enterprise microservices in the Payment Software Industry. This architecture uses three smart agents that work together. The Dev Agent writes the code, the Security Agent checks the code for security issues, and the Dev Rework Agent automatically fixes any problems found. All three are coordinated through a central MCP hub that uses knowledge retrieval (RAG) to make better decisions. This approach provides both a clear design model and real-world implementation guidance for building intelligent, self-driven development systems that stay secure while delivering software faster.
Keywords: AI Agents, SSDLC, MCP, Payments, Autonomous Development, RAG, Security Automation, Enterprise Architecture

Rza Bashirov

A Hybrid Petri Net Framework for Predicting Therapeutic Targets for β-Globin Disorders

Eastern Mediterranean University, Türkiye

Abstract: This work presents a hybrid Petri net-based formal modeling, simulation, and quantitative analysis of

the fetal-to-adult hemoglobin switch, a regulatory process central to β-globin disorders. The proposed model integrates discrete representations of drug and gene therapeutic interventions with continuous dynamics of gene expression, protein interactions, and multiprotein complex formation, enabling executable system-level analysis within a unified formalism. The hybrid Petri net model is calibrated and validated using published qPCR data, ensuring quantitative consistency with experimentally observed gene expression fold-changes under both physiological and perturbed conditions. Stochastic simulations are performed to evaluate the dynamic response of the regulatory network to multiple drug-based and gene–based interventions. This computational setting enables direct, objective comparison of alternative therapeutic strategies and supports systematic exploration of novel intervention scenarios. Simulation results reproduce known experimental outcomes and further predict previously unexplored combinatorial targeting strategies that yield substantially higher γ-globin induction than existing approaches. These findings illustrate the effectiveness of hybrid Petri nets as a rigorous computational methodology for hypothesis-driven target discovery in complex drug-gene-disease networks.
Keywords: Hybrid Petri net, Quantitative modeling, β-thalassemia, Targeted drug discovery, Gene therapy

Zarina Bashirova

Creation of AI-Based Model to Assess Children's Intellectual Potential

Azerbaijan State Pedagogical University, Azerbaijan
Institute of Mathematics, Azerbaijan

Abstract: Information technology constitutes a main part of our lives in modern era. These technologies create opportunities for the utilization of new methods, forms, and means in education, the formation of children as an individual, the identification and development of their hidden and obvious skills. These possibilities pave the way for the improvement of more effective methods to assess children's intellectual skills. This paper presents the AI-based conceptual system architecture that is offered with the purpose of assessing children's intellectual potential. The suggested system receives children's behaviour indicators (reaction period to tasks, percentage of correct answers, sustained attention, interest level, etc.), passes them through the initial processing stage, determines key indicators according to those data, and forms a general assessment result by means of the AI module based on predefined rules. The model aims to identify the children's potential at an early stage, to reveal their strengths and weaknesses, and to determine their individual development directions. The offered model could be considered an efficient system enabling educators to simplify and optimize their work, to design individual training strategies, and to monitor children's development. This model could analyse children's behaviour indicators, define the level of skills and shape their individual profiles.

Keywords: Artificial Intelligence, Model, Assessment System, Behaviour Indicators, Intellectual Potential

Yusif Binnatov

The Role of Information Technology in Improving Tender Mechanisms

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: In modern economic conditions, tender mechanisms play an important role in ensuring the efficient use of financial resources of the state and private sector. Globalization, the development of the digital economy and increasing demands for transparency in public procurement necessitate the improvement of tender mechanisms. Traditional tender mechanisms are in some cases accompanied by information asymmetry, high influence of the human factor, subjectivity in decision-making and corruption risks, which leads to a decrease in economic efficiency, especially in areas with high financial intensity, such as the construction sector. In this regard, the integration of information technologies into tender mechanisms acts as one of the main directions of increasing their functional effectiveness. Electronic tender systems, digital procurement platforms, big data and artificial intelligence-based analytical tools allow for the automation of tender processes, increasing transparency and strengthening the competitive environment. The article systematizes the theoretical foundations of tender mechanisms, examines the impact of information

technologies on the organization and results of tender processes, and also evaluates the economic efficiency of the application of electronic tender mechanisms in the construction sector based on empirical generalizations. The research results show that the application of information technologies allows for a reduction in operating costs in tender processes, the formation of winning proposals at a more optimal level compared to the initial cost of projects, and the provision of savings to public funds. The article puts forward practical proposals for improving tender mechanisms in Azerbaijan on a digital basis, taking into account international experience. The purpose of the study is to evaluate the role of information technologies in improving tender mechanisms on a scientific basis and to put forward practical suggestions.
Keywords: tender mechanisms, information technologies, electronic tendering, digitalization, public procurement

Arkadii Chikrii, Viktor Vyshenskyy
The Role of Information in Game Problems of Intercepting Controlled Targets
V.M. Glushkov Institute of Cybernetics of National Academy of Sciences of Ukraine, Ukraine
Abstract: This study compares several methods for pursuing controlled targets in game-theoretic problems. Particular attention is given to the information requirements necessary for implementing these methods. The pure pursuit method requires minimal information — only the direction from the pursuer to the evader. At the

other extreme, parallel navigation and proportional navigation require maximal information, including the current positions of both players and the evader's control input at each instant of time. The beam-rider method occupies an intermediate position: it requires only the distance to the pursuer from some reference point and the angular velocity vector of the evader. Computer simulations were conducted to model pursuit dynamics under various evader behaviors. These simulations allow the calculation of interception times for different methods and evader trajectories. The results show that, in some cases, methods with lower information requirements can achieve shorter interception times, whereas methods with higher information demands may perform significantly worse. These findings high-light the need for further research into the effectiveness of the considered methods, as well as their associated information requirements.
Keywords: Differential Games, Pure Pursuit, Parallel Navigation, Proportional Navigation, Beam-rider, Resolving Function

Afrin Akter Dolna, Ananna Sardar, Nowshin Nowyer Oyshi, Mohammad Nyme Uddin

Machine Learning–Based Prediction of Lighting Levels in University Classrooms

Building Energy & Environmental Management-BEEM Enhanced by AI, Dhaka, Bangladesh

Abstract: The regulation of lighting levels in the classroom is very essential to ensure that the learning environment is

healthy and comfortable for the students, who spend a significant amount of time in the classroom. Low lighting levels can lead to increased visual fatigue, reduced concentration, and high levels of stress among students, which can ultimately affect their performance in class. Despite its significance, there is a lack of research studies that involve the use of data analysis in understanding the relationship between lighting levels in the classroom and stress among students, especially in developing nations. The objective of this study is to propose classification-based machine learning (ML) models for predicting the lighting level, in a classroom environment in a university setting, which is a critical environmental factor that can affect student stress levels. A total of 300 data samples were collected from a classroom environment in a university in Dhaka, Bangladesh. The parameters considered both qualitative and quantitative parameters including environ-mental parameters, demographic parameters, perceptual parameters, and architectural parameters. For predicting the level of lighting, ML models such as Extreme Gradient Boosting (XGBoost), Random Forest (RF), and Decision Tree (DT) were used. To enhance the accuracy of the models, Gridsearch CV was used. The performance of the models was evaluated using classification matrix. The models showed good performance in predicting the level of lighting; however, the performance of the XGBoost model was the best, with the highest accuracy of 98.33%, followed by the RF model with 93.33%, while the performance of the DT model was

the lowest, with 73.33%. The results of SHapley Additive exPlanations (SHAP) analysis indicated the most influential factors on lighting level. The present study proposes a machine learning-based approach to predict classroom lighting conditions in relation to student stress, and it provides valuable insights into how various indoor environmental conditions affect student stress. The results of this study could be used to devel-op evidence-based classroom design and management strategies to improve student comfort and reduce stress. In future, this study should be extended to a larger dataset, seasonal effects, and various environmental conditions to improve its generalizability.
Keywords: Machine learning models, Lighting levels, Student stress, University classrooms, Feature analysis

Sergei Dotsenko, Vladimir Semenov
On Centrality Ordering in Logistics Networking
Taras Shevchenko National University of Kyiv, Ukraine
Abstract: We consider an index of the centrality of a graph vertex based on the vector of distances from that vertex to other vertices. It is shown, that for the indices under consideration, the partial order axioms are satisfied. Besides, it was also shown, that well-known centrality measures such as closeness centrality and harmonic centrality are based on the vector centrality index we are considering, while betweenness centrality is not in general case. At the end, an illustrative example of calculating the centrality index of stations on the Baku metro map was

considered. For this example, comprehensive calculations and comparisons were performed. The example under consideration demonstrated two approaches to comparing vertex centrality indices. The first (quantitative) approach is based on direct calculations and comparison of the results. This approach is of practical interest. The second (qualitive) approach is based on the graph structure and the position of the vertices within the graph. This approach works only in some particular cases and is of more theoretical than practical interest.
Keywords: simple graph, line graph, tree, centrality measure, closeness centrality, harmonic centrality, metro map

Oleg Dranko, Anna Belova
Data Collection Algorithm for Price Optimization of Cash Flow
V.A. Trapeznikov Institute of Control Sciences of the RAS, Russia
Abstract: This paper examines a pricing model based on its impact on various organizational development criteria. We reviewed the Azides model of the organizational life cycle, identifying certain stages where cash flow is the primary economic criterion. We developed a model for optimal pricing based on cash flow, identifying the conditions for a price that maximizes cash flow. A big data collection algorithm was used to analyze financial statements in the in-formation technology sector. We processed the financial statements of 2.9 million Russian organizations. From the

resulting dataset, a subset of IT companies was selected for analysis. The resulting data allowed us to test the model on real data. Our empirical testing confirms the theoretical predictions of the model. The optimal price that maximizes cash flow is not a static value but depends critically on the organization's position in its life cycle. The large-scale dataset provides strong external validity to these conclusions.
Keywords: management, modeling, optimization, life cycle, prices, cash flow, profit, investments, big data

Oleg Dranko, Kirill Trushin

A Model of Factors Affecting Industry Value Added Growth

V. A. Trapeznikov Institute of Control Sciences of the RAS, Russia

Abstract: We examined enterprise performance indicators used to calculate and model value added and its contribution to gross domestic product growth. The approach is based on a simple linear model, focusing on managing performance parameters that reflect an enterprise's ability to convert revenue and investment into value added. The relationships between individual company-level indicators and aggregated industry characteristics are analyzed, allowing for the identification of structural differences, bottlenecks, and growth opportunities. A key focus is on examining how enterprise performance indica-tors influence the total value added of an industry and, consequently, the dynamics of GDP,

calculated using the production method as the aggregate value added of all economic sectors. This approach provides a quantitative framework for selecting priority areas for public and private investment, aimed at maximizing value added growth for a given resource allocation. The proposed approach allows us to rank enterprises and industries based on their real contribution to value creation, support the structural restructuring of the economy, and justify economic policy measures aimed at accelerating sustainable economic growth by concentrating investments in the most effective segments.
Keywords: modeling, management, system dynamics, forecasting, growth, value added, indicative planning, factors

Mustafa Sefer Erdoğan, Sait Demir, Emrah Özkaynak
Complex Network-Based Centrality Analysis of FIFA World Cup Matches
Karabuk University, Türkiye
Abstract: Analysis of sporting events holds significant potential for understanding the complex interactions between teams and players. Traditional statistical methods for analyzing football matches are limited in revealing the complex relationships between teams in these events. In this study, matches from the FIFA World Cup between 1930 and 2014 were analyzed and interpreted using complex network structures based on complex network theory. Degree distribution, clustering coefficient, density, diameter, modularity, betweenness centrality, closeness

centrality, and composite centrality score metrics of the complex network structure, created using a total of 83 teams and 578 unique match pairings, were calculated. Calculated metrics show that the World Cup match network has a "small-world" structure with low density, high clustering coefficient, and short average path length. Modularity analysis identified five different communities, and it was observed that these communities were formed based on geographical and historical factors. Centrality analyses revealed that Brazil, Italy, and Argentina were the most centrally located teams in the network. The obtained topological metrics demonstrate that long-term, match-based team interactions in World Cup history can be successfully modeled using complex network theory, and that the network structure of matches throughout the tournament's history can be systematically examined.
Keywords: Complex Networks, Centrality, Small-World, Data Mining, Sports Networks

Sahib Farzaliyev, Gulbade Abbasova, Namig Abdullayev, Shaig Guluzada

Genetic Algorithm-Based Optimization of High-Rise Reinforced Concrete Construction: A Methodology for Integration with National Structural Norms

Azerbaijan University of Architecture and Construction, Azerbaijan

Archi Burea Azerbaijan LLC

Abstract: Finding an optimal balance between time, cost, and resource efficiency remains a critical challenge in high-

rise construction project management. This study optimises the construction process of a 12-storey monolithic reinforced concrete building using a multi-objective Genetic Algorithm (GA). Distinct from recent global literature, the primary scientific novelty of this research is the direct integration of Azerbaijan's National Normative Database (DESN-2021) into a mathematical model developed in Python 3.9. This approach ensures that labour intensity and machine productivity parameters strictly adhere to regional technical standards. While the model is validated against these specific standards, the developed algorithm is designed for universal applicability and can be adapted to other international structural codes. The project was divided into 48 independent construction zones, and simulations were performed within defined resource constraints, including crane availability, labour force, and formwork rotation. Results indicate that the proposed optimisation model reduces the total construction duration from 172 to 148 days (13.9%). Furthermore, tower crane utilisation was stabilised at 80-85%, significantly reducing idle time and achieving direct economic savings of approximately 25,000 AZN per building block. These findings establish a reliable, data-driven decision support mechanism for implementing digital management systems and enhancing economic performance in the regional construction sector.
Keywords: Genetic Algorithm, High-rise construction, Monolithic reinforced concrete, Resource optimization,

DESN-2021 norms, Construction scheduling, Economic efficiency, National structural standards

Shavkat Fazilov, Shukhrat Mamadjanov

System Analysis of Acne Diagnostics Using Artificial Intelligence

Digital Technologies and Artificial Intelligence Development Research Institute, Uzbekistan
Tashkent International University, Uzbekistan

Abstract: Acne, considered one of the dermatological disorders, is a widespread skin disease that often occurs during crucial developmental stages in adolescents and can lead to long-term psychosocial consequences. Traditional methods, such as assessing overall severity and counting rash elements, are limited by subjectivity and time constraints. This article focuses on a systematic review of the latest advancements in diagnosing acne, detecting and counting rash elements, and assessing severity using artificial intelligence (AI), highlighting the potential of AI-based methods to improve objectivity, reproducibility, and clinical effectiveness. A comprehensive literature search was conducted in PubMed, Scopus, arXiv, Embase, and Web of Science databases for studies published from 2017 to February 2026. The search strategy included terms related to "acne" and various AI methodologies (e.g., "neural network," "deep learning," "convolutional neural network"). During the research process, 391 articles were reviewed, of which 39 articles met the final criteria. Data were extracted on study design, dataset characteristics

(including internal and open-access resources such as ACNE04 and AcneSCU), AI architectures (primarily CNN-based models), and performance indicators. Although AI-based models have demonstrated high accuracy under controlled conditions, the scarcity of large public datasets, the predominance of data from specific ethnic groups, and the lack of comprehensive external validation reveal significant barriers to implementation in clinical practice. The research findings indicate that while AI has the potential to standardize acne assessment, reduce observer variability, and enable self-monitoring through mobile platforms, there are considerable challenges in achieving reliable real-world application. Future research should prioritize the creation of large, diverse, and openly accessible datasets and conduct prospective clinical trials to ensure fair and effective dermatological care.
Keywords: acne, artificial intelligence, acne position, dermatology, image classification, computer vision

Jinan Fiaidhi, Supprethaa Shankar, Tharun Sekar, Kushal Kushal, Sabah Mohammed
Investigation into Generating Medical Narratives: Can US Medical Licensing Exams (USMLE) Be Reliably Generated and Verified?
Lakehead University, Canada
Abstract: Clinical Narratives and USMLE share the same base line representing storytelling for describing clinical cases. However, USMLE is more structured narrative that is used for assessment. In this paper, we are presenting a

Graph Retrieval-Augmented Generation (GraphRAG) pipeline tailored for USMLE-style clinical narratives. Our method integrates a Neo4j-based UMLS knowledge graph with a MedQA vector store, and introduces two key innovations: (i) graph-enhanced query expansion to enrich retrieval coverage, and (ii) an adaptive re- ranking mechanism that jointly weights symbolic and semantic evidence before LLM decoding. Evaluation on a set of USMLE- style questions demonstrates that the proposed LLM-Informed strategy outperforms both context-strict and baseline LLM approaches, achieving higher correctness and stronger citation alignment. While experiments are limited to a small dataset, results highlight the promise of hybrid graph–vector retrieval for improving factual accuracy and interpretability in clinical question answering.
Keywords: Clinical Narratives, USMLE, GraphRAG, GenAI, Question-Answering Mechanisms

Oğuz Findik, Maha Albayati
Ensemble Strategies for Turkish Legal Extractive Summarization Using Semantic Voting and Rouge-Weighted Averaging
Karabuk University, Türkiye
Abstract: The increasing volume of Turkish legal documents poses a significant challenge for legal professionals who must sift through complex, domain-specific language to extract essential information. While extractive summarization has shown promise in many

languages, Turkish presents unique difficulties due to its agglutinative morphology and the rigid structure of legal discourse. Existing approaches primarily rely on single-method techniques, often failing to capture semantic relevance and contextual structure. To the best of our knowledge, this study introduces the first domain-oriented ensemble approach for Turkish legal extractive summarization, enhancing baseline TF-IDF and TextRank outputs through semantic voting and ROUGE-guided weighting. A curated 100 Turkish court decisions dataset was developed and annotated with expert-written reference summaries to evaluate summarization quality. Performance was assessed using ROUGE metrics, with the Semantic Voting approach yielding modest improvements (ROUGE-1: +9%, ROUGE-2: +6%) over the TextRank baseline. The ROUGE-Weighted Averaging method demonstrated substantial gains (ROUGE-1: +49%, ROUGE-2: +88%, ROUGE-L: +10%, ROUGE-Sum: +42%), confirming the effectiveness of dynamically weighted ensemble models. This work offers a valuable tool for judges, lawyers, and legal researchers by significantly reducing the time and effort required to review lengthy legal texts, while ensuring the extracted summaries remain accurate, relevant, and easy to interpret.
Keywords: ensemble methods, extractive summarization, ROUGE evaluation, semantic similarity, Turkish legal summarization

Konul Gafarbayli, Bayram Aslanov

Smart Buildings, Smart Villages, and Smart Cities: Applications of Digital Technologies in Architecture

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: The global transition toward digital transformation has revolutionized architecture and construction, paving the way for intelligent systems that improve sustainability, efficiency, and livability. Smart buildings, smart villages, and smart cities represent an interconnected framework where architecture integrates information technologies such as the Internet of Things (IoT), Building Information Modeling (BIM), artificial intelligence (AI), and data analytics. This paper explores the application of these technologies in the field of architecture, focusing on energy management, sustainable urban planning, and digital infrastructure. The study highlights examples from both global and Azerbaijani contexts, including the "Aghaly Smart Village" project in Zangilan, which stands as a leading model for post-conflict reconstruction and rural innovation.

Keywords: Smart building, smart city, smart village, architecture, digital technologies, BIM, IoT, Azerbaijan

Shahla Gahramanova, Kamal Ibrahimov

From Caspian Shores to Mountain Peaks: ICT-Powered Tourism Resilience in Azerbaijan

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: Azerbaijan's diverse geography – from mountain resorts and forested national parks to coastal areas along the Caspian Sea and historic urban centers – makes the country increasingly vulnerable to climate-related risks that affect tourism. The country spans 9 out of 11 major climate types, which generates highly varied tourism patterns, including more than 2 million annual visitors to Baku and approximately 250-300 thousand to major mountain resorts such as Shahdag and Gabala. These hazards – including heatwaves, landslides, flooding, coastal storms and pressures on heritage sites pose challenges to visitor safety and long-term sustainable development. This paper examines how information and communication technologies (ICT) can strengthen tourism risk management and climate adaptation in Azerbaijan, including regions with still-developing digital infrastructure. The paper highlights a range of accessible ICT tools (weather monitoring platforms, mobile alert systems, open-source GIS mapping and digital route guidance) that can support early warning, visitor management and spatial planning. Special attention is given to the role of crowdsourced information, including tourist feedback, geotagged images and community-based reporting. These sources can provide valuable insights even in the absence of costly technological systems. Based on this analysis, the paper proposes a practical model for integrating ICT into local governance and destination management in Azerbaijan. The findings suggest that even simple digital solutions can enhance climate resilience,

protect cultural and natural heritage and improve the overall safety and experience of visitors. This approach supports Azerbaijan’s broader strategy to develop smart, sustainable and competitive tourism destinations.

Keywords: Azerbaijan Tourism, Climate Adaptation, Risk Management, ICT Tools, Sustainable Destinations

Ilya Galaktionov, Vladimir Toporovsky, Oleg Kolesnikov

Semi-Automatic Laser Beam Profile Shaping System with the Phase-Only Spatial Light Modulator

Moscow Technical University of Communications and Informatics, Russia

Abstract: The precise spatial shaping of a laser beam's intensity profile remains a critical and persistent challenge in modern optics, with significant implications for di-verse applications ranging from industrial laser cutting and welding to advanced fields like long-distance wireless energy transmission. A primary objective involves converting the laser's native Gaussian intensity distribution, characterized by a central peak and radial decay, into optimized profiles tailored for specific tasks. For instance, generating a uniform "flat-top" profile is essential for achieving consistent results in applications such as material surface processing and holographic recording, where even energy deposition is paramount. Conversely, an annular "doughnut-like" profile, featuring a central intensity null, promotes a uniform radial temperature distribution on a target. This is highly advantageous for

stabilizing thermal processes like laser melting and crystal growth. To address this need for dynamic and precise beam control, an automated, closed-loop adaptive optical system was constructed and evaluated. This system integrates a phase-only spatial light modulator (SLM) as the active wavefront-shaping element, coupled with a camera that functions as an intensity analyzer within a feedback loop. We present experimental results demonstrating the system's successful generation of both flat-top and doughnut-like intensity distributions from an initial Gaussian beam. The performance was quantified by measuring the "power-in-the-bucket" efficiency, representing the fraction of the initial beam's total energy contained within the target profile. The system concentrated approximately 60% of the energy into the doughnut-like annulus and approximately 75% into the flat-top distribution, validating the efficacy of this adaptive, SLM-based approach for complex beam shaping.
Keywords: Spatial Light Modulator, Wavefront Correction, Control Algorithm, Beam Shaping, Adaptive Optics

Ilya Galaktionov, Oleg Kolesnikov, Vladimir Toporovsky
Framework for Optimization of the Piezoelectric Wavefront Correctors in Free-Space Optical Communication Links
Moscow Technical University of Communication and Informatics, Russia

Abstract: This work presents a comprehensive framework aimed at optimizing parameters of piezoelectric wavefront correctors used to compensate atmospheric turbulence effects in free-space optical communication systems. The optimization of the deformable mirror parameters is based on the dynamical and spatial conditions of the atmospheric turbulence such as Fried parameter and Greenwood frequency. . The main contributions include development of an advanced simulation model incorporating key factors such as actuator geometry, material properties and dimensions of the wavefront corrector elements. By addressing these challenges, this study significantly enhances the efficiency and robustness of adaptive optics solutions, enabling high-quality data transmission over long distances despite adverse atmospheric disturbances. Results demonstrate substantial improvements in signal-to-noise ratio and overall system stability compared to conventional approaches.
Keywords: adaptive optics, atmospheric turbulence, free-space optical communication

Khanlar Gamzaev, Sevinc Kerimova

Computer Simulation of the Elastic Regime of the Development of a Single-Well Reservoir with an Unknown Initial State

Azerbaijan State Oil and Industry University, Azerbaijan

Abstract: To describe the elastic regime of the development of a single-well oil reservoir, a model of a turbulent filtration flow of a single-phase liquid is

proposed, presented in the form of a nonlinear parabolic equation with respect to the volume flow of the liquid. The laws of change in the time of the well flow rate and the pressure at the bottom of the well are considered to be set. The distribution of fluid flow in the reservoir at the initial moment of time, as well as the presence of a hydrodynamic connection between the reservoir and the external region, are considered unknown. Within the framework of the proposed model, the task is to determine the distribution of fluid flow in the reservoir, including the boundary. This problem belongs to the class of boundary value inverse problems without initial conditions. To numerically solve the inverse problem, a discrete analogue of the problem on a uniform difference grid is first constructed using the method of difference approximation. To solve the resulting system of linear equations, a computational algorithm is proposed that makes it possible to determine the flow rate of a liquid at all nodal points of the calculated part, with the exception of a certain triangular area. The calculated value of the fluid flow rate at the outer boundary of the formation determines the presence or absence of a hydrodynamic connection between the formation and the outer region. Numerical experiments for a model oil reservoir were carried out based on the proposed computational algorithm.
Keywords: Single-Well Oil Reservoir, Elastic Development Mode, Turbulent Filtration Law, Boundary Value Inverse Problem Without Initial, Conditions, Difference Approximation Method

Sachli Ganiyeva

Analysis of Oil Reserves in the Caspian Sea from Geological and Ecological Aspects

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: Surrounded by five littoral states: the Republic of Azerbaijan (Azerbaijan), the Islamic Republic of Iran (Iran), the Republic of Kazakhstan (Kazakhstan), the Russian Federation, and Turkmenistan, the Caspian Sea is the largest landlocked body of water on Earth. The isolation of the Caspian basin, combined with its climatic and salinity gradients, has created a unique ecological system with nearly 400 species endemic to the Caspian waters. Today, many Caspian species are threatened by overexploitation, habitat destruction, pollution, and climate change. This has a negative impact on human well-being, social and economic sectors, and ecological services. Oil production in the Caspian Sea basin, particularly offshore platform operations, impacts the region's ecological balance. The environmental impact, particularly on aquatic bioresources, zoobenthic organisms, phytoplankton, and bird populations, demonstrates the complexity and responsibility of sustainable exploitation of these resources. Along with studying the existing geological potential, understanding and assessing the environmental impacts is a key prerequisite for the region's sustainable development. Therefore, the study of oil resources requires a comprehensive approach, not only from a geological but

also an environmental perspective. The main objective of this article is to systematically analyze the geological characteristics of oil resources located in the Azerbaijani sector of the Caspian Sea and their environmental impacts, assess the current situation, and provide scientifically sound recommendations for the future.

Keywords: oil spills, Caspian Sea, natural disaster, tectonic faults, anthropogenic impact

Vagif Gasimov, Nargiz Mammadzada

Data Shuffling Algorithm for Preserving Privacy and Utility of Analysis

Baku Engineering University, Azerbaijan
Azerbaijan Technical University, Azerbaijan

Abstract: The reconciliation of individual privacy with data utility re- mains a pivotal challenge in modern data science, particularly concerning the statistical correlations between variables that enable re-identification attacks. While traditional anonymization techniques such as differential privacy or perturbative masking often degrade data fidelity by introducing noise, this study introduces Maze and Random edges bases Shuffle, a novel data-preserving algorithm designed to adjust the Pearson correlation coefficient between numerical variables to a precise target value solely through permutation operations. By modeling the shuffling process as a Markov chain over a stochastic, conflict-free edge swap mechanism on a constructed graph, we establish a robust theoretical framework rooted in spectral graph theory. We rigorously prove that

constructing the underlying graph with a specific expander-like structure—combining a Depth First Search (DFS) maze with random short- cuts—ensures a constant spectral gap independent of the dataset size N. Consequently, we demonstrate that the correlation converges to the target at an exponential rate, requiring only a constant number of mixing rounds. This theoretical guarantee allows the Maze-Shuffle algorithm to achieve a total linear time complexity of O(N), significantly outperforming traditional O(N log N) rank-based methods such as the Iman- Conover transformation or computationally prohibitive O(N^3) optimal transport approaches. Furthermore, the proposed method perfectly pre- serves the marginal distributions of the data, offering a zero-loss utility guarantee for univariate statistics while providing a tunable mechanism to minimize relational information leakage.
Keywords: Data Privacy, Correlation Control, Expander Graphs, Markov Mixing Times, Spectral Graph Theory, Linear Time Algorithms

Vagif Gasimov, Artughrul Gayibov

Agricultural Land Mapping in the Karabakh Region of Azerbaijan Using Dynamic World and Machine Learning

Baku Engineering University, Azerbaijan

Abstract: Agricultural land mapping supports land-use planning and monitoring, yet supervised classifiers often face limited locally validated labels. This paper reports a

Google Earth Engine workflow for Agricultural Land Code (ALC) mapping in Azerbaijan's Karabakh economic region and compares Random Forest and Classification and Regression Tree (CART) classifiers. Filtering the FAO GAUL level-2 boundaries in Azerbaijan in Shusha, Aghdam, Khojaly yielded an Area of Interest (AOI) feature count of 2. The analysis window was 2024-01-01 to 2024-12-31. ALC pseudo-labels were constructed by combining a stable Dynamic World label from mean class probabilities (confidence threshold 0.55) and ESA WorldCover cropland/grassland codes to define 0 (non-ag/other), 1 (cropland), and 2 (pasture/grassland). Predictors formed a 22-band stack from Sentinel-2 Surface Reflectance Harmonized imagery, four indices, SRTM topography, Dynamic World probability bands, and the WorldCover map. Stratified sampling produced 1800 points, split into 1250 training and 550 test samples. On the test set, Random Forest achieved overall accuracy 0.9745, kappa 0.9618, and macroF1 0.9740; CART achieved overall accuracy 0.9982, kappa 0.9973, and macroF1 0.9982.
Keywords: Google Earth Engine, Sentinel-2, Dynamic World, ESA WorldCover, Agricultural Land Mapping, Random Forest, CART

Aydin Gasimov

Parameter-Efficient Fine-Tuning of Compact Large Language Models for Multi-Domain Sentiment Analysis

Azerbaijan State Oil and Industry University, Azerbaijan

Abstract: Parameter-efficient fine-tuning (PEFT) offers a practical path for adapting compact large language models (LLMs) when computational budgets are tight. This paper investigates whether low-rank adaptation (LoRA) of a 270M-parameter Gemma backbone can deliver competitive sentiment classification performance across heterogeneous domains and label granularities. We evaluate three benchmarks: FinancialPhrase- Bank (three-class), SST-5 (five-class), and a six-class emotion dataset. The study compares predictive quality, ranking behavior, calibration, and resource efficiency, reporting accuracy, macro-F1, ROC-AUC/PRAUC, Expected Calibration Error, Brier score, training time, peak GPU memory usage, and checkpoint size. Results indicate that LoRA-adapted compact models achieve strong accuracy and ranking quality with reliable probability estimates, while dramatically reducing trainable parameters and memory footprint relative to full fine-tuning. We further analyze class-level error patterns and reliability curves to characterize model behavior under domain shift and label ambiguity. These findings highlight a favorable quality–efficiency trade-off and support PEFT as a viable strategy for sentiment analysis in resource-constrained settings.
Keywords: parameter-efficient fine-tuning, LoRA, sentiment analysis, calibration, compact LLMs

Samir Guliyev, Seymur Mirzabekov
Synthesis of Zonal Controls for Lumped Systems with Memory Under Discrete Observations

Azerbaijan State Oil and Industry University, Azerbaijan
French-Azerbaijani University (UFAZ), Azerbaijan
Abstract: This paper proposes an expanded feedback control synthesis framework for nonlinear lumped-parameter systems under partial observability and sampled-data conditions. In the considered formulation, both the model parameters and the initial state of the system are assumed to be uncertain, and their values are only known to belong to prescribed admissible sets with given probability distributions. To achieve robust performance under these uncertainties, we partition the measured output into finitely many zones and assign zone-dependent feedback laws with memory. The control input is updated only at discrete sampling instants using the current output sample, delayed output samples, and a finite-window integral (moving-average) memory term, and is held constant between updates (zero-order hold). This structure reduces feedback synthesis to a finite-dimensional parametric optimization problem over the zone-dependent gains. We introduce a performance objective that combines regulation quality and control effort, averaged over uncertain initial conditions and parameter variations. The resulting optimization problem is solved by gradient-based methods using analytically derived (adjoint-based) gradient formulas with respect to the zonal gains. Numerical experiments on a nonlinear benchmark system illustrate feasibility of the framework and quantify the influence of discrete observations and memory terms on settling time and control energy.

Keywords: zonal feedback control, sampled-data control, memory-dependent control, discrete-time observations, parametric optimization, lumped systems

Samir Guliyev, Zulhija Guliyeva

Adaptation of Static Models' Parameters of Objects with Feedback

Azerbaijan State Oil and Industry University, Azerbaijan
University of Miami Herbert Business School, United States

Abstract: In the work, we propose an approach for concurrent adaptation of static model parameters and optimization of operating regimes for decision-making systems aimed at improving the operation of technological processes. This makes it possible to obtain a locally optimal mathematical model in the vicinity of the optimal operating regime, rather than a globally averaged approximation constructed over the entire observation range. The work presents computational formulas and iterative algorithms for the implementation of the proposed approach, including (i) a multi-stage active experimentation scheme and (ii) a continuous iterative update based on weighted regression. The main advantage of the proposed solution variants is that the final decision is optimal with respect to the mathematical model constructed predominantly from (or emphasized toward) those observations of the information model that are closest to the optimal solution. Thus, the resulting model can be considered locally optimal with respect to the decision made, which improves the

accuracy and consistency of optimal regime determination compared with the classical two-stage identification–then–optimization procedure. The results of conducted numerical simulations confirm that the proposed integrated approach can significantly enhance decision-making quality when optimizing technological processes via static surrogate models, and can yield better operating regimes than those obtained using a fixed nominal model.
Keywords: static models, parametric identification, optimization, weight functions, least-squares regression, information model

Huseyngulu Guliyev, Nikita Tomin, Najaf Orujov, Nijat Huseynov, Arif Guluzade

Methodological Foundations for Improving the Accuracy of Short-Term Forecasting of Wind Power Plant Output Based on Machine Learning Methods

Azerbaijan Technical University, Azerbaijan
Institute of Energy Systems named after L.A. Melentyev SB RAS, Russia
Baku Engineering University, Azerbaijan
Artishok events" LTD, Azerbaijan

Abstract: Renewable energy, primarily wind and solar power plants, is playing an increasingly significant role in the structure of the global energy system. At the same time, wind energy conversion systems (WECS) are characterized by a number of specific features, the most significant of which is the variability of the wind resource. Changes in wind speed lead to fluctuations in generated power,

creating additional challenges for integrating WECS into modern power systems. As the installed capacity and number of WECS increase, their impact on the reliability indicators of electrical networks becomes more noticeable. In this regard, the tasks of short-term forecasting of wind speed and generated power, ensuring the stability and reliability of network operation, as well as organizing effective maintenance of installations in the event of faults, become particularly relevant. Solving these problems plays a key role in maintaining the stable operation of the power system as a whole. This paper presents the results of short-term forecasting of wind speed and WECS power output using neural network approaches, namely Extreme Learning Machine (ELM) and Long Short-Term Memory (LSTM). Modeling and calculations were carried out in the Matlab and R software environments for the distribution networks of the Absheron Peninsula (Azerbaijan), which include wind energy installations.

Keywords: renewable energy sources, wind energy, solar installations, forecasting, neural network, machine learning

Tarana Guliyeva, Tarana Mammadova, Aypara Shabanova

Computer Simulation of Waterhammer

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: A water hammer is a sudden increase or decrease in pressure in a hydraulic system caused by wave

processes. This phenomenon is caused by the inertia and elasticity of the fluid. The presented article considers the issue of modeling this process in WaterGEMS software.
Keywords: water hammer, software, pipe, valve pressure, wave, tank, pipeline network

Parvin Guliyeva
Carriage of Goods Within the Country
Azerbaijan University of Architecture and Construction, Azerbaijan
Abstract: The article examines the organization of domestic freight transportation by road, focusing on the growing demand for such services in Azerbaijan due to rapid urban development, population growth, and expanding infrastructure. Road transport is highlighted as the most preferred mode for internal cargo movement because of its flexibility, speed, and ability to provide door-to-door delivery. The study emphasizes that successful freight transportation requires not only compliance with legal regulations but also careful consideration of customer expectations, cargo characteristics, and operational efficiency. Factors such as cargo size, weight, type, urgency, and special handling requirements play a key role in selecting appropriate vehicles, routes, and drivers. The technical condition of vehicles and drivers' working schedules are also identified as critical elements for ensuring safety and reliability in a competitive market. By analyzing the practices of several cargo transportation companies operating within the country, the article

illustrates how integrated services—such as packaging, labor support, insurance, and warehousing—contribute to higher customer satisfaction. The advantages and disadvantages of road transport are discussed, alongside a classification of cargo types commonly transported domestically. A significant contribution of the article is the proposal to develop an integrated information system for managing cargo transportation processes. This system would centralize order management, vehicle and driver data, and execution tracking, potentially supported by GPS and mobile applications. Such digital solutions are presented as an effective way to improve transparency, efficiency, and service quality in domestic freight transportation.
Keywords: transport, freight, cargo, packing, evaluation, customer, enterprises, requirements, labor force

Nurtakin Guliyeva Shukurova
Industrial Control Systems Protocols and Topologies
Azerbaijan Technical University, Azerbaijan
Abstract: Article investigates the impact of various network topologies used in the PROFIBUS and PROFINET communication protocols, which are widely used in industrial automation systems, on performance and system resilience. The aim of the study is to determine the possibilities for optimizing the topology selection in Industrial Control Systems (ICS) networks in terms of connection reliability and continuity. In the initial phase of the study, the bus, star, tree, and ring topologies were

modeled in the GNS3 simulation environment and tested under scenarios such as cable breaks, network load, and changes in traffic intensity. The results showed that in the line topology, a 100% link loss was observed during a cable break, whereas in the ring topology, link continuity was maintained thanks to the alternative transmission path. In the next phase, to address the identified weaknesses, the implementation of redundant structures, network segmentation, switch architecture optimization, and the creation of alternative transmission paths were proposed at the theoretical and simulation levels. It should be noted that the optimization measures have not been fully implemented in a real industrial environment; they have only been evaluated within the framework of modeling and analysis. Based on the simulation results, the application of redundant and distributed structures has the potential to increase link continuity during failure conditions and can enhance the overall reliability of the system. At the same time, segmentation and the use of alternative transmission paths can reduce network latency and minimize packet loss. The obtained results provide a methodological contribution to the scientific justification of topology selection during the design of industrial networks and to ensuring the continuity of production processes. Furthermore, the practical implementation and experimental verification of the proposed optimization mechanisms on real hardware is considered appropriate for future research.

Keywords: Industrial Control Systems network, PROFIBUS, PROFINET, GNS3, topology optimization

Gonca Gulsen, Refik Samet

The Impact of Malware Features on Malware Detection Accuracy in Information and Communication Systems

Ankara University, Türkiye

Abstract: Malware is a critical threat to cybersecurity and is increasing over time in information and communication systems. Numerous studies exist in the literature on detecting and mitigating malware attacks. According to these studies, artificial intelligence-based methods, particularly deep learning and machine learning, stand out with their innovative and powerful approaches. The limitation of the current literature is the insufficient number of studies examining the impact of malware features on the accuracy and performance of malware detection and classification. This study proposes a methodology that examines malware detection and the impact of malware features on the accuracy and performance of malware detection and classification using deep learning and machine learning models. Based on the proposed methodology, certain malware features, particularly those indicating traffic density, play a crucial role in detecting malware attacks. In fact, even when used individually, these features successfully detect malware and removing them negatively impacts the accuracy and performance of the models. To achieve maximum accuracy,

multiple relevant malware features are used in model training. These findings demonstrate that accurate malware detection depends not only on selecting the best and most reliable models but also on choosing relevant malware features. This approach reduces errors caused by features that don't contribute to the model and create noise, while simultaneously improving the model's generalization ability.
Keywords: Cybersecurity, Malware, Malware Features, Malware Detection, Deep Learning, Machine Learning

Gulnar Gurbanova, Ibrokhimali Normatov, Ruzmat Dadazhanov, Kamoliddin Jabbarov

Algorithm for Constructing a Non-Degenerated Quadratic Stochastic Operator by Binomial Distributions

National University of Uzbekistan named after Mirzo Ulugbek, Tashkent, Uzbekistan
Azerbaijan University of Architecture and Construction, Azerbaijan
University of Public Safety of the Republic of Uzbekistan Tashkent, Uzbekistan

Abstract: This article presents quadratic stochastic operators and their three classes, namely non-degenerate, completely positive, and irreducible, and hhere we are limited to constructing only the non-degenerate class of quadratic stochastic operators. This class of operators is built on linear graphs using binomial distributions. The construction of the calculation of the coefficients of the

operators for the construction of the quadratic stochastic operator is presented. In the construction of non-degenerate quadratic stochastic operators, their basic conditions and properties are studied, and an algorithm that allows for the systematic construction of operators is proposed. Restrictions on the coefficients are strictly mathematically justified, and the properties of the operator's movement in the invariant simplex are analyzed. The existence of fixed points and their trajectories of operator dynamics are studied. The theorem on the existence of fixed points is proved, in which necessary and sufficient conditions are established in depth. The obtained results show that the structural properties of non-degenerate quadratic stochastic operators have a significant impact on the evolution of probability distributions. The research results are based on the theory of stochastic processes and their close connection with dynamical systems. At the same time, the theoretical results obtained in the article are illustrated with specific examples.
Keywords: Graph, probability measure, quadratic operator, non-degenerate, completely positive, irreducible

Chingiz Hajiyev, Mert Sever
Relative Satellite Navigation Based on Local Sensor Measurements
Istanbul Technical University, Türkiye
National Defense University, Türkiye

Abstract: This paper is devoted to the problem of relative satellite navigation, addressing the estimation of relative position and velocity between cooperating satellites using local onboard sensor measurements. In this context, relative information is obtained from inter-satellite observations such as azimuth, elevation, and range measurement. To create relative model, Hill Clohessy-Wiltshire (HCW) approach is used. To cope with these challenges, the Extended Kalman Filter (EKF) is adopted as the estimation framework, in which the nonlinear relative orbital dynamics and measurement models are linearized about the current state estimate to enable recursive fusion of predicted states and local sensor data. This approach yields real-time relative state estimates and associated error covariances with moderate computational complexity, making it well suited for autonomous formation flying, rendezvous and docking, and other distributed satellite missions requiring robust and high-precision navigation.
Keywords: Relative Satellite Navigation, Hill Clohessy-Wiltshire, Extended Kalman Filter

Chingiz Hajiyev

Difference Kalman Filter Robust to Systematic Measurement Errors

Istanbul Gelisim University, Türkiye

Abstract: The article proposes a new discrete Kalman filter that takes into account unknown systematic measurement errors. In this case, the filtering algorithm estimates the

differences between two successive states. The differences between two successive measurements are used as measurements, as a result of which the systematic measurement errors mutually exclude each other. Corresponding expressions for estimating the state, the variance of the estimation errors, and the gain coefficient of the difference filter are derived. An estimation algorithm that is robust to instantaneous anomalous measurements is proposed. This ensures the robustness of the difference filter to instantaneous anomalous measurements. The proposed filter significantly improves the quality of estimation in the presence of constant or slowly changing biases and instantaneous anomalous measurements in observations. Theoretical studies and computer simulations are carried out for a linear one-dimensional dynamic system.
Keywords: Estimation, Kalman Filter, Systematic Error, Difference Filter, Inertial Navigation

Chingiz Hajiyev, Ahmet Talha Bektaş

Adaptive Iterative Least Squares Estimation for GPS-Based Navigation of Small Satellites Under Variable Visibility Conditions

Istanbul Gelisim University, Türkiye
Istanbul Technical University, Türkiye

Abstract: Global Navigation Satellite System (GNSS)–based navigation is the primary method for autonomous orbit determination of Low Earth Orbit (LEO) satellites. However, the highly dynamic space environment introduces challenges such as frequent satellite visibility changes due to Earth occultation, antenna field-of-view limitations, and variable signal strength. This paper proposes an adaptive Iterative Least Squares (ILS) framework to address the effects of highly variable GPS satellite visibility for small LEO satellites. The method employs a high-fidelity orbital dynamics model based on Cowell's formulation, including J_2–J_4 Earth gravitational perturbations, atmospheric drag modeled using NRLMSISE-00, and third-body perturbations. A three-stage visibility filtering process is implemented, incorporating geometric occultation checks, antenna pattern constraints using Patch-Excited-Cup (PEC) antenna characteristics, and link-budget-based C/N_0 thresholding. A realistic measurement noise model is implemented by scaling pseudorange variance as a function of the instantaneous carrier-to-noise density ratio. The estimator utilizes QR decomposition to enhance numerical stability and adopts a warm-start strategy to improve convergence performance. Simulation results using the STSAT-3 reference satellite indicate high-precision positioning, achieving an RMSE of 2.00 m with eight or more visible satellites. Furthermore, the estimator demonstrates robustness during severe visibility degradation (4 < 6), maintaining an RMSE of 3.72 m despite poor geometric conditions.

Keywords: GPS navigation, LEO satellites, Iterative Least Squares, Variable visibility, Noise modeling, Orbit determination

Chingiz Hajiyev, Aydoğan Soylu

Accuracy Analysis of Distance Measurement Based Position Determination Methods

Istanbul Gelisim University, Türkiye

Istanbul Technical University, Türkiye

Abstract: Numerous studies have been conducted in the literature to determine the position of aircraft from the past to the present. The reason for this is that accurate and reliable aircraft position is a fundamental requirement for the safety and efficiency of modern global air traffic management. In this study, a comparative analysis of terrestrial radionavigation techniques is presented for aircraft position estimation. Three distinct algorithms, which are Distance Measurement, Distance Difference Measurement, and Distance Sum Measurement, were implemented and evaluated using a kinematic aircraft model simulated under realistic flight conditions with additive noise and systematic sensor bias. The performance of each method was assessed through Root Mean Square Error (RMSE) metrics across multiple flight altitudes ranging from 1000 m to 3600 m. The simulation results demonstrate that while the Distance Measurement method offers superior longitudinal accuracy, it is highly susceptible to systematic biases, particularly in the vertical domain. In contrast, the Distance Difference and Distance Sum methods exhibit greater robustness against bias errors. A key finding of this research is the significant correlation between flight altitude and vertical positioning accuracy; higher altitudes consistently yielded lower

vertical errors due to improved geometric configurations relative to ground stations. According to our results, the Distance Difference method provides the most balanced performance for applications requiring reliable 3D positioning in bias-prone environments.

Keywords: Terrestrial Radionavigation, Distance Measurement, Distance Difference Measurement, Distance Sum Measurement, Position Error

Manar Abdulqawi Ahmed Hasan, Sedat Akleylek

Benchmarking NIST Round 2 Multivariate Signature Schemes: UOV, MAYO, and QR-UOV

Istinye University, Türkiye
University of Tartu, Estonia

Abstract: Post-quantum multivariate signature schemes have attracted considerable interest due to their compact signatures and efficient verification. However, existing performance evaluations suffer from a critical limitation: each scheme is benchmarked on different hardware platforms with varying processors, compilers, and optimization settings, making performance comparison infeasible. We present same-platform evaluation of three NIST Round 2 candidates: UOV, MAYO, and QR-UOV. All schemes were evaluated on Intel Core i7-10510U (1.80 GHz, 2 vCPUs, 3.8 GB RAM) running Ubuntu 22.04 with GCC 11.4.0 (-O3 -march=native) under identical conditions. Profiling using Callgrind (instruction-level) and gprof (function-level) revealed distinct bottlenecks. Matrix multiplication dominates UOV: 83.08% (1.24×1010 instructions), 87.86% (6.86×1010), and 90.58% (2.00×1011) for Categories I, III, V. MAYO's transpose_16x16_nibbles function consumes 36-80% CPU time. QR-UOV's thread management (libgomp) unexpectedly dominates 52-70% execution (1.55×1010 to 2.10×1010 instructions), leaving less than 40% for cryptographic computation. We evaluated three optimizations: (1) lookup tables for GF(16)/GF(127)/GF(256) with 256B/16KB/64KB tables, (2) AVX2 vectorization, (3) OpenMP parallelization. MAYO achieved 111-394% performance improvement (average 278%) with AVX2. UOV improved 15.0% using lookup tables (Category III) and 7.6-14.9% with OpenMP. QR-UOV showed minimal response (less than 1% speedup) and 1-2% OpenMP degradation. Results demonstrate that lookup table performance depends on interactions between table size, cache hierarchy (32KB L1, 256KB L2, 8MB L3), and computational intensity rather than size alone. Measurement variance remained less than 2% across 10 runs. All implementations passed NIST Known Answer Tests. This provides practitioners with actionable deployment guidance, demonstrating that multivariate schemes require tailored optimization strategies rather than uniform approaches.

Keywords: Post-quantum cryptography, Multivariate signatures, Performance optimization, vectorization, Cache analysis, Efficient implementation

Nazim Hasani

Comparative Analysis of Some Semi-Supervised Learning Approaches for Automated Labeling of Objects in Image-Based Object Detection Problems

Baku Engineering University, Azerbaijan

Abstract: Object detection in modern computer vision systems spans a wide range of applications, from autonomous transportation to medical diagnostics. However, training high-accuracy models requires large volumes of labeled data, which is both time-consuming and resource-intensive to obtain. This paper investigates the application of Semi-Supervised Learning (SSL) methods to address the challenge of limited labeled data. The study analyzes the fundamental principles of SSL and modern approaches employed in object detection. The core of this research involves the implementation and comparative analysis of three distinct methodologies: graph-based, pseudo-labeling, and clustering-based approaches.Visual recognition problems are considered in both classification and object detection contexts. In the experimental evaluation, the performance of these methods on the MNIST and COCO datasets is assessed using mAP (mean Average Precision) and accuracy metrics, along with MSE (Mean Squared Error) and MAF (Mean Absolute Frequency/Error) to evaluate the prediction error of object coordinates. Results indicate that the pseudo-labeling method achieves high accuracy, the graph-based approach provides more stable performance on structured data, and the clustering-based method acts as an additional regularizer on weakly structured datasets. In conclusion,

this study demonstrates the effectiveness of SSL methods in real-world applications and provides practical guidance for future research.

Keywords: Semi-Supervised Learning, Object Detection, Computer Vision

Yadulla Hasanli, Ibrahim Mohsumov

Green Input-Output Model in Azerbaijan and Its Analysis

Scientific-Research Institute of Economic Studies, Azerbaijan State University of Economics (UNEC), Azerbaijan
Azerbaijan State University of Economics (UNEC), Azerbaijan

Abstract: This study develops a single-region environmentally extended input–output (EEIO) model for Azerbaijan for the year 2021 in order to quantify how economic activity generates both direct and supply-chain (indirect) emissions. The model integrates the 2021 symmetric input–output table of the State Statistical Committee of the Republic of Azerbaijan (81 sectors, at basic prices) with fuel-combustion CO_2 emissions data from the International Energy Agency (IEA). To harmonize economic and energy statistics, the 81 IO sectors are mapped and aggregated into the IEA's seven end-use production groups, producing a consistent 7×7 "Green IO" table. Using the Green IO table, the Leontief inverse and sectoral emission intensities are applied to calculate direct emission intensities and total (embodied) emission

multipliers, while demand-driven emissions are classified by final demand categories, including the import adjustment (EEI - Emissions Embodied in Imports; used here as a domestic import adjustment under the domestic-technology assumption) and the CIF/FOB valuation term in the national accounts. The Green IO model is constructed and implemented. The results indicate that mapped producer-sector emissions are concentrated mainly in the Electricity and heat producers and Transport sectors. Multiplier analysis shows that indirect emissions dominate the total footprint in the Industry as well as the Commercial and Public Services sectors, revealing a high dependence on upstream stages of the supply chain. Household final consumption is the largest driver of domestically induced emissions; because direct household fuel combustion is not included in the producer-sector emissions vector, the IEA "Residential" emissions are added ex post to obtain a more complete household footprint. The findings highlight the decisive role of decarbonizing the energy sector and reducing transport emissions for lowering both direct and economy-wide emissions, while also noting the need for cleaner supporting inputs to reduce indirect footprints in industry and services.
Keywords: Green input–output model, Environmentally extended input–output (EEIO), Leontief inverse, CO_2 emissions, Consumption-based emissions, Demand-driven emissions, Azerbaijan, IEA energy statistics

Kanan Hasanov, Konul Aghayeva

Artificial Intelligence–Driven Decision Support Systems for Human Resource Management in the Digital Economy

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: The evolution of digital transformation is reshaping human resource management (HRM) practices, particularly in economies undergoing rapid technological and institutional change. In Azerbaijan, HRM now operates within an environment marked by expanding data availability, growing digital infrastructure, and heightened demands for evidence-based decision-making. Despite these advances, many organizations continue to rely on fragmented data systems and intuition-led decisions, which hinders strategic HR capabilities. This study introduces an artificial intelligence (AI)–driven decision support system (DSS) tailored to the context of Azerbaijan's digital economy. Conceptualizing HR as a complex and dynamic management object, the proposed model integrates data acquisition, analytical processing, decision logic, and feed-back loops. The system enhances workforce planning, performance evaluation, and human capital development, while promoting transparency and managerial accountability. By embedding AI capabilities with-in HR decision structures, the research contributes to the development of intelligent HRM systems suitable for emerging economies.

Keywords: Artificial intelligence, decision support systems, sustainable human resource management, digital

transformation, workforce analytics, intelligent information systems, emerging digital economies, decent work and economic growth, Azerbaijan

Tukezban Hasanova

Information Technologies and Artificial Intelligence in Research on the Interaction of Waves and Cylindrical Structures

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: Study of the dynamics of solid bodies in fluid under the influence of surface waves represents a highly relevant problem in modern hydraulic engineering and in the design of structures operating in marine environments. The impact of waves on structural elements, especially those of cylindrical shape modeling pipes or load-bearing components, has a direct effect on their stability, durability, and the efficiency of technological processes. When designing offshore platforms, break-waters, and other hydraulic structures, it is essential to account for the specific features of wave interaction with cylindrical bodies, since the resulting oscillations may lead to additional loads, fatigue effects, and changes in operational characteristics. In this work, the problem of motion of a rigid cylinder maintaining a vertical position in fluid with a free surface under the action of incoming long harmonic waves is considered. Particular attention is given to the disturbance of the incident wave caused by the presence of the moving cylinder, which significantly affects the

dynamics of the system. To solve the problem, the operational method is applied, allowing the transformation of the governing equations into Laplace–Carson images, as well as the numerical solution of the Volterra integral equation of the first kind. This approach makes it possible to avoid computational difficulties associated with finding complex roots of transcendental functions and evaluating improper integrals. The practical significance of the study lies in the possibility of applying the obtained results in the design and calculation of hydraulic structures, as well as in the development of modern information technologies for modeling and managing complex objects under the influence of external wave processes. The integration of artificial intelligence methods and numerical algorithms opens up prospects for creating intelligent systems capable of predicting the behavior of structures in real time, which is particularly important for the safe and efficient operation of facilities exposed to intensive external wave impacts.
Keywords: Intelligent Information Systems, Operational Method, Cylinder Motion, Surface Waves

Arzu Hasanova

Information Technologies and Melioration: Modern Approaches to Efficient Land and Water Management

AzUAC, Azerbaijan

Abstract: Contemporary challenges in agricultural water management require the integration of advanced information technologies (IT) into melioration systems. Digital monitoring, remote sensing, GIS-based land

analysis, and automated control of irrigation and drainage infrastructures significantly increase the efficiency, sustainability, and reliability of land reclamation measures. This article examines the role of IT in the design, operation, and assessment of melioration systems, with emphasis on irrigated agriculture, collector-drainage networks, and soil–water monitoring. Current technological innovations and their practical implications for sustainable land use are also discussed.

Keywords: water management, information technologies (IT), melioration systems

Vugar Hashimov

Control of Stabilization of Membrane Oscillations with Optimization of Location and Control Points

Institute of Mathematics, Azerbaijan

Abstract: The paper proposes an approach to the synthesis of lumped source control in distributed feedback systems. Using the example of the problem of damping membrane oscillations with point stabilizers, the locations of the stabilizers, the locations of the measuring points of the membrane state, and the parameters of the linear feedback that determines the relationship between the measurements of the membrane state and the operating modes of the stabilizers are optimized. The formulas of the gradient of the functional for the optimized parameters are obtained. Computer experiments were carried out using numerical optimization methods of the first order, and the

influence of measurement accuracy on the membrane stabilization process was analyzed.

Keywords: thin membrane, oscillations, control synthesis, lumped source, vicinity of the control point, loaded differential equation, gradient projection method

Vugar Hashimov, Javad Manafov, Sadig Malikov

Mobile Positioning and Navigation Correction System Based on Visual Recognition of Urban Address Signs

National Aviation Academy of Azerbaijan, Azerbaijan

Abstract: The objective of this work is to develop a mobile system for visual navigation using street signs, street name posters, house number plates, or address signs on the facades of houses and buildings in populated areas, using computer vision. The advantage of using street signs and address signs is that they provide passive positioning systems that are independent of satellite signals, especially in conditions of poor satellite visibility where GNSS is unavailable, to pinpoint one's location. The proposed approach can be used in visual navigation of cities, in the development of software for smart glasses for people with visual impairments, in the navigation of robots and autonomous systems when autonomous drones and delivery robots find the desired house not by geo-coordinates (which may have an error), but visually, by reading the house number from a sign. Using machine learning applied to computer vision application development, artificial intelligence models were created that differentiate address signs on the facades of houses

and buildings from the names of other elements of the urban environment. Computer simulations were conducted, and the experimental results were presented.

Keywords: address signs, navigation, computer vision, machine learning, synthetic data

Sayyara Hidayatzade, Gulchin Abdullayeva

Monitoring and Assessment of Drinking Water Environmental Safety in the Jeyranbatan Reservoir Using an Intelligent Information System

Institute of Mathematics, Azerbaijan

Abstract: The composition of water in the Jeyranbatan Reservoir is determined by complex multiparametric factors that interact with each other. In many cases, the combined influence of several factors may exceed the sum of their individual effects. Therefore, the identification of diagnostic and prognostic indicators requires the development of new approaches for processing primary monitoring data. The main objective of this study is to ensure the environmental safety of drinking water in the Jeyranbatan Reservoir. Particular attention is paid to monitoring physical, chemical, organoleptic, and microbiological parameters of water quality. The study is based on observational data collected during the period 2014–2020. Time series were constructed using measurement results to analyze the dynamics of water quality indicators. The paper proposes the development of an intelligent information system aimed at ensuring the environmental safety of water in the Jeyranbatan

Reservoir. The system includes protection of the reservoir as a physical object, monitoring of water input and output parameters, processing of laboratory test results, expert evaluation, and comparative analysis of measured indicators with international drinking water standards. The proposed approach focuses on the creation of a centrally managed intelligent information system. In addition, the study investigates the impact of deviations of measured parameters from standard limits on human health. The results demonstrate the importance of intelligent data processing and monitoring for improving drinking water quality and ensuring its environmental safety.
Keywords: environmental safety, artificial reservoir, physical-chemical, microbiological properties, intelligent information system, functional model, conceptual model

Duc Long Hoang, Dudarenko Natalia Alexandrovna
Synthesis of Composite Integral Fixed-Time Sliding Mode Control with Hölder-Adaptive Observer for Nonlinear Robotic Manipulators
Le Quy Don Technical University, Viet Nam
ITMO University, Russia
Abstract: This paper proposes a new fixed-time robust control architecture for robotic manipulators, termed Composite Integral Fixed-Time Sliding Mode with Hölder-Adaptive Observer. The method is designed to overcome key limitations in existing fixed-time and fast terminal sliding mode controllers, including reaching-phase

vulnerability, observer latency, and excessively aggressive adaptive gains. First, a novel integral sliding function with memory is introduced, where a decaying memory kernel embeds the accumulated tracking error into the manifold. This design removes the reaching phase entirely, ensuring global invariance from the initial instant while suppressing chattering and improving transient smoothness. Second, a Hölder-weighted adaptive gain law is developed, guaranteeing strict positivity, eliminating sign drift, and enabling smooth gain decay when the error approaches zero. Third, a composite fixed-time observer is constructed by merging a Hölder-type disturbance estimator with a high-order sliding observer, yielding an explicit fixed-time bound independent of initial estimation errors. Rigorous stability proofs are provided, including new lemmas, positivity preservation, and disturbance estimation, as well as new theorems establishing global fixed-time sliding and closed-form settling-time bounds for the entire robot system. The proposed method is validated on a high-fidelity 3-degree-of-freedom industrial manipulator model and comparatively evaluated against some advanced benchmark controllers. Simulation results demonstrate that the proposed controller achieves significantly lower overshoot, faster settling, smaller steady-state errors, and reduced chattering while maintaining robustness against time-varying disturbances and unmodeled dynamics. The framework is lightweight, model-independent, and suitable for real-time implementation in modern robotic platforms.

Keywords: Fixed-time control, sliding mode, integral sliding function, adaptive observer, Hölder adaptive law, manipulators, disturbance estimation

Duc Long Hoang

Synthesis of Terminal Synergetic Controller Based on Nonlinear State Observer for 2-Dof Helicopter System

Le Quy Don Technical University, Viet Nam

Abstract: This paper presents the synthesis of a robust control scheme for a Two Degree-of-Freedom Helicopter System based on Terminal Synergetic Control combined with a Nonlinear State Observer. The 2DOFHS is a highly nonlinear, strongly coupled MIMO system characterized by parametric uncertainties and unknown external disturbances, which makes control design particularly challenging. To address these issues, a terminal synergetic control strategy is developed to ensure finite-time convergence of the pitch and yaw angles to their desired reference values, while guaranteeing closed-loop stability in the presence of bounded disturbances. Since the terminal synergetic control law requires full state information, a nonlinear state observer is designed to estimate the unmeasured state variables, namely the angular velocities of the pitch and yaw motions. The observer is constructed to achieve fast and accurate state estimation, enabling effective implementation of the proposed control law without direct measurement of all system states. Lyapunov-based stability analysis is carried out to rigorously prove finite-time convergence of the

tracking errors and asymptotic convergence of the observer estimation errors. The effectiveness and robustness of the proposed controller–observer structure are validated through comprehensive simulation studies under different operating conditions, including set-point regulation and trajectory tracking scenarios, as well as in the presence of bounded external disturbances. The simulation results demonstrate fast transient response, high tracking accuracy, and strong disturbance rejection capability, confirming the superiority of the proposed approach for controlling nonlinear helicopter systems.
Keywords: 2-DOF Helicopter System, Terminal Synergetic Control, Nonlinear State Observer, Lyapunov function

Rena Huseynova, Sevda Akhmedova, Elchin İskenderzade, Farid Samedov, Elshan Rahimov
Investigation of Extreme Visibility Properties in Nature During Visual Observations
Azerbaijan University of Architecture and Construction, Azerbaijan
Azerbaijan State University of Economics, Azerbaijan
National Aerospace Agency, Scientific Research Institute of Aerospace Informatics, Azerbaijan
National Aerospace Agency, Institute for Space Research of Natural Resources, Azerbaijan
Baku Higher Oil School, Azerbaijan
Azerbaijan Technical University, Azerbaijan
Abstract: A discrete-heterogeneous model of the road is analyzed. The extreme properties of the total value of the

observer's contrast threshold are investigated, taking into account Koshmid's law and the visual illumination threshold, taking into account Allard's law. It is shown that, at a certain interrelation between atmospheric attenuation and visibility, the maximum value of the integral definitions of the thresh-old contrast according to Koshmid's law and the visual illumination threshold according to Allard's law is achieved. The article also examines the conditions for minimum visibility on motorways in rainy weather. The following tasks are discussed and solved: 1) Finding a semi-empirical relationship between meteorological visibility on roads and visibility distance for drivers in rainy weather. 2) Determining the conditions for the appearance of a minimum visibility range in rainy weather for drivers. A semi-empirical expression has been obtained linking meteorological visibility and visibility distance in the rain for drivers. It is deter-mined that in rainy weather, if there is a positive regression dependence of back-ground radiation on the intensity of rain, the visibility distance for car drivers decreases to a minimum.
Keywords: discrete-heterogeneous model, threshold contrast, regression relationship

Elman Imamaliyev, Ziraddin Qasimov
The Role of Artificial Intelligence in Robot Technologies
Azerbaijan Technical University, Azerbaijan
Abstract: The rapid expansion of robot technologies and artificial intelligence (AI) has created unprecedent-ed

opportunities for their effective application across diverse domains. The integration of AI into robotic systems is no longer a futuristic concept but a practical reality that is reshaping industry, healthcare, the service sector, agriculture, and military operations. Unlike earlier generations of robots that relied solely on pre-programmed instructions, modern AI-driven robots are capable of perceiving complex environments, processing multimodal sensor data, and making autonomous decisions in real time. This transformation enables robots to operate with higher precision, adapt-ability, and resilience, thereby broadening their scope of application. In industrial contexts, AI-powered robots enhance automation, optimize production lines, and improve safety standards. In healthcare, they support surgical procedures, rehabilitation, and patient monitoring, while in the service sector they facilitate personalized interactions and efficient task execution. Military and defense applications emphasize autonomous navigation, surveillance, and decision-making under dynamic conditions. Furthermore, the integration of machine learning and deep learning algorithms allows robots to continuously improve their performance by learning from past experiences, predicting future scenarios, and adapting to changing environments. Key enabling technologies such as SLAM (Simultaneous Localization and Mapping), LIDAR sensors, and computer vision systems provide the foundation for advanced robotic autonomy. These innovations not only improve navigation and environmental mapping but also strengthen human–

robot collaboration through natural language processing and cooperative robotics. Consequently, ongoing re-search into AI integration is of critical importance, as it drives both technological progress and addresses broader social, economic, and ethical implications.

Keywords: Artificial Intelligence, Robotics, Autonomous Systems, SLAM (Simultaneous Localization and Mapping), LIDAR, Computer Vision, Machine Learning, Human–Robot Interaction, Sensor Data Processing, Decision-Making Algorithms

Jamila Imamaliyeva

IoT-Based Principles for Damaged Building Analysis: Real-Time Monitoring and Risk Assessment

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: The Internet of Things (IoT) provides a modern and comprehensive framework for monitoring and analyzing damaged buildings in real time. Unlike traditional inspection methods, which are often periodic and reactive, IoT systems enable continuous observation of structural conditions through distributed sensor networks. These sensors, strategically embedded in critical components such as columns, walls, and foundations, measure parameters including vibration, tilt, strain, temperature, humidity, and gas concentration. The collected signals are digitized via micro-controllers and transmitted through communication protocols such as Wi-Fi, LoRaWAN, ZigBee, or NB-IoT to cloud-based platforms. Once in the cloud, data

undergo preprocessing, filtering, and normalization before being analyzed using advanced statistical methods, anomaly detection algorithms, and machine learning models. This analytical layer allows the system to identify deviations from normal behavior, forecast potential risks, and classify safety levels ranging from normal to warning and danger. Automated alerts are then delivered to engineers and decision-makers via dashboards, mobile applications, or direct notifications, ensuring rapid response. In integrated smart environments, IoT systems can also trigger automatic actions, such as shutting down gas pipelines, activating alarms, or initiating evacuation procedures. This study presents a systematic overview of IoT operation principles in damaged building analysis, emphasizing sensor deployment, data acquisition, cloud transmission, analytical modeling, and decision-making processes. Results demonstrate that IoT-based monitoring significantly enhances structural safety, supports preventive maintenance, and reduces human and material losses. Furthermore, the integration of IoT with artificial intelligence provides predictive capabilities, enabling early detection of structural risks and offering a reliable foundation for resilient urban infrastructure.
Keywords: Internet of Things (IoT), damaged buildings, structural monitoring, anomaly detection, real-time analytics, risk assessment

Mazahir Isayev, Arzu Akhundov, Heydar Rzayev

Principles of Developing an Intelligent Monitoring System for Main Pipelines

Institute of Mathematics, Azerbaijan

Abstract: The article presents the principle of developing an intelligent monitoring system for a main pipe-line. The main task here is to detect electronic measuring devices placed on the main pipeline, accurately determine their coordinates (location) and monitor the current state of their metrological characteristics. UAVs, integrated with the intelligent monitoring system, perform autoflights along the pipeline, the system collects and processes accurate information about the sensors, and, detecting violations, performs an auto-calibration function if necessary. Since the accuracy of the process of performing the above-mentioned operations also depends on the coordination of the UAV system and the orientation sensors that determine its local motion dynamics, monitoring of these sensors has also been studied as an important issue. All this is realized thanks to the current measurements of the spatial coordinates of the sensors and the UAV system. The article presents the principle of building the architecture of the monitoring system, synchronization between its modules, multisensor and adaptive control, and considers the issues of data integration and high-precision determination of the coordinates of distributed sensors. As an example, the Baku-Tbilisi-Ceyhan main oil pipeline scenario was considered, and the monitoring system (UAV) successfully approaches each sensor according to the coordinates of the measuring devices in

the local area and takes (reads) their current data. The developed monitoring system and its intellectual information-measuring subsystem demonstrated high measurement accuracy and recognition process in a complex, real environment, and the adequacy of the collected results was simulated in the MATLAB software environment.

Keywords: Highway, Pipe, Belt, Sensor, Intelligent System, Coordinate, High Precision, Recognition.

Ramiz Iskenderov, Şevket Ateş, Nijat Mastanzade, Tural Rustamli, Nariman Abdinli

Application of Computational Programs for Determining the Dynamic Parameters of a Cable-Stayed Bridge with Seismic Isolators

Azerbaijan University of Architecture and Construction, Azerbaijan

Karadeniz Technical University, Türkiye

Hydrotrans Engineering, Azerbaijan

Abstract: This paper presents a comprehensive dynamic investigation of Azerbaijan's longest planned cable-stayed bridge, a multi-span structure with a 1,100 [m] main span, subjected to dead, live (A-15), and seismic (MSK-64, intensity IX) loads. Using detailed finite-element models in SAP2000, we quantify how cable pretension influences the global stiffness, modal periods, and internal force distribution. A single-concave friction pendulum (SCFP) isolation system (R = 6 [m], μ = 0.08) is iteratively designed to achieve an effective isolator stiffness of 3,415 [kN/m], a

fundamental period extension from 2.0 [s] to 4.2 [s], and a displacement capacity of 0.78 [m]. Spectral acceleration demands decrease by up to 40%, resulting in reductions of 20–30% in deck shear forces and cable tension peaks. The results demonstrate that SCFP bearings significantly enhance seismic resilience for long-span cable-stayed bridges in high-activity regions.
Keywords: Seismic isolation, Cable-stayed bridges, Finite element model, Single concave friction pendulum (SCFP) bearing

Ismayil Ismayilov

New Approach for Handling Uncertainty in Rule-Based Expert Systems

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: The objective of this paper is to propose the utilization of certain properties within the chain of fired rules as a tool for handling uncertainty in rule-based expert systems. The domain problem chosen for this study involves revealing the etymology of Turkic (Oghuz) ethnonyms (tribal names). We introduce the rules’ chain based approach and suggest quantitative (based on the number of rules fired in a rules' chain) and qualitative (based on the frequencies of rules fired in rules' chains) methods. In the specific application, a new approach and methods aim to handle uncertainties arising from 'weak implications' caused by the irregularity of Turkic linguistic changes and uncertainties stemming from 'unknown data'

due to the lack of multidisciplinary supporting data for the etymologies of ethnonyms. Our proposed approach and the accompanying methods offer a robust tool for handling uncertainty in rule-based expert systems, particularly in cases where traditional approaches and methods are not applicable.
Keywords: Rule-based expert system, uncertainty, chain of rules, rules fired, ethnonym, etymology

Reshad Ismibayli, Sona Rzayeva
Genetic Algorithm–Based Timetabling Model for Universities Using the Bologna (credit-Modular) Education System
University of Architecture and Construction, Azerbaijan
Institute of Mathematics, Azerbaijan
Abstract: This work is devoted to an approach for developing class schedules in universi-ties operating within the framework of the Bologna Process. The approach takes into account the specific features of the Bologna Process compared to the classi-cal education system. These include the absence of a fixed study group (cohort), students' free choice of their own learning trajectories, and division of subjects in-to modules. The disciplines that comprise these modules are, in turn, divided into compulsory courses, elective courses within the chosen specialty, and free elec-tives. Creating a university timetable is a complex combinatorial optimization prob-lem with numerous constraints, including instructors’ and students’ preferences,

methodological and organizational requirements, and the need to avoid resource collisions. This problem is NP-hard; therefore, as its size increases (number of students, instructors, courses), finding a solution by analytical methods within an acceptable time becomes impossible. It is well known that genetic algorithms are successfully applied to many combinatorial optimization problems, including scheduling tasks. In this work, a genetic algorithm is used to generate the timetable, based on the DEAP (Distributed Evolutionary Algorithms in Python) framework, Python for the adaptive greedy algorithm, and Delphi for database management. Through the use of an adaptive greedy algorithm to form the initial population, the genetic algorithm begins its operation with a suitable population in which most individuals represent valid schedules. The algorithm has been tested on an illustrative example, and numerical results are presented.
Keywords: scheduling, genetic algorithm, greedy algorithm, hard constraints, soft constraints, population, individual, selection, crossover, mutation

Rumella Jafarova

The Role of Information Technology and Artificial Intelligence in the Development of the Construction Sector of Azerbaijan and Their Impact on Economic Growth and Well-Being

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: The application of Information Technologies (IT) and Artificial Intelligence (AI) in the construction sector of Azerbaijan has created significant opportunities to enhance construction quality, improve economic efficiency, and foster competitive business environments. These technologies are transforming the industry by accelerating construction processes, reducing costs, and increasing the accuracy of designs, all while improving overall project management. IT and AI allow for better planning, resource optimization, and risk management, leading to the successful completion of projects in shorter timelines. In addition to the operational benefits, the integration of IT and AI contributes to broader economic growth. These technologies stimulate the development of high-tech industries, create new jobs, and attract foreign investments. As the construction sector modernizes, it attracts global expertise and investors, boosting Azerbaijan's competitive position in the international market. Furthermore, the implementation of these technologies has a direct impact on improving the welfare of the population. By increasing the quality of buildings, enhancing safety measures, and improving urban infrastructure, IT and AI contribute to a higher standard of living. This creates a stable foundation for future prosperity, ensuring sustainable economic growth. This article examines the role of IT and AI in Azerbaijan's construction sector, exploring how their adoption not only supports economic progress but also enhances social well-being, leading to the long-term development of the

country's construction industry and overall societal advancement.

Keywords: Digital Transformation, BIM, Big Data Analytics, Smart Buildings, Economic Growth, Project Management

Gulara Jafarova

The Integration of Intelligent Management Systems in Philology: Applications in Education and Research

The College of Construction under the Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: Intelligent Management Systems (IMS) present advanced solutions for the analysis, synthesis, and management of data. This paper investigates the application of IMS within the field of philology, focusing on the management of linguistic data, text analysis, and language education. The study highlights how these systems can be leveraged in the educational sector, as well as their potential to transform fields such as literature, translation, and other linguistic disciplines. The objective is to showcase the ways in which IMS can assist professionals working in philology by enhancing their ability to manage and interpret complex language data. Additionally, the paper discusses the future prospects of integrating IMS with philological research and education, emphasizing the role of emerging technologies in shaping the future of linguistic studies. The integration of these systems is expected to significantly improve research efficiency, streamline educational processes, and offer innovative

approaches to text analysis, thereby fostering the continued evolution of philology in the digital era.

Keywords: Intelligent, Management, Systems

Femi Johnson, Ajayi Folu, Adebiyi Bukola, Ogunrinde Seun

IML-SMA: Integrated Machine Learning Strategic Market Analytical Model for Phone Price Classification

Federal University of Medicine and Medical Sciences, Nigeria
Yaba College of Technology, Lagos, Nigeria
Federal College of Education, Lagos, Nigeria
Federal University of Technology, Akure, Nigeria

Abstract: This paper develops an integrated machine learning model for mobile phone price classification and strategic market analysis, utilizing a publicly available Kaggle Mobile Price Classification dataset. A comparative evaluative pipeline featuring four supervised learning algorithms including Random Forest, Logistic Regression, XGBoost and Support Vector Machine was used for evaluating and classifying devices into four distinct price ranges (Very Cheap, Cheap, Expensive and Very Expensive). The experimental results derived demonstrate ensemble methods, particularly Random Forest, achieve superior performance with an accuracy of 99.98%. Feature importance analysis identifies improved 4G connectivity feature as the most critical predictor, accounting for 30.6% of the classification decision, supported by Random Access Memory (RAM) size, Battery power, Camera's pixel

resolution and Internal Memory. Beyond predictive modeling, the model extends to derive actionable market intelligence, analyzing how features are bundled across price segments and identifying key value drivers for different market tiers. The dual contribution of this study provides a reproducible technical methodology for price classification and strategic insights for product positioning, feature prioritization, and competitive analysis in the smartphone industry which offer practical guidance for manufacturers in optimizing product portfolios and for consumers in making informed purchasing decisions based on technical specifications.

Keywords: Machine Learning, Price Classification, Mobile Market Analysis, Feature Importance, Random Forest, Consumer Electronics, Strategic Positioning

Meiirzhan Kalen

Digital Technologies and Their Impact on the Optimization of Business Processes in the Company: Focus on RPA

Kazakh-British Technical University, School of Information Technology and Engineering, Almaty, Kazakhstan

Abstract: Digital technologies are reshaping how companies optimize their business processes. In particular, Robotic Process Automation (RPA) has emerged as a powerful tool for automating repetitive tasks and improving process efficiency. This paper examines the impact of RPA on business process optimization in the context of an order processing workflow at a real company

(LLP KazParts) in Kazakhstan. We model and implement an RPA solution that automates the end-to-end order pipeline—from online customer order entry through automatic creation of sales orders and payment postings in the 1C enterprise system to final shipment. A one-week experimental deployment is conducted to compare the RPA-driven process against the manual process in terms of processing speed, error rates, and throughput. The RPA implementation achieved significant performance gains, reducing average order handling time by over 80% and virtually eliminating data entry errors. However, several limitations were observed in handling complex exceptions and dynamic customer requirements. To address these shortcomings, we propose an improved hybrid RPA+AI model that combines rule-based automation with artificial intelligence components for greater flexibility. The results demonstrate the substantial benefits of RPA for business process optimization in the company while highlighting the value of integrating AI to handle process variability.
Keywords: Robotic Process Automation, Business Process Optimization, Digital Transformation, Order Processing, Intelligent Automation, 1C Enterprise

Maksat Kalimoldayev, Mukaddas Arshidinova
Integration of Machine Learning Models with Big Data for Energy Consumption Forecasting and Management
Institute of Information and Computational Technologies, Kazakhstan

Abstract: This article presents the integration of various machine learning models and algorithms for energy consumption forecasting. The object of study is the EWT-LSTM-RELM-IEWT hybrid model, which combines feature extraction, time series forecasting, and fast regression methods. The performance of this model is compared with traditional algorithms such as SVR, CNN, and XGBoost on a dataset of household electricity consumption. The quality of the forecast is evaluated using the MAE metric. Experiments show that the proposed hybrid model provides 15–20% higher accuracy than traditional methods, is robust to noise, and has improved generalization ability.
Keywords: Forecasting, hybrid system, wavelet analysis, extreme machine learning

Abdulvahit Karail, Yasin Ortakci
Impact of Optimizer: Comparative Analysis of Loss Functions in Different Models
Karabük University, Türkiye
Abstract: This study compares the performance of different artificial neural network models for data classification problems. The models used include Multilayer Perceptron (MLP), Kolmogorov–Arnold Network (KAN), and Liquid Time-Constant Networks (LTC). Model training was performed on the MITBIH ECG dataset, and modern optimization strategies with different loss functions were systematically compared. Evaluation metrics such as accuracy, macro-F1, precision, and recall

were assessed. The findings show that KAN models provide high accuracy, while LTC models operate more slowly due to their time-step based calculations.

Keywords: Optimizers, loss functions, Kolmogorov–Arnold Network, Liquid Time-Constant Networks, Multilayer Perceptron

İrem Karakaya, Talya Temizceri

From Prediction to Explanation: SHAP-Based Delivery Delay Analytics for e-Commerce Last-Mile Logistics

Bartın University, Türkiye
Dogus University, Türkiye

Abstract: The rapid expansion of e-commerce has increased the operational importance of accurately identifying deliveries at risk of delay. Although recent studies have improved predictive performance, less attention has been given to the interpretability of model outcomes and their practical value for logistics decision-making. This study introduces an explainable machine learning framework for predicting delivery delays in last-mile e-commerce operations. An order-level modeling structure was developed using the publicly available Olist dataset by integrating customer, product, and shipment characteristics. Logistic Regression, Random Forest, and XGBoost models were evaluated under imbalanced data conditions, with particular attention to threshold calibration. The results show that XGBoost offers the most stable discrimination when appropriate decision thresholds are used. To improve transparency, SHAP

(SHapley Additive exPlanations) was used to interpret model outputs. The analysis demonstrates that the promised delivery time is the most influential factor in determining delay risk, indicating that many failures may result from optimistic planning decisions rather than solely from operational disruptions. The findings indicate that integrating prediction with explainability generates actionable insights, which support realistic commitment setting, risk prioritization, and more effective resource allocation in e-commerce logistics.
Keywords: Delivery Delay Prediction, Last-Mile Logistics, Explainable Artificial

Hidayat Karimov, Tarana Quliyeva

Architectural Education in the Age of Artificial Intelligence: Are We Training Architects or Algorithm Operators?

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: The article analyzes the transformation of architectural education amidst the rapid implementation of Artificial Intelligence (AI). It examines the influence of algorithmic tools on the formation of professional thinking, responsibility for design decisions, and the role of the instructor in studio work. The author challenges the notion of AI as a neutral and purely progressive tool, pointing to the risks of replacing architectural reasoning with a mere selection from generated options, the blurring of authorship, and the erosion of professional ethics.

Particular attention is paid to the "illusion of professional maturity," the acceleration of the learning process, and the degradation of studio discourse. Possible solutions are proposed based on the critical use of AI, returning responsibility to the design subject, and reimagining the pedagogical function of the teacher. The conclusion emphasizes that AI should be viewed not as a replacement for architectural thinking, but as a challenge that necessitates deeper reflection and a strengthening of the profession's ethical foundations.
Keywords: Computer Technologies in Architecture, Digital Design, BIM Modeling, Parametric Architecture, Digital Design Transformation, Architectural Visualization, Innovations in Design Practice, Algorithmic Modeling, Digital Design Environment, Professional Competencies of the Architect

Nermin Kartli

A Dynamic Programming Approach for the Fuzzy Minimum Cost Maximum Flow Problem in the Multi-Stage Networks

Ankara University, Türkiye

Abstract: This study proposes a novel dynamic-programming-based heuristic algorithm, tailored to multi-stage networks, for solving the minimum-cost maximum-flow problem in a fuzzy environment. In the problem under investigation, edge costs on the network are modeled with parametric fuzzy numbers, and uncertainty is transformed into deterministic subproblems using the α-cross-

section approach. In the proposed method, a dynamic-programming-based shortest-path algorithm, developed to accommodate the multi-stage network structure, is applied to the deterministic problem obtained for each α level. In this process, which is performed on the residual network, the capacity dominance criterion is considered along with cost minimization, and paths with higher flow capacity are preferred among alternative paths with the same cost. This approach ensures a more balanced and stable solution process. The algorithm is based on updating the residual network at each increment step and defining reverse edges with negative costs. This results in an iterative improvement process similar to classical minimum cost flow methods. Left and right end solutions are calculated separately, the results are combined, and defuzzification is applied in accordance with fuzzy decision theory. The effectiveness of the proposed algorithm was evaluated through numerical experiments performed on randomly generated multi-stage test networks. The results show that the developed method can produce consistent, stable, and computationally efficient solutions under different uncertainty levels. In this respect, the study offers a practical and applicable approach to solving fuzzy network flow problems.

Keywords: Fuzzy optimization, Maximum flow at minimum cost, Multi-stage networks, Dynamic programming, Alpha-cuts method, Parametric fuzzy numbers, Supply chain networks, Heuristic algorithms.

Azer Kasimzade, Varol Koç, Hasan Yılmaz, Emin Nematli, Furkan Gunday

Integration of Nonlinear Structural Analysis into Decision Support Systems for Smart Building Applications

Azerbaijan University of Architecture and Construction, Azerbaijan
Ondokuz Mayıs Universty, Türkiye
Milli Savunma Bakanlığı, Türkiye
Giresun University, Türkiye

Abstract: This study proposes a framework for integrating classical building performance analysis into intelligent building management systems. Damage distribution, story displacements, and performance analysis values were obtained from a reinforced concrete system using nonlinear analysis, and these results were evaluated as data types that can be used by smart building systems. Thus, the usability of a classical engineering study on structural seismic analysis and system design in information technology-based smart building monitoring, control, and digital decision support system applications was investigated. The risky floors of the structure after an earthquake and whether evacuation is necessary can be determined automatically by smart building decision support systems. However, the system's ability to make these decisions depends on the number, location, and values of story displacements and plastic hinges. These can be determined as limit values through prior seismic performance analyses. Moreover since a numerical model

has been established for the structure and behaviors under earthquake scenarios have been obtained, these results can be updated with sensor data in the future. Therefore, the structural analysis model can be presented as the core of the building's digital twin. Smart building damage monitoring scenarios can be established before an earthquake by accepting the magnitudes obtained from the structural analysis as critical limits for sensors measuring story acceleration, displacement, and vibrations. Furthermore, synthetic data generated from structural analyses can play a critical role in AI training by producing modeling outputs such as damage patterns and performance results. This can contribute to big data systems for AI training.

Keywords: Nonlinear structural analysis, Seismic performance assessment, Performance-based evaluation

Azer Kasimzade, Varol Koç, Hasan Yılmaz, Emin Nematli, Furkan Gunday

A New Approach in Structural Control: An Industrial Application for the Tallest Building in the Caucasus

Azerbaijan University of Architecture and Construction, Azerbaijan
Ondokuz Mayıs Universty, Türkiye
Milli Savunma Bakanlığı, Türkiye
Giresun University, Türkiye

Abstract: Baku, the capital of Azerbaijan, is located on the Caspian Sea coast and is there-fore subject to winds that sometimes intensify almost daily. This situation makes the

control of dynamic behavior critical in terms of both safety and user comfort in the Baku Tower (BT), the tallest building in the Caucasus region. For this rea-son, the structure is equipped with a Tuned Mass Damper (TMD) system with a mass of 400 tons to reduce wind and earthquake-induced vibrations. In this study, the dynamic analysis results in modal and time domains were compared by modeling the damped and undamped cases of BT using the Finite Element Meth-od (FEM). According to the results, the use of TMD provides approximately a 7% increase in period and approximately a 6% reduction in peak horizontal dis-placement. In the second stage of the study, the Structural Health Monitoring (SHM) system installed on the building is examined. The dynamic behavior of the structure is continuously monitored through accelerometers and sensors placed on critical floors. Real-time comparisons of the obtained data send warning signals to the building management and power control systems if critical threshold values are exceeded. Therefore, structural control system performance and indicators ob-tained from numerical dynamic analyses are correlated with the real-time SHM system. Thus, the analysis results are evaluated beyond their design and verifica-tion uses and integrated into building operation and safety decision-making pro-cesses. Critical parameters such as floor displacements, vibration characteristics, and peak displacements obtained from dynamic analyses are used as monitorable threshold values by the SHM system. In this way, this data is transformed into operational decision criteria that can be transferred to the building control system. The integrated use of structural control systems and SHM applications in a high-rise building has been examined through analysis and practical applications.

Keywords: Structural control, Tuned mass damper, Structural health monitoring

Aydin Kazim-Zada, Gulchin Abdullayeva, Hayat Guseynova

On Some Informative Features of the Rock Artificial Artificials of Azerbaijan and Central Asia

Azerbaijan University of Architecture and Construction, Azerbaijan
Institute of Mathematics of the Ministry of Science and Education of the Republic of Azerbaijan, Azerbaijan

Abstract: The article examines the presence of informative features for classifying rock art discovered in the territories of the world-famous Gobustan State Historical and Artistic Reserve in the Republic of Azerbaijan, as well as the Sarmishsay Natural Archaeological Site in the Navoi Region of the Republic of Uzbekistan. A number of rock art images of animals, goats, deer, dancing people, hunting scenes, and images of individual hunters are considered. Images of similar hunters are allocated to a separate subgroup from the group of hunting scenes. To digitize the rock art images of hunters, the images were placed on a grid. Their distribution density graphs are constructed and presented along both the OX and OY axes. These distribution density data are one of the additional informative features of rock art. Also, to determine the similarity of the considered

images of hunters, a pairwise comparison of the drawings, found separately in the 10th-8th centu-ries BC in Gobustan, was conducted. For this purpose, the pairwise Student's t-test method was used. Examples of symmetrical petroglyphs, representing the natural majority of asymmetrical ones, are presented. The areas of convex polygons are constructed and calculated by finding minimum envelopes using examples of rock art. Minimum convex envelopes are found using the Jarvis algorithm (a gift-wrapping algorithm), with subsequent calculation of the area of a convex polygon based on the coordinates of the vertices on a plane. The centers of gravity of the rock art drawings, considered as planar figures, are calculated. Examples of symmetrical petroglyphs, representing the natural majority of asymmetrical ones, are presented. The presence or absence of symmetry, the determination of the areas of convex polygons, and the found values of the centers of gravity of rock art, along with other informative features, contribute to the high-quality process of recognition and identification of petroglyphs in general. Using an online resource, the percent-age of similarity of the images of hunters was determined by pairwise comparison.
Keywords: rock art, informative features, symmetry, convex polygons, center of gravity, recognition, identification, distribution density

Khalid Khalilov, Leila Mahmudbayli, Kamran Gasimov

The Principle of Constructing a Distributed Parameter and Multichannel Measurement and Control System

Azerbaijan University of Architecture and Construction
Baku Business University, Azerbaijan
Azerbaijan University of Technology, Azerbaijan

Abstract: This paper presents an in-depth investigation of advanced design principles for multichannel information–measuring systems intended for complex, multiparameter objects. Current trends and development opportunities aimed at improving system architecture, measurement intelligence, and overall accuracy of multichannel, multiparameter, and multifunctional measurement systems are analyzed. Particular attention is given to the theoretical foundations and practical implementation of intelligent measurement algorithms, structural system models, and mechanisms for functional adaptation and system extensibility. The study also addresses modern approaches to system self-adjustment and sensor auto-calibration, enabling long-term stability and reliability under varying operating conditions. To ensure a comprehensive and systematic solution, computer-based modeling was employed to simulate the integrated application of structural–algorithmic and test-based measurement methods, along with the construction of an associated information model. The effectiveness of the proposed approach is validated through experimental testing, confirming the clarity, robustness, and accuracy of the obtained measurement results.

Keywords: intellectual, informational, multisystem, structural, algorithmic, test, measurement, method, model

Al Khan, Ainur Mukhiyadin

Safety-Critical AI Decision Support: Formal Verification of Neural Network Controllers for Autonomous Medical Systems

Esil University, Kazakhstan

Abstract: The integration of artificial intelligence into autonomous medical systems—such as closed-loop drug delivery, robotic surgery, and ventilator management—promises transformative improvements in patient care. However, the safety-critical nature of these applications demands rigorous guarantees that neural network controllers will never produce harmful actions, even under rare or adversarial conditions. Traditional testing-based validation is insufficient for neural networks, which can exhibit unexpected behavior in corner cases. This paper introduces VeriMed, a novel formal verification framework specifically designed for neural network controllers in autonomous medical systems. Our approach combines three core innovations: (1) a physiological state space abstraction that reduces infinite-dimensional patient dynamics to tractable verification domains while preserving clinical safety properties, (2) a reachability-guided verification engine that efficiently computes exact output bounds for neural networks with Lipschitz-bounded activations, and (3) a clinically-grounded specification language that translates medical safety requirements (e.g.,

"never administer insulin when glucose is below 70 mg/dL") into formally verifiable constraints. We evaluate VeriMed on three medical AI systems: an artificial pancreas for type 1 diabetes, a sedation controller for mechanical ventilation, and a robotic surgical assistant for retinal microsurgery. Across 147 clinically-defined safety properties, VeriMed achieves 100% verification coverage with average runtime of 4.7 minutes—sufficient for pre-deployment certification. The framework detects 12 previously unknown safety violations in state-of-the-art controllers, including a critical insulin overdose scenario missed by 10,000 hours of simulation testing. Crucially, VeriMed provides provable guarantees: when a property is verified, no possible patient trajectory (within modeled physiology) can violate it. This work establishes that formal verification of neural network medical controllers is not only possible but practical, offering a pathway toward certifiable autonomous medical AI.
Keywords: Formal Verification, Neural Network Controllers, Safety-Critical Systems, Autonomous Medical Systems, Reachability Analysis

Al Khan, Nuraiym Kadyralieva, Malika Baizakova
Detection of Autism Spectrum Disorder in Children Aged 3–8 Using Machine Learning and Natural Language Processing: A Multi-Resolution Linguistic Framework with Pragmatic Enhancement
INAI, Kyrgyzstan

Abstract: Autism Spectrum Disorder (ASD) affects approximately one in fifty-four children, yet roughly twenty-five percent of cases remain undiagnosed, delaying critical early interventions that could improve developmental outcomes. Traditional diagnostic methods rely on resource-intensive clinical assessments, subjective behavioral observations, and parent-reported questionnaires, which are often inaccessible in underserved communities and prone to interpretive variability. Recent advances in machine learning and natural language processing offer promising avenues for automated ASD detection using speech data, but existing approaches predominantly focus on surface-level linguistic features such as Mean Length of Utterance, overlooking deeper pragmatic and discourse-level abnormalities that characterize autistic communication. This paper presents a novel multi-resolution linguistic framework that integrates syntactic, semantic, and pragmatic feature extraction with an ensemble attention mechanism for ASD detection in children aged three to eight years. Our approach introduces three key innovations: first, a hierarchical feature engineering pipeline that captures linguistic patterns at the utterance, conversational turn, and discourse levels; second, a pragmatic enhancement module that quantifies theory-of-mind deficits through pronoun resolution and referential communication analysis; and third, a confidence-calibrated ensemble classifier that combines gradient-boosted decision trees with a lightweight transformer architecture. Evaluated on the TalkBank

CHILDES and ASDBank corpora comprising eighty-six children, our framework achieves ninety-one point two percent accuracy, outperforming baseline models by seven point three percentage points while maintaining interpretability through SHAP-based feature attribution. The results demonstrate that integrating pragmatic language features significantly improves detection accuracy and provides clinically meaningful insights into individual linguistic profiles, advancing the development of non-invasive, scalable ASD screening tools.
Keywords: Autism Spectrum Disorder, Natural Language Processing, Machine Learning, Pragmatic Language Analysis, Early Childhood Screening

Al Khan, Akylai Zhumabekova, Artem Kipin
Deep Learning Model Compression and Optimization for Real-Time Edge Computing in IoT Environments.
INAI (Kyrgyz-German Institute of Applied Informatics), Kyrgyzstan
Abstract: The proliferation of Internet of Things (IoT) devices coupled with deep learning capabilities has created unprecedented opportunities for intelligent edge applications, yet the inherent resource constraints of edge hardware—limited memory, processing power, and energy budgets—remain fundamental barriers to deploying sophisticated neural networks. This paper presents a comprehensive framework for deep learning model compression and optimization tailored specifically for real-time inference on resource-constrained edge devices in IoT

environments. We propose a synergistic approach combining structured pruning, uniform quantization, and knowledge distillation that collectively achieves up to 18.5× model size reduction while maintaining 94.7% of baseline accuracy across multiple benchmark datasets including CIFAR-10, ImageNet, and custom IoT sensor data. The framework introduces a novel sensitivity-aware layer-wise compression strategy that adaptively allocates pruning rates and bit-widths based on each layer's contribution to overall network performance, preventing degradation in critical feature extraction pathways. Extensive evaluations on representative edge hardware platforms—including ARM Cortex-A72, Raspberry Pi 4, and Google Coral Edge TPU—demonstrate average inference latency improvements of 7.3× and energy consumption reductions of 12.8× compared to uncompressed baselines, enabling previously infeasible real-time computer vision, anomaly detection, and sensor fusion applications. Furthermore, we present an adaptive runtime optimization mechanism that dynamically adjusts compression ratios based on available computational resources and application-specific latency requirements, ensuring reliable performance under varying edge conditions. The proposed methodology provides a practical blueprint for deploying state-of-the-art deep learning models in production IoT environments where real-time responsiveness and resource efficiency are paramount.

Keywords: Edge computing, Internet of Things, Real-time inference, Resource-constrained optimization, Deep learning deployment, Embedded AI

Natavan Khasayeva, Arzu Akhundov, Heydar Rzayev, Mehriban Mammadova

Intelligent Information-Measuring System for Scanning Liquid Flows

Azerbaijan Technical University, Azerbaijan
Institute of Mathematics, Azerbaijan
Azerbaijan State Oil and Industry University, Azerbaijan

Abstract: This study presents the development and validation of an Automated Liquid Flow Scanning and Intelligent Measurement System (ALFSS) designed to provide high-accuracy, adaptive, and real-time monitoring of liquid flow processes in complex industrial and scientific environments. Traditional liquid flow measurement systems, including mechanical flow meters, analog sensors, and conventional digital measurement platforms, often suffer from limitations such as low adaptability, high sensitivity to noise, calibration drift, and reduced reliability in nonlinear and dynamically changing flow conditions. These limitations significantly affect the stability, accuracy, and robustness of measurement results, particularly in large-scale industrial infrastructures and safety-critical systems. To address these challenges, the proposed system integrates multisensor measurement ar-chitectures, adaptive filtering techniques, intelligent data processing and real-time decision-making algorithms into a unified

intelligent measurement platform. The system architecture is based on a layered structure consisting of a sensor layer, signal conditioning layer, data acquisi-tion layer, processing unit, intelligent analysis layer, decision system, and visualization and control interface. This modular design ensures scalability, flexibility, and compatibility with different industrial and laboratory environments. A comprehensive mathematical modeling framework is developed, including fluid flow dy-namics models, state-space representations, measurement equations, and integrated error mod-els. The system incorporates stochastic modeling approaches to represent uncertainties, sensor noise, calibration errors, and environmental disturbances. Adaptive estimation is achieved through Kalman filtering and extended data fusion techniques, enabling optimal state estimation under noisy and uncertain conditions. Multisensor data fusion strategies are implemented to enhance measurement reliability, improve accuracy, and provide redundancy against sensor failures. An intelligent algorithmic framework is proposed, including automated flow scanning, adaptive filtering, sensor fusion, fault detection, anomaly analysis, and intelligent decision generation. The system is capable of detecting abnormal flow behaviors, identifying system faults, and generating corrective control actions in real time. Simulation models are developed using MATLAB/Simulink environments to validate system performance, stability, and robust-ness. Performance evaluation is carried out using quantitative metrics such as

root mean square error (RMSE), accuracy indices, response time, and stability criteria based on Lyapunov theory. The obtained results demonstrate that the proposed ALFSS significantly outperforms clas-sical measurement systems in terms of accuracy, adaptability, robustness, and reliability. The system shows strong resistance to noise, high sensitivity to dynamic flow variations, and stable performance under nonlinear operating conditions. The developed framework is suitable for applications in water supply systems, oil and gas pipelines, chemical process industries, energy systems, hydraulic infrastructures, laboratory measurement platforms, and aerospace fluid systems. The proposed smart measurement system provides a scalable, adaptive, and future-oriented solution for next-generation automated fluid flow monitoring and control technologies, providing higher accuracy, stability, and adaptability compared to classical measurement methods [1–5].
Keywords: Intelligent, fluid flow, test measurement, Kalman filter, adaptive control

Natavan Khasayeva, Mazahir Isayev

Development of a System and Algorithm for Automatic Calibration of Electronic Scanning and Sensor Devices of Unmanned Aerial Vehicles

Azerbaijan ISC, Azerbaijan

Abstract: Unmanned aerial vehicles (UAVs) utilize inertial monitoring systems (IMS) that ensure stable flight, precise

scanning of objects, and accurate data collection and transmission. They primarily utilize various electronic devices (ED), such as magnetometers, barometric sensors, velocity sensors, and navigation receivers. During scanning, the parameters of these devices change either abruptly or gradually over time due to temperature fluctuations, mechanical vibrations, aging, and electromagnetic interference, leading to distortion and inaccuracy of measurement and scanning results. Therefore, this article addresses this pressing issue and proposes an algorithm and system for automatic calibration of scanning devices and measuring sensors installed on UAV platforms. The algorithm implements intelligent scanning, control, measurement, and adaptive control through analytical modeling. It evaluates and verifies the consistency between current and previous parameter values. If an acceptable limit (value) is exceeded, the error is automatically compensated for using the corresponding algorithm. This article formulates a mathematical model of scanning process errors and develops an adaptive automatic calibration procedure based on recursive evaluation. To validate the theoretical results, a case study of an inertial-barometric measurement subsystem is presented. Furthermore, specialized computer modeling and simulation allows for a wide-range analysis of the results, confirming the effectiveness and convergence of the proposed approach. The developed method also simplifies computational complexity, improves measurement accuracy, and improves flight

smoothness. It demonstrates the applicability of the obtained results to modern UAV platforms.
Keywords: scan, measurement, device, sensor, auto calibration, adaptive control, algorithm, mathematical model

Mykola Kosovets, Liliya Tovstenko, Alexander Tovstenko

Organization of Spatial Computing in a Distributed System Using Artificial Intelligence

Institute of Applied Control Systems, NAS of Ukraine, Ukraine
V.M. Glushkov Institute of Cybernetics NAS of Ukraine, Ukraine
Technical University Graz, Ukraine

Abstract: This article explores the integration of spatial computing and distributed information processing systems by leveraging spatial object data from various sensors—such as spatial sensing via physical field sensors—and information obtained through indirect methods. It examines the use of artificial intelligence to synthesize data and extract specific knowledge that is not directly inferable from raw input, enabling a deeper understanding of and real-time interaction with the physical environment. Organizing spatial computing within a distributed environment is a step toward creating an accurate representation of reality. The application of AI transforms chaotic data streams from video and radio sensors into a structured dataset, interpretable through specialized field-

processing algorithms. Spatial computing inherently relies on distributed multiprocessor real-time processing.

Keywords: Spatial computing, distributed processing, artificial intelligence, real-time multiprocessor

Polina Kremuschenko

Automatic Shadow Detection and Suppression in Images Using Deep Neural Networks

Samara National Research University, Russia

Abstract: Shadows are one of the major factors that reduce the reliability of computer vision systems, especially in aerial image analysis. They distort object boundaries, change color characteristics, and negatively affect the performance of segmentation, detection, and 3D reconstruction algorithms. This problem is particularly critical for unmanned aerial vehicle (UAV) imagery, urban monitoring, and geospatial analysis tasks. This paper presents a modular two-stage approach for automatic shadow detection and removal in aerial photographs. The proposed method combines deep learning-based segmentation with modern image inpainting techniques. At the first stage, shadows are detected using a fine-tuned YOLO11s-seg neural network model trained on a custom annotated dataset of aerial images. The model generates binary masks that accurately localize shadow regions under different lighting conditions and scene types. At the second stage, the detected shadow areas are restored using the LAMA (Look At My Assistant) inpainting algorithm, which reconstructs image content based on both local

textures and global contextual information. A dataset containing aerial images of urban, industrial, rural, and natural environments was collected and manually annotated for training and evaluation. Experimental results demonstrate that the proposed approach effectively identifies large and complex shadow regions and significantly improves the visual quality of the images after restoration. In addition, object detection accuracy increases when shadow-removed images are used as input, confirming the practical value of the method. The proposed system can be integrated into real-time or near real-time computer vision pipelines for aerial monitoring, navigation, and geographic information systems. Future work will focus on extending the approach to video sequences with temporal consistency and improving robustness under complex illumination conditions.
Keywords: shadow detection, shadow removal, aerial imagery, YOLO11, LAMA, image, inpainting, computer vision

Hakan Kutucu, Oktay Kara

Automated PCB Component Verification Via Cad-Aware Multi-Task Deep Learning

Karabuk University, Türkiye

Abstract: Printed Circuit Board (PCB) inspection is a critical stage in electronics manufacturing, traditionally relying on manual or rule-based procedures that are time-consuming, error-prone, and difficult to scale for densely populated boards. Recent advances in deep learning have

significantly improved visual inspection capabilities; however, most existing approaches focus primarily on component detection or classification, without sufficient geometric refinement or integration with design data. In this study, we propose a CAD-aware multi-task inspection pipeline that integrates high-resolution object detection, component-level keypoint localization, semantic segmentation, and CNN-based classification within a unified framework. The extracted component attributes are systematically mapped to Computer-Aided Design (CAD) reference designators and Bill of Materials (BOM) entries, enabling automated verification of component presence, type correctness, and placement consistency. Experimental evaluations on real PCB images demonstrate that the proposed approach achieves reliable detection of small-scale components while providing refined geometric and semantic information suitable for industrial verification workflows.
Keywords: PCB Inspection, Deep Learning, YOLO, Segmentation, Keypoint Estimation, CAD/BOM Integration

Hakan Kutucu, Eslem Akman, Nevin Köremezli Keskin, Merve Başdemirci, Onur Başdemirci
Mamnet-Tr: A Large-Scale Annotated Mammography Dataset for the Turkish Population
Karabuk University, Türkiye
Karabük Medikar Hospital, Türkiye
Karabük University Training and Research Hospital, Türkiye

Abstract: Breast cancer is one of the most commonly diagnosed cancers among women worldwide, and early detection plays a critical role in reducing disease-related mortality rates. Although mammographic screening forms the cornerstone of this process, image interpretation is a step that requires a high level of expertise and carries a risk of error. The high radiologist-to-image ratio and regional imbalances in specialist distribution limit the effectiveness of screening programmes particularly in rural areas. In this context, deep learning-based Computer-Aided Diagnosis (CAD) systems have emerged as an important supporting tool. Existing literature on mammography-based artificial intelligence predominantly relies on publicly available datasets such as DDSM, MIAS, and INbreast. However, because these datasets do not adequately represent the breast tissue characteristics specific to different ethnic and geographic populations, the generalisability of the developed models to local populations remains limited. In this study, MAMNET-TR, a comprehensive mammography dataset specific to the Turkish population, is presented. The dataset comprises a total of 5,018 cases and 17,928 mammographic images collected between 2019 and 2025 from Karabük University Training and Research Hospital, following institutional ethical approval. Images were annotated by expert radiologists through a web-based platform using BI-RADS categories, breast density classifications, and radiological finding attributes. Cases with inter-observer disagreement were re-evaluated by a third radiologist, and final labels were established by

consensus. The annotation process is currently underway; the dataset is anticipated to encompass 31,550 mammographic images across 8,394 cases upon full completion. MAMNET-TR constitutes a novel resource that complements existing international datasets in terms of multi-expert annotation and its representation of phenotypic characteristics specific to the Turkish population.
Keywords: Mammography dataset, Breast cancer screening, BI-RADS classification, Computer-aided diagnosis, Domain adaptation, Turkish population

Denis Kutuzov, Alexey Osovsky, Alina Iakupova, Alexey Loginov, Rodion Sinitsyn
A Fuzzy Logic Approach to Congestion Prediction in NoC Video Codecs
Astrakhan State Technical University, Russia
Abstract: This paper presents a system for predicting routers congestion in an MPEG-4 video codec implemented using Networks-on-Chip (NoC) technology. The growing level of parallelism and increasing on-chip traffic volumes in modern hardware video codecs significantly raise the probability of local congestion within the interconnection network, which in turn degrades latency, throughput, and overall system performance. To detect pre-critical operating conditions, a fuzzy inference model is developed. The model considers a set of key parameters, including average router buffers occupancy, packet injection rate (PIR), and the structural importance of nodes determined

by the Betweenness Centrality metric (BC). By combining traffic-related and topological information, the proposed approach captures nonlinear dependencies between network parameters. Unlike conventional threshold-based techniques, it provides a continuous estimation of congestion probability and enables identification of transient network states preceding overload. Simulation results confirm the effectiveness of the method and demonstrate its suitability for integration into an intelligent NoC control loop supporting dynamic packet injection regulation, adaptive routing, and traffic balancing mechanisms.
Keywords: Network-on-Chip (NoC), congestion detection, fuzzy logic, buffer occupancy, packet injection rate (PIR), dynamic traffic management, MPEG-4

Ilaha Latifova, Nigar Ismayılova, Cecilia Zanni-Merk
Comparative Forecasting of CO_2 Emissions Using ARIMA, Prophet, and LSTM Models
Azerbaijan State Oil and Industry University, Azerbaijan
Normandie Université, INSA Rouen Normandie, LITIS
Rouen, France
Abstract: Accurate forecasting of carbon dioxide (CO_2) emissions is essential for understanding climate change dynamics and informing global mitigation strategies. This paper compares the performance of three time series forecasting approaches—AutoRegressive Integrated Moving Average (ARIMA), Prophet, and Long Short-Term Memory (LSTM) networks—using global CO_2 emissions

data from 1970 to 2023 obtained from the World Bank. The dataset, aggregated across 251 countries, was divided into training and testing subsets for model evaluation. Forecast accuracy was assessed using evaluation metrics for regression analysis. Results show that Prophet achieved the highest predictive accuracy outperforming ARIMA and LSTM. Forecasts for 2024–2028 consistently indicate a continued upward trend in global CO_2 emissions. On the other hand, Hidden Markov Model (HMM) was used for capturing regime shifts in the time series dynamics. These findings highlight the limitations of localized forecasting studies and underscore the importance of global-scale modeling. The results also emphasize the urgency of coordinated international policy interventions to mitigate the projected rise in emissions.
Keywords: carbon dioxide emissions, time series forecasting, ARIMA, Prophet, LSTM

Sabina Maharramova

Application of Information Technologies in Risk Modeling of Water Management Facilities in the Kura-Araz Plain

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: This study explores the application of advanced information technologies in the risk assessment and modeling of water management infrastructures—including dams, canals, pumping stations, and drainage systems—within the Kura–Araz Lowland. The primary objective is to

elucidate the role of Geographic Information Systems (GIS), remote sensing data, database technologies, and statistical-computational modeling in the integrated evaluation of hydrometeorological, geological, and anthropogenic risk factors. Findings demonstrate that the deployment of information technologies substantially enhances early risk detection, optimizes decision-making processes, and supports the sustainable management of water resources.
Keywords: Kura–Araz Lowland, water management infrastructure, risk modeling, GIS, information technologies

Rashad Mahmudov

Smart City Algorithms for Post-Conflict Urban Reconstruction: A Data-Driven Decision Support Model for the Karabakh Region

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: Post-conflict urban rebuilding necessitates open, data-driven methods for prioritizing infrastructure restoration and public service provision against uncertainty, constrained resources, and swiftly changing demographic trends. Conventional reconstruction planning methods frequently depend on administrative sequencing instead of methodical assessment, potentially diminishing efficiency and long-term sustainability results. This paper presents a smart city algorithm intended to facilitate incremental urban redevelopment using a systematic multi-criteria decision-support framework. The framework

incorporates spatial, infrastructural, demographic, economic, and energy-related parameters, such as damage intensity, anticipated population return, access to key services, network connectivity, infrastructure interdependencies, and renewable energy potential. The variables are standardized and weighted through a multi-criteria evaluation framework to provide a composite Reconstruction Priority Index (RPI) for urban districts. The technique facilitates scenario modeling within financial, technical, and implementation restrictions, permitting planners to evaluate alternative phasing strategies and analyze sensitivity to variable weight modifications. By systematizing prioritizing logic via a computational framework, the approach diminishes subjectivity in decision-making and enhances transparency in public governance procedures. The methodology is illustrated through specific areas in the Karabakh region, where significant reconstruction efforts offer a pertinent background for algorithm-assisted planning. Simulation outcomes demonstrate the model's capacity to optimize infrastructure investment allocation, improve access to vital services, and synchronize rebuilding methods with sustainability goals, including energy efficiency and resilient urban systems. The suggested methodology enhances the incorporation of smart city technology into post-conflict urban governance by providing a scalable and transportable decision-support framework. Aside from the Karabakh scenario, the framework offers methodological guidelines for other places in recovery, where algorithmic prioritizing can promote balanced, transparent, and sustainable urban reconstruction.

Keywords: Smart city algorithms, post-conflict reconstruction, decision-support, infrastructure prioritization, sustainability.

Elgiz Mahmudov

The Role of Information Technologies in STEAM Education

Mingachevir State University, Azerbaijan

Abstract: This article explores the role of information technologies in STEAM education, focusing on their impact on teaching methods, student engagement, and interdisciplinary learning. STEAM education integrates Science, Technology, Engineering, Arts, and Mathematics to foster creativity, critical thinking, and problem-solving skills. The development of digital tools, including artificial intelligence, virtual laboratories, interactive multimedia, and learning management systems, has significantly transformed the educational landscape. This paper analyzes current trends, challenges, and opportunities associated with integrating information technologies in STEAM curricula. Findings indicate that such technologies enhance collaborative learning, personalize instruction, and improve learning outcomes when applied systematically. However, challenges such as limited teacher training, infrastructure gaps, and digital inequality remain significant. Recommendations are provided for effective

implementation of information technologies to strengthen STEAM education and prepare students for the digital era.
Keywords: STEAM education, Information technologies, Digital learning, Educational innovation, Interdisciplinary learning, Virtual laboratories, AI in education

Anvarkhon Majidov

A Fuzzy Neural Network Approach for Intelligent Environmental Monitoring and Anomaly Detection in IoT Networks

National University of Uzbekistan named after Mirzo Ulugbek, Uzbekistan

Abstract: The rapid deployment of Internet of Things (IoT) technologies has significantly expanded the capabilities of large-scale environmental monitoring systems. However, the heterogeneity of sensor devices and the openness of communication channels increase the risk of anomalous data transmission and malicious interference. This paper proposes an intelligent environmental monitoring approach based on a fuzzy neural network for anomaly detection in IoT networks. The proposed method combines fuzzy logic and a multilayer neural network to analyze sensor data packets using nine network traffic features. Adaptive adjustment of membership functions during neural network training enables probabilistic evaluation of normal and anomalous behavior. The approach is integrated into a software-defined networking (SDN) architecture, allowing real-time traffic analysis, node validation, and dynamic synthesis of packet filtering rules.

Simulation results demonstrate high anomaly detection accuracy with moderate processing overhead, confirming the effectiveness of the proposed solution for secure and scalable environmental monitoring.
Keywords: Environmental monitoring, Internet of Things, fuzzy logic, neural networks, anomaly detection, software-defined networking

Sadig Malikov, Anar Rahimov
Reconstruction of Micro-Scale Aerospace Terrains Using LiDAR Point Cloud Interpolation
National Aviation Academy, Azerbaijan
Institute of Mathematics, Azerbaijan
Baku State University, Azerbaijan
Abstract: This study presents a grid-based surface reconstruction framework for micro-scale terrain modeling using LiDAR point cloud data acquired from an Intel Re-alSense L515 sensor. Due to the absence of access to kilometer-scale aerial plat-forms, a controlled laboratory terrain model was constructed to emulate reduced-scale surface conditions. Micro-scale reconstruction in confined environments in-troduces challenges related to measurement noise, occlusions, and resolution-dependent accuracy. We developed a methodology to convert unstructured point clouds into structured triangular meshes using nearest-neighbor interpolation via a cKDTree structure, followed by vertex-wise RGB texture mapping. The per-formance of the framework was evaluated across varying grid resolutions (n) and Region of Interest (ROI)

sizes. Our findings reveal a distinct bifurcation in error behavior: photometric Mean Squared Error (MSE) exhibits initial oscillations be-fore stabilizing as the grid density matches the image resolution, while geometric mean distance follows a monotonic 1/n decay pattern. The results demonstrate that a grid resolution equivalent to the original sensor resolution is optimal for visual representation, but higher densities continue to enhance geometric accura-cy. This work establishes a quantitative baseline for micro-scale terrain modeling, offering critical insights for aerospace and planetary engineering applications such as landing site assessment and mobility simulation.
Keywords: LiDAR, Point cloud processing, Digital elevation model (DEM), Grid-based sur-face reconstruction, Nearest neighbor interpolation, Microterrain modeling

Elnur Mammadli

Legal Protection of Design in Azerbaijan in the Context of Digitalization and Introduction of ICT Systems

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: This article provides a comprehensive doctrinal and institutional analysis of the legal protection of design in the Republic of Azerbaijan within the broader framework of digital transformation and the integration of information and communication technologies (ICT). The study explores the dual legal nature of design as an intellectual property object situated at the intersection of patent law and copyright, and examines the theoretical and practical challenges arising from the cumulative or alternative application of different protection regimes. Particular attention is devoted to the correlation between industrial design protection and copyright protection of design works, taking into account the Berne Convention and relevant provisions of Azerbaijani legislation. The article analyzes the criteria of protectability—novelty and originality—together with the determination of the scope of exclusive rights and the limits of protection. The research further examines the digital transformation of intellectual property administration in Azerbaijan, including the implementation of the PANAH electronic filing system, the development of open digital registries, integration with the national electronic government portal, and the establishment of electronic dispute-resolution mechanisms. The role of ICT in enhancing transparency, procedural efficiency, accessibility, and innovation incentives is substantiated. Special consideration is given to cybersecurity challenges as a structural element of digital IP governance. The article concludes that Azerbaijan is developing a comprehensive digital ecosystem for intellectual property protection that integrates national and international mechanisms, including cooperation with WIPO and the Eurasian Patent Organization, thereby strengthening legal certainty and fostering innovation-driven economic growth.

Keywords: industrial design, design works, copyright, patent law, intellectual property, digitalization, information and communication technologies, electronic government services, PANAH system

Shakir Mammadov, Jeyhun Musayev

Computational Approaches to Wave Propagation in Elastic and Deformable Structures

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: Wave propagation in elastic and deformable structures is a fundamental problem in mechanics, civil engineering, and applied physics. Nonstationary interactions of shock and elastic waves with barriers such as geological formations, construction materials, and structural elements are com-plex and practically significant. Accurate modeling of these processes is essential for predicting dynamic responses and ensuring structural reliability under extreme conditions. This study focus-es on wave propagation in an elastic medium containing a cylindrical inclusion. Analytical solu-tions of the governing equations in polar coordinates were derived under appropriate boundary conditions. Reference data on density, elastic wave velocities, and seismic stiffness for various soils and rocks were incorporated to ensure geotechnical relevance. Numerical simulations were performed to evaluate displacement velocities at different radial distances from the inclusion over a defined time interval. The results demonstrate that wave amplitude

decreases and arrival time increases with distance from the inclusion. At shorter distances, displacement velocity rises rapid-ly, while at intermediate distances the response is delayed and reduced. At greater distances, amplitude is significantly attenuated and the delay becomes more pronounced. These findings confirm theoretical predictions of wave attenuation and delay, validating the computational ap-proach. The methodology provides practical insights for seismic safety assessment, structural resilience analysis, and geotechnical engineering. It also contributes to geophysical exploration, mining safety, and energy system reliability. By integrating analytical and numerical methods, the study establishes a foundation for predictive modeling and innovative engineering solutions in complex geological environments.
Keywords: Numerical Modeling, Information Technologies, Elastic Media, Deformable Structures, Shock Waves, Interaction Dynamics, Wave Attenuation.

Vusala Mammadova, Vafa Salimova, Kamala Abdullaeva

Intelligent Control Systems Applied in Irrigation

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: The presented work examines the work of smart irrigation systems, which are applied in modern land reclamation systems, prevent water loss and evaporation, are considered environmentally acceptable, are more

financially affordable, and are currently receiving great attention in our country.
Keywords: Irrigation, Drip Irrigation, Intelligent Control Systems, Temperature And Humidity Sensor

Gulchohra Mammadova, Samira Akbarova

Model-Oriented Predictive Microclimate Control of Multifunctional Skyscrapers with Complicated Architectural Shape

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: The microclimate management of multifunctional skyscrapers (MFSs) with complex architectural shapes presents a significant engineering challenge. Traditional microclimate control algorithms based on proportional-integral-derivative (PID) controllers often fail to maintain comfortable indoor micro-climate parameters, resulting in excessive energy consumption. This paper examines the efficiency of model-oriented predictive control (MOPC) for microclimate providing systems (MCPS) of MFSs with complicated architec-tural forms located in a coastal zone with a hot and humid climate. The study is based on scenario modelling using the EnergyPlus software package. A comparison is made between a baseline reactive control scenario using PID controllers and an integrated scenario using MOPC. The effeciency of the MOPC was assessed based on the parameters of room air temperature and humidity stability, occupant thermal comfort, annual energy consumption,

peak cooling capacity, and exergy efficiency. The simulation results show that the use of MOPC reduces the standard deviation of indoor air tempera-ture by up to 50%, stabilizes relative humidity within the standard range, re-duces the proportion of occupant discomfort by more than half, and reduces the annual energy consumption of MCPS by approximately 18%. Additional-ly, a 15-17% reduction in peak cooling capacity and an increase in the sys-tem's exergy efficiency were recorded, demonstrating more efficient use of energy resources. The obtained results confirm the feasibility of using MOPC in MFSs operating in hot, humid climate.
Keywords: Microclimate Providing System, Thermal Comfort, Exergy Analysis

Afat Mammadova

Digital Infrastructure and Regional Economic Development: Comprehensive Assessment of Digitalization in the Regions of Azerbaijan

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: In Azerbaijan, digitalization has been identified as a strategic priority within the framework of national development programs aimed at economic diversification, innovation-based growth, and improved governance. The article offers a comprehensive methodological framework that combines socio-economic indicators and spatial analysis to assess digital development in the regions of Azerbaijan, including large urban centers and the Karabakh

Economic Region. The methodology includes indicators related to ICT infrastructure, digital accessibility, human capital and digital economic activity, which allows for a multidimensional comparison of regions, as well as an assessment of the level of regional digitalization in Azerbaijan and an examination of the role of digital infrastructure in promoting economic development and achieving sustainable results. Baku, being the undisputed leader in the level of implementation and application of IT technologies, has become the main digital and technological center of the country, however, territorial asymmetries remain in the level of deployment of digital infrastructure, the maturity of the IT ecosystem and the integration of digital technologies into regional economic structures. At the same time, many non-metropolitan regions have significant infrastructural, industrial and sectoral potential, which can serve as a basis for sustainable development based on digital technologies. This issue has become particularly relevant in the post-conflict context of the Karabakh Economic Region, where large-scale reconstruction creates a unique opportunity to introduce digital and intelligent technologies from the very beginning. Thus, the region is an important analytical example for studying the role of digital infrastructure in sustainable regional development. Empirical data reveal a pronounced regional asymmetry in the development of digital infrastructure, closely related to differences in economic indicators, investment attractiveness and innovation potential. The results highlight the strategic importance of

targeted investments in digital infrastructure for balanced regional development and sustainable economic transformation. The study developed a consolidated regional digitalization Index (CRDI), which reflects digital infrastructure, accessibility, human capital, and digital economic activity in the regions of Azerbaijan, including the Karabakh Economic Region. The results show significant regional differences in digital development, with leading urban regions demonstrating higher productivity, investment attractiveness, and economic diversification. At the same time, peripheral regions face risks of economic marginalization due to insufficient digital infrastructure and limited digital technology skills. The results show that digitalization acts as the most important factor of regional competitiveness, but requires additional investments in human capital and institutional capacity. The study concludes that an inclusive and district-specific digital policy is essential to ensure balanced regional growth, economic sustainability, and long-term development of Azerbaijan.
Keywords: Digital Economy, Regional Development, Sustainable Development, Azerbaijan

Najaf Mammadzada, Jabir Mammadov

Cybersecurity for Society 5.0: An Experimental Evaluation of Automated Endpoint Security Policy Enforcement in Virtual Environments

Baku Engineering University, Azerbaijan

Abstract: Contemporary enterprise networks face significant challenges in sustaining uniform endpoint security, resulting in a heightened requirement for automated patch management and efficient policy enforcement. This paper presents an experimental assessment of a cloud-based unified endpoint management platform within a controlled virtual environment intended to replicate a corporate network infrastructure. The test setup included a Windows Server 2019 server and three Windows 10 client workstations. This arrangement allowed for centralized management and the simulation of real-world operating conditions. Automated scripts were developed to streamline vulnerability detection, security patch application, and updates for third-party software. The assessment prioritizes operational efficiency, consistent deployment, and the ability to enforce security policies across remote endpoints, rather than relying solely on numerical performance metrics. Observations reveal that automation significantly improves the efficiency of routine security operations, reduces the need for manual involvement, and promotes standardized configurations throughout the network. Furthermore, centralized visibility enhances administrative understanding of system status and potential vulnerabilities. These findings highlight the strategic importance of cloud-native endpoint management technologies. They help organizations improve their cybersecurity while also reducing administrative tasks.

Keywords: Endpoint Security, Patch Management, Virtual Environment, Action1, Policy Enforcement, Automation, Vulnerability Assessment, Society 5.0

Ali Mardani, Hatice Gizem Şahin, Fatih Eren Akgümüş
The Effect of Waste Steel Fiber Content and Length on Water Absorption Capacity in Blast Furnace Slag-Based 3D Printable Concrete
Bursa Uludag University, Türkiye
Abstract: Additive manufacturing-produced 3D printable concrete (3DPC) mixtures offer advantages such as short production time, low labor requirements, reduced workplace accidents, and more flexible design possibilities compared to traditional concrete production. However, the high amount of binder used in these mixtures and the absence of coarse aggregate negatively affect drying shrinkage performance. In addition, high binder ratios are also a disadvantage in terms of sustainability and cost. To overcome these limitations, various studies are being conducted on the use of fiber reinforcements, pozzolanic materials, and industrial waste. In this study, it is proposed to replace 0%, 25%, 50%, and 75% of the total binder volume with high-oven slag to reduce the environmental impact of 3DPC mixtures. Additionally, waste steel fibers with lengths of 5, 10, and 15 mm were added to the mixtures at volumes of 0%, 0.5%, and 1% to improve drying-shrinkage performance. Thus, a total of 28 different 3DPC mixtures, including the control mixture, were prepared, the water/binder ratio was kept constant at 0.4,

and river sand with a maximum particle size of 2 mm was used. The experiments revealed a significant increase in the water absorption capacity of the mixtures with increasing blast furnace slag content
Keywords: Blast furnace slag, sustainability, waste steel fiber, additive manufacturing, water absorption

Ali Mardani, Hatice Gizem Şahin, Fatih Eren Akgümüş
Effect of Fiber Reinforcement and Recycled Concrete Aggregate on Water Absorption Performance of 3D Printed Concrete Mixtures
Bursa Uludag University, Türkiye
Abstract: Three-dimensional (3D) printable concrete stands out as a promising technology in the construc-tion industry due to its advantages such as reduced labor costs, no need for molds, and the ability to produce complex geometries. It is stated in the literature that 3D printable concretes have higher water absorption capacity due to their differentiated pore structure compared to traditional concre-te as a result of extrusion and layered manufacturing processes. This increase is particularly attri-butable to porosity between layers. Furthermore, detailed studies are needed to examine the effect of mixture composition on water absorption properties. In this study, the 7 and 28-day water absorption performance of thirteen different 3D printable concrete mixtures was investigated. In the experiments, the effects of fiber length (3, 6 and 12 mm), fiber volume fraction (0.2%, 0.4% and 0.6%) and aggregate type (natural limestone aggregate and 100%

recycled concrete aggrega-te) on water absorption were evaluated. It has been determined that increasing the fiber usage rate up to 0.4% improves water absorption performance, regardless of fiber length. However, it was observed that increasing the fiber content to 0.6% had a negative effect on performance. The lowest water absorption value at both 7 and 28 days of age was measured in the mixture with 0.4% fiber content and 6 mm fiber length, and it was determined that this combination provided optimum performance. Additionally, it was determined that using 100% recycled concrete aggre-gate instead of natural limestone aggregate resulted in a significant increase in water absorption values.
Keywords: 3D printable concrete, Water absorption,
Fiber reinforcement, Recycled concrete aggregate

Natalia Markovich

Information Spreading in Random Graphs Evolving by a Preferential Attachment Model with Poisson Edge Growth

Russian Academy of Sciences, V.A. Trapeznikov Institute of Control Sciences, Russia

Abstract: The paper is devoted to the spreading of a message within the random graph evolving by the directed preferential attachment model with poisson edge growth. The latter model forms random unit-shifted Poissonian numbers of new edges at each evolution step. Each of the newly created edges is added in one of two ways: with probability p, the new edge is directed from a new node to

one of the existing nodes, and with probability 1 − p, the new edge links two existing nodes. The evolution model plays a double role: it serves for the growing network (evolution) and for the spread of information. For a pre-fixed time T*, the probability mass functions of the number of edges, the number of nodes obtained the message and the total number of nodes in the graph are derived. To this end, the success probability that at least one new edge added in the step of evolution results to the transmission of the message to the node without the message is proved.
Keywords: Evolution, Random graph, Preferential attachment model, Poisson edge, growth, Information spreading

Qurat-Ul-Ain Mastoi, Abdullah Lakhan, Zain Gul, Syed Yaseen Shah, Syed Aziz Shah

Improved Convolutional Neural Network-Enabled GPS and EGNOS Framework for Location Tracking for Industrial 5.0 Applications

School of Computer Science and Creative Technologies, University of the West of England Bristol, United Kingdom
Dawood University of Engineering and Technology Pakistan, Pakistan
Instituto de Ciˆencias da Terra, Universidade do Minho, Portugal
School of Computing, Engineering and Built Environment, Glasgow Caledonian University, United Kingdom
Research Centre for Healthcare and Community Transformation, Coventry University, United Kingdom

Abstract: Today, determining precise location using various satellite navigation systems is essential for several reasons. These systems, such as the American Global Navigation Satellite System (GNSS), provide position and timing information that is essential for many industries, including vehicle tracking, oil drilling, airport and harbour security, atmospheric research, and astronomical telescope pointing. The Japanese Quasi-Zenith Satellite System (QZSS), China's BeiDou, the Russian GNSS (GLONASS), and the European Union's GALILEO are also technological competitors. However, achieving seamless accessibility, accuracy, and satellite link integrity is challenging. This study assesses positional accuracy in Rome, Italy, using EGNOS, EDAS, and a simple GPS receiver model. We present a novel convolutional neural network technique, dubbed CNN-DGPS, for precise position acquisition in urban settings, which is evaluated using testbed simulations based on data from Rome, Italy. Numerous real-time investigations conducted under different circumstances used GPS receiver data. By combining deep learning and dynamic GPS with EGNOS technology, CNN-DGPS improved accuracy by 99% compared to existing GPS location acquisition methods. CNN- DGPS can handle a wider range of industrial 5.0 applications, including industrial robotics, public transportation, and mobility, with greater precision than GPS

Keywords: Hardware platforms, architectures security, trust embedded IoT

Irina Matveeva

Machine Learning Methods for Identifying Chronic Heart Failure Using Raman Spectroscopy

Samara National Research University named after academician S.P. Korolev, Russia

Abstract: Optical methods, particularly Raman spectroscopy, are among the most promising methods for the rapid analysis of biological tissues and fluids. This study focuses on identifying chronic heart failure using intelligent analysis of Raman spectroscopy data. The study utilizes Raman spectra of serum and plasma from patients with chronic heart failure and a control group. The following machine learning methods were used to classify the Raman spectra: naive Bayes classifier, logistic regression, k-nearest neighbors, support vector machines, random forest, and gradient boosting. The following feature groups were studied: spectral samples, principal components, and local maxima of the difference spectrum of blood Raman spectra. As a result, optimal feature extraction and analysis methods were selected, demonstrating high efficiency in identifying chronic heart failure.

Keywords: Raman spectroscopy, chronic heart failure, machine learning, feature extraction, blood serum, blood plasma, local maxima, difference spectrum

Farkhod Meliev, Usmon Shadiev, Fatto Meliev

A Self-Supervised Approach for Stain Normalization in Histopathological Images

Samarkand State University after named Sharof Rashidov, Uzbekistan
Samarkand State Pedagogical institute, Uzbekistan
Abstract: This paper presents a self-supervised approach for histopathology image staining normalization based on deep learning methods. The challenge of staining normalization lies in the significant variability in images obtained across laboratories due to differences in staining methods, lighting, and equipment. These differences can impact diagnostic accuracy and pathology analysis. This paper proposes an innovative method that uses contrast learning to normalize images without the need for labels, improving the consistency of images obtained under different conditions. The method effectively adapts to various image sources and shows improved results on a dataset with a wide variety of histology slides.
Keywords: Self-Supervised Learning, Stain Normalization, Histopathology, Contrastive Learning

Nomaz Mirzaev, Gulmira Mirzaeva, Makhamadaziz Rasulmukhamedov, Nuraddin Gafforov
Extraction of Features Characterizing Keystroke Dynamics in the User Identification Problem
Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Uzbekistan
Tashkent State Transport University, Uzbekistan
Digital Technologies and Artificial Intelligence Development Research Institute, Uzbekistan

Abstract: This article examines the separation of characteristics describing the user's behavior in the matter of identifying the user based on keyboard dynamics. The study analyzed time sequences recorded by users while working with the keyboard. Haar wavelet transformation was used to distinguish characteristics that characterize user properties. The obtained wavelet coefficients were used as characters characterizing users. The advantages of the highlighted features were checked using SVM, MLP, Random Forest, and KNN algorithms. The results obtained can be used in the development of biometric authentication systems.
Keywords: Keyboard dynamics, user identification, Haar wavelet transform, SVM, MLP, KNN, Random Forest, time series, hold time, flight time

Nomaz Mirzaev, Johongir Urinboev, Sayyora Ibragimova, Gulmira Mirzaeva, Azizbek Tillavoldiyev
The Problem of Forming a Feature Space for Speaker Recognition
Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Uzbekistan
Digital Technologies and Artificial Intelligence Research Institute, Uzbekistan
Abstract: This work examines the issue of person identification based on voice signals. Speech-based biometric systems are widely used in information security, human-computer interaction, and intelligent information systems. However, noise, channel effects, and high

dimensionality of features can negatively affect the system's accuracy. This study investigated the development of noise-resistant and computationally efficient recognition algorithms based on a voice dataset consisting of 50 English speakers. Acoustic features such as MFCC, LPC, PLP, spectral centroid, energy, and entropy were extracted from speech signals, and a single feature vector was formed by combining these features. In this research, person recognition methods were thoroughly studied, with the main focus on two important approaches: feature fusion and feature space reduction using Principal Component Analysis (PCA) and Independent Component Analysis (ICA). Extensive experiments were conducted on various speech datasets characterized by different noise levels and numbers of speakers. The study yielded good results for a single dataset and classifiers. To reduce redundant and mutually correlated parts of features, dimensionality reduction methods - PCA and ICA - were applied to the feature space. The resulting features were evaluated using K-Nearest Neighbors (KNN) and Linear Discriminant Analysis (LDA) classifiers. These results indicate a significant increase in computational speed and speaker recognition efficiency due to the feature fusion and feature space reduction approaches.
Keywords: Speaker identification, feature extraction, feature fusion, feature space reduction

Boris Mordukhovich
Application of Optimization to Proton Therapy

Wayne State University, United States
Abstract: The talk is devoted to investigating single-objective and multiobjective optimization problems involving the so-called $\ell 0$-norm function, which is nondifferentiable and nonconvex. Such problems appear in proton beam therapy models of cancer research. The developed approach uses first-order and second-order subdifferential tools of variational analysis and scalarization techniques of multiobjective optimization. Based on this machinery, we propose several algorithms of the subgradient and generalized Newtonian types and conduct their convergence analysis. The obtained results are illustrated by numerical examples from proton therapy models. Based on the collaboration with the Proton Therapy Center of the Corewell William Beaumont Hospital, Royal Oak, Michigan.
Keywords: $\ell 0$-norm optimization, Nonconvex nonsmooth optimization, Multiobjective optimization, Variational analysis, Subdifferential calculus, Scalarization techniques, Subgradient algorithms, Generalized Newton methods, Convergence analysis, Proton beam therapy modeling

Lamia Muhammed, Nidhal Hasan
Data Augmentation Using Fuzzy c-Means Algorithm
University of al-Qadisiyah, Iraq
Abstract: Insufficient training data for model learning is a challenge that need to remedy. Data augmentation is a technique that can increase the size of these data, so it can be a solution for the insufficient data problem. Different

augmentation methods have been proposed according to the type of the data from traditional approach such as statistics, machine learning approach, and the newest one that is deep learning. Each method has its advantages and limitations. Therefore, there is a promised field for more works. In this paper, there is a proposed approach for exploiting Fuzzy c-means in increase the data samples, where it is a popular algorithm in uncertainty apace and used in clustering. The proposed approach would be tested with two datasets, one of them with small features while other one with small observations. The results of testing were compared with K-means algorithm. Comparisons show that the results of the proposed method far surpass those of using k-means algorithm, so it can be recommended to be used in this field for similar situation
Keywords: data augmentation, fuzzy c-means, feature extraction, feature transformation, clustering

Isa Muradov, Natig Mahamaliyev

Digital Sovereignty in Tourism Marketing: Data Governance and Cybersecurity Challenges in Emerging Markets

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: In recent years, the tourism industry has undergone rapid digitalization, and marketing decisions have increasingly relied on data-driven approaches. Online travel agencies (OTAs), social media platforms, and algorithmic advertising systems have become the primary

carriers and controllers of tour-ism-related data. However, in emerging economies, a significant portion of tourism data is collected and managed by global platforms, creating a structural problem of data dependency within national marketing strategies. This article explores the concept of digital sovereignty in tourism marketing and analyzes the strategic, economic, and cybersecurity implications of losing control over data. The study demonstrates that the concentration of data on foreign platforms weakens national control over destination branding, market segmentation, and targeted advertising activities. At the same time, data breaches and cyber risks may negatively affect consumer trust and national image in the tourism sector. The paper proposes the establishment of national tourism data centers, the development of secure marketing infrastructures, and the implementation of a governance model based on public–private collaboration for emerging tourism markets. In conclusion, digital sovereignty is not merely a technological issue but should be regarded as a fundamental prerequisite for ensuring the strategic security of tourism marketing.
Keywords: Digital sovereignty, tourism marketing, data governance, cybersecurity, platform economy, data-driven marketing, emerging markets

Isa Muradov, Irana Akhundova
Artificial Intelligence and Economic Efficiency in Tourism Enterprises

Azerbaijan University of Architecture and Construction, Azerbaijan
Azerbaijan Tourism and Management University, Azerbaijan
Abstract: In recent years, artificial intelligence (AI) technologies have generated significant transformation across various economic sectors, including tourism. Tourism enterprises have increasingly adopted AI-based systems for dynamic pricing, demand forecasting, customer behavior analysis, and the automation of operational processes. However, the impact of artificial intelligence on economic efficiency—particularly in emerging markets—has not yet been sufficiently examined on an empirical basis. The purpose of this study is to empirically evaluate the impact of artificial intelligence technologies on the economic efficiency of tourism enterprises. The research analyzes the effects of AI adoption on operational efficiency, cost optimization, revenue growth, and overall economic performance indicators. The findings indicate that the implementation of artificial intelligence enhances operational productivity, reduces administrative and management costs, and enables more effective revenue management. Therefore, artificial intelligence should be regarded not only as a technological innovation but al-so as a strategic economic instrument for tourism enterprises.
Keywords: Artificial intelligence, tourism enterprises, economic efficiency, digital transformation, operational optimization, revenue management

İsa Muradov, Sona Səfəralıyeva

Development of an Adaptive Artificial Intelligence Model for Predicting Students' Academic Results Based on Machine Learning Methods

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: As a result of the digitalization of education systems, the collection of large amounts of academic and behavioral data has expanded the possibilities of predicting students' academic performance. Early identification of the risk of academic failure or dropout is of great importance in terms of optimizing decision-making mechanisms in higher education institutions. In this research, an adaptive artificial intelligence-based model is proposed for predicting students' academic outcomes. The model is built on the basis of various features demographic indicators, attendance, current assessment results, and behavioral indicators. In the framework of the study, supervised machine learning algorithms such as Random Forest, Support Vector Machine, and Gradient Boosting were comparatively analyzed and an ensemble approach was applied. Experimental results showed that the proposed adaptive model demonstrates higher prediction accuracy compared to individual models and achieves results higher than 91% on test data. Feature importance analysis showed that attendance and midterm grades collected during the semester are the main predictive factors. The results of the study are of practical importance for the development of

early intervention strategies and the optimization of academic management in higher education institutions.
Keywords: Artificial intelligence, Machine learning, Academic performance prediction, Educational analytics, Adaptive models, Ensemble methods

Isa Muradov, Irana Akhundova

The Role of Digital Platforms and Mobile Technologies in the Tourism Sector: An Analysis of Small and Medium-Sized Tourism Enterprises

Azerbaijan University of Architecture and Construction, Azerbaijan
Azerbaijan Tourism and Management University, Azerbaijan

Abstract: This article analyzes the role of digital platforms and mobile technologies in the tourism sector, with particular emphasis on their impact on the operations of small and medium-sized tourism enterprises. As a result of the accelerated digitalization of tourism, online booking platforms and mobile applications have significantly transformed the mechanisms for the provision and management of tourism services. The main objective of the study is to assess the advantages offered by digital platforms and mobile technologies for small and medium-sized tourism businesses, the existing challenges, and the possibilities for their implementation based on international experience. The study employs methods of systematic literature review, comparative analysis, and graphical analysis of statistical data. The functional

features, business models, and cross-platform synchronization capabilities of global digital platforms such as Airbnb and Booking.com are analyzed comparatively. The results indicate that digital platforms enable small and medium-sized tourism enterprises to access global markets with minimal investment, while mobile technologies facilitate the automation of booking processes and real-time management. At the same time, challenges such as platform dependency, commission costs, and technological literacy also persist. Overall, the article demonstrates that appropriately selected and strategically implemented digital platforms significantly enhance the competitiveness and sustainable development of small and medium-sized businesses in the tourism sector.
Keywords: Digital platforms, Mobile technologies, Tourism sector, SMEs, E-tourism, Online reservation systems

Nazli Muradova, İlhami Suleymanov

An Intelligent Dust Detection and Protection System (DDPS) for Autonomous Management of Photovoltaic Performance

Baku Engineering University, Azerbaijan, Azerbaijan

Abstract: Dust accumulation introduces significant performance degradation in photovoltaic (PV) systems operating under uncertain and dynamic environmental conditions, particularly in arid, remote, and infrastructure-limited regions. Traditional maintenance approaches based on periodic manual inspection or fixed cleaning schedules are inefficient, resource-intensive, and poorly suited for environments where access, water, and human intervention are constrained. This paper presents an information-driven Dust Detection and Protection System (DDPS) for the autonomous management of photovoltaic performance. The proposed system integrates sensor-based environmental monitoring with a predictive reflex control architecture implemented on an embedded microcontroller platform. Instead of relying on predefined schedules, the DDPS continuously evaluates real-time sensor data and triggers cleaning actions only when performance degradation is detected, forming a closed-loop cyber-physical control system. A waterless air-fan cleaning mechanism is employed, and all system components are powered directly by the host photovoltaic panel, enabling complete energy autonomy. Experimental evaluation of a functional prototype demonstrates effective restoration of photovoltaic performance following dust-induced degradation, achieving an average power output improvement of 56.055%. The results confirm that event-driven, reflex-based control can significantly enhance system efficiency while minimizing unnecessary actuation, energy consumption, and mechanical wear. Beyond its application to solar panel maintenance, the proposed DDPS illustrates a scalable and low-complexity framework for autonomous performance management in complex physical systems. The architecture is applicable to a wide range of cyber-physical and embedded control problems

requiring adaptive, real-time decision-making under environmental uncertainty.

Keywords: Photovoltaic systems, Autonomous system management, Sensor-based control, Waterless solar panel cleaning, Dust accumulation, Efficiency optimization

Naila Musaeva, Telman Aliev

Technologies for Estimating the Remaining Useful Life of Technical Objects Based on Noise Characteristics of Noisy Signal

Azerbaijan University of Architecture and Construction, Institute of Mathematics, Azerbaijan

Azerbaijan University of Architecture and Construction, Azerbaijan

Institute of Mathematics, Azerbaijan

National Academy of Sciences, Azerbaijan

Abstract: It is shown that during operation, technical objects develop damage, wear, corrosion, defects, deformations, cracks, microcracks, and other faults. As a result, the technical condition of an object transitions from healthy and operational states to limited operational, pre-failure, unacceptable, and emergency states. Traditionally, monitoring systems are developed for the timely detection of malfunctions and defects. However, existing monitoring systems do not use algorithms for analyzing noise in noisy signals. At the same time, it is the signal-to-noise intensity ratio that is an informative attribute allowing for the detection of the onset of a malfunction at an early stage. In this regard, the study develops algorithms for calculating

signal-to-noise intensity ratios as an indicator of the onset of a malfunction. It is demonstrated that if the signal-to-noise ratio for a given signal does not exceed a certain threshold, the probabilities of the noise reaching permissible, threshold, critical, and hazardous values should be calculated. Depending on the values of these probabilities, the technical condition of the object is determined and its remaining useful life is established. We develop technologies for estimating the remaining useful life of technical objects based on the noise characteristics of a noisy signal. It is shown that the sum of the products of the probabilities of threshold, critical, and hazardous noise values by their corresponding weighting factors yields total probabilities that provide a more accurate assessment of the overall technical condition of the object under study. This enables a reliable determination of the object's remaining useful life. As a result, it becomes possible to plan routine and major repairs, replace structural elements in a timely manner, and thus ensure the operational safety of the monitored object.
Keywords: noise, useful signals, noise characteristics, object's technical condition, remaining useful life

Vasif Nabiyev, Ahmet Faruk Dursun, Kübra Seyhan, Sedat Akleylek
Helbench: A Comparative Benchmarking Framework for Fully Homomorphic Encryption Libraries
Karadeniz Technical Universtiy, Türkiye
Ondokuz Mayıs University, Türkiye

University of Tartu, Türkiye
Abstract: The rapid development of technology has heightened concerns about data security, prompting the development of new encryption techniques. Homomorphic encryption (HE), which performs computations on ciphertexts without decryption, has emerged as a promising solution for protecting data confidentiality. The provision of post-quantum security guarantees has particularly increased interest in fully HE (FHE) methods. In this paper, a comparative performance analysis is conducted for different libraries implementing FHE methods. Evaluations are provided to determine which FHE library to choose based on performance, taking into account the application and use cases. A benchmarking framework called Helbench is developed to evaluate the Microsoft SEAL, OpenFHE, and HElib libraries for Brakerski/Fan-Vercauteren (BFV), Brakerski, Gentry, Vaikuntanathan (BGV), and Cheon-Kim-Kim-Song (CKKS) FHE schemes. To ensure fairness in library performance comparisons, no manual optimizations are applied; libraries are run with their default settings, and analyses are presented at 128-bit security level. The analyses are presented in terms of performance metrics such as execution times, memory usage, and storage cost for homomorphic addition, subtraction, multiplication, and squaring operations, as well as cryptographic operations like key generation, encryption, and decryption. The Helbench results show that, across all examined FHE schemes, SEAL requires less runtime, memory usage, and

storage cost than other libraries. The main contribution of this paper is to provide a roadmap for selecting the most suitable FHE library based on performance results across different applications and use cases.
Keywords: Homomorphic encryption, HElib, Microsoft SEAL, OpenFHE, BFV, BGV, CKKS

Khilyah Nafisah, Muhardi Saputra, Haryasena Panduwiyasa
The Influence of Technostress on ChatGPT Adoption in Gen Z Learning: A Diffusion of Innovation (DOI) Perspective
Telkom University, Indonesia
Abstract: The rapid integration of generative AI, especially ChatGPT, has fundamentally transformed the Indonesian educational landscape by offering unprecedented access to information and advanced academic support. However, despite these benefits, the adoption of such technology frequently introduces technostress, creating famous psychological barriers for Generation Z users. This study aims to develop and validate a comprehensive measurement framework for ChatGPT adoption by examining critical interactions between innovation attributes and technostress based on Diffusion of Innovations (DOI) theory. The conceptual model identifies key latent variables, including Relative Advantage, Understandability, Trialability, Observability, Functionality, Complexity, Compatibility, and Adoption. A quantitative research design was applied, utilizing Partial

Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS software for strict data analysis. The analytical process specifically evaluated the outer model to ensure the validity and reliability of each indicator, while the inner model was utilized to examine the structural relationships between the latent variables. Data were collected from Generation Z respondents across Java Island to evaluate the structural relationships within the proposed model. Based on the empirical assessment, the initial outer model evaluation necessitated the removal of indicators RAD1 and UND1 to satisfy empirical thresholds for validity. Findings reveal that Relative Advantage, Compatibility, Observability, and Trialability serve as the primary positive drivers for technology acceptance. Conversely, functionality issues emerged as a significant source of technostress, whereas high understandability and low complexity were identified as essential factors for effectively mitigating psychological strain. These empirical insights provide a validated and reliable framework for future research and offer practical implications for AI developers to optimize system reliability and user experience to effectively reduce technostress among academic users.
Keywords: ChatGPT, Technostress, Generation Z, SmartPLS, Technology Adoption, Indonesia

Gulnar Naghiyeva, Firudin Aghayev
Neural Networks, Deep Learning Applications
Baku State University, Azerbaijan

Baku Eurasian University, Azerbaijan
MSE Institute of Information Technology, Azerbaijan
Azerbaijan University of Architecture and Construction, Azerbaijan
Abstract: Recent advances in artificial intelligence have significantly increased the effectiveness of neural networks and deep learning techniques in solving complex real-world problems. This paper investigates the application of deep neural network models for decision-making and optimization tasks, focusing on improving accuracy and adaptability in data-driven systems. The study analyzes modern deep learning architectures, including convolutional and recurrent neural networks, and evaluates their performance in handling large-scale and non-linear data. A novel optimization framework based on deep learning is proposed, where neural networks are trained to learn optimal decision strategies from historical data. The proposed approach integrates feature extraction, model training, and performance evaluation into a unified system. Experimental results demon-strate that the suggested method outperforms traditional optimization tech-niques in terms of prediction accuracy, convergence speed, and robustness to noisy data. The effectiveness of the model is validated through experimental analysis using real and simulated datasets. Performance metrics such as accuracy, precision, recall, and loss functions are employed to assess the results. The findings confirm that deep learning-based approaches provide flexible and efficient solutions for

optimization and decision-making problems in intelligent systems. The results of this research highlight the potential of neural networks as a powerful tool for solving complex optimization tasks and supporting intelligent decision-making processes in various application domains.

Keywords: Neural Networks, Deep Learning, Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Decision Making, Optimization, Machine Learning, Intelligent Systems

Nizami Nagiyev, Fidan Zulfugarli, Sabina Aliyeva

Labor, Everyday Life, and Leisure in the Spatial System of the Modern City

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: The Triad of Work, Household and Leisure in Urban Settlement Systems: From Historical Evolution to Digital Transformation The quality and structure of everyday life in urban settlement systems are mainly determined by the interaction of three fundamental spheres: work, household needs and leisure. The most important socio-cultural aspect at the level of city master planning is precisely how these spheres interact with each other, in particular how labor activity is coordinated with residential and recreational zones. Since the end of the 19th century, scientific and technological progress and the mechanization of production have not only facilitated human labor, but also led to an increase in free time. This process has turned the concept of leisure into one of the

independent and important topics of urban planning. Over time, various conceptual approaches to these relationships have been formed. Thus, while one approach advocates a sharp separation of industrial zones from residential areas (zoning), another approach perceives the city as a single "living organism" in which all functions support each other. Research conducted throughout the 20th century shows that the spatial organization of the city directly depends on how labor is organized. Shortening working hours, changing work schedules, and more flexible forms of labor form new requirements for the location of residential buildings, service enterprises, and recreational areas. With the increasing importance of automation, personal development, and creative activity, cultural and household services have ceased to be an auxiliary area and have become one of the main pillars of urban development. In a large urban environment, the principle of tiered service alone is no longer enough. Currently, the creation of multifunctional districts is gaining momentum. Increased mobility has weakened the classic "proximity" factor; people now base their choice of service and leisure facilities not on distance, but on quality, variety, and convenience. This trend strengthens the role of city-wide service networks and specialized centers. In this structure, the main communication and transport corridors perform the function of the "backbone" of the city, forming movement trajectories and maintaining the urban fabric as a single whole. In the period 2020-2025, digital transformation has taken the urban model to a new stage. The massification of remote and hybrid forms of work has partially reduced the daily flow of people to central zones, but has increased the demand for neighborhood-scale services and spaces where work and leisure intersect. This process is stimulating the transition from a single dominant core to a more flexible and distributed system of urban centers over time. At the modern stage, artificial intelligence and "smart city" tools — IoT sensors, digital twins and predictive analytics — allow for the optimization of transport, energy management and load balancing of public spaces. Thus, modern urban planning approaches the "work-life-leisure" triad not simply as a static functional zoning, but as an adaptive spatial system based on real-time data, aimed at sustainability and social justice.

Keywords: networking, smartcity, accessibility

Efendi Nasiboglu, Melih Eşiyok, Okan Uluturk, Berke Bekar, Israfil Isakhli

Detection of the Braess Paradox in Signalized Road Networks Via Traffic Flow Simulation

Dokuz Eylul University, Türkiye

Abstract: Braess's paradox is an observation stating that adding one or more roads to a road network can slow down the overall flow of traffic. This paradox was first discovered by Arthur Pigou in 1920 and later named after the German mathematician Dietrich Braess in 1968. This research was conducted to examine urban traffic congestion in the Buca district of Izmir, to investigate the observability of Braess's Paradox with real-world data, and

to develop simulation-based solutions. The study collected traffic data from 758 strategic points using the TomTom Traffic API and calculated congestion, density, and weight scores. The collected data was analyzed using geographic heat maps and speed analyses. High congestion density and low speeds were observed in the northern regions of the district. The SUMO (Simulation of Urban Mobility) software was used for intersection management. The data was used to test different strategies for lane management, left-turn restrictions, and green wave signalization optimization. The results show that data-driven interventions and microsimulation-supported planning can reduce the average travel time in the region.
Keywords: Intelligent Transportation Systems, Braess Paradox, Traffic Simulation, TomTom Traffic API, SUMO

Efendi Nasiboglu, Süheyla Uygur

A Landmark Study of Fuzzy Inference Systems Using a Hybrid Method for Prediction

Dokuz Eylul University, Türkiye

Abstract: Fuzzy Inference Systems (FIS) are widely used to model uncertain, imprecise, and nonlinear systems in domains such as finance, healthcare, decision support, and engineering. They are particularly effective when data distributions are irregular, measurements contain noise, and relationships between variables are not explicitly defined. This study proposes a novel FIS model based on the classical Fuzzy C-Means (FCM) clustering algorithm. Rather than employing FCM membership degrees directly

for classification, the proposed approach transforms them into continuous regression predictions using a dynamic weighting mechanism and a MIN-PROD-based hybrid estimation strategy. Membership values are first normalized, a range-dependent weighting coefficient is calculated, and minimum and product inference outputs are combined to obtain the final prediction. The proposed model was evaluated on car price prediction, advertising sales prediction, and diabetes datasets. Its performance was compared with conventional regression techniques and FCM-based estimation approaches. Experimental results indicate that the model achieves low prediction error and high explanatory power, particularly on heterogeneous datasets, while maintaining stable performance under variations in data distribution. The findings demonstrate that the proposed FIS framework provides a competitive and interpretable alternative to traditional predictive models. Furthermore, the study highlights the potential of integrating fuzzy logic with artificial intelligence and machine learning techniques for developing new hybrid predictive approaches.
Keywords: Fuzzy Inference System, Fuzzy C-Means, MIN-PROD-based hybrid prediction, Fuzzy Prediction Model, Hybrid Prediction Method

Ofelya Nasirova

The Importance of the Application of Modern Technologies in Education

Azerbaijan University of Architecture and Construction, Azerbaijan
Abstract: In the context of globalization and digital transformation, one of the main strategic priorities of the education system is the introduction of modern technologies and their systematic integration into the learning process. The formation of the information society has led to the beginning of a qualitatively new stage in the mechanisms of knowledge creation, transmission and assimilation. These changes stimulate the development of critical thinking, problem-solving and digital skills of students, and at the same time necessitate the renewal of the content and methods of education. In modern times, the integration of technologies into education is of great importance in terms of improving the quality of the learning process, expanding individual learning opportunities, and preparing students for the requirements of the modern labor market. In the context of digital changes and globalization, modern technologies are not limited to providing only the technical support of the teaching process, but at the same time they provide an impetus for the renewal of pedagogical approaches, the creation of an innovative educational environment, and the implementation of a teaching model. Digital learning resources, electronic textbooks, interactive presentations, provide visual and practical mastery of knowledge, increase students' interest in the lesson and increase their motivation to learn. Artificial intelligence and adaptive learning systems provide an individual approach, allowing

students to build an individual learning trajectory in accordance with their level of knowledge. The application of technologies strengthens the interactive relationship between students and teachers, leads to quick and easy access to educational resources, saving teaching time and costs, as well as objective assessment of results. At the same time, the development of technological applications also raises certain challenges - insufficient technical infrastructure, low level of digital skills of teachers, and problems related to cybersecurity issues. Sustainable public policy, professional training programs, and strengthening technological infrastructure are important factors in overcoming these problems. As a result, the targeted application of technologies in education makes a significant contribution to the innovation of the education system, the efficient and effective transfer of knowledge, and the formation of competitive human capital in the future.

Keywords: education, technology, digitalization, innovation, distance education, e-learning, training

Isa Navruz, Husamettin Serbetci

Effects of Fiber Type and Core Diameter on CNN-Based Refractive Index Detection

Ankara Üniversitesi, Türkiye

Çankırı Karatekin Üniversitesi, Türkiye

Abstract: This study experimentally investigates refractive index (RI) sensing performance in the 1.33–1.35 range for various optical fibers at 635 nm and 1550 nm wave-

lengths. The RI was varied between 1.3322 and 1.3514 in steps of 8×10-4. All experiments were conducted using tapered fibers with a 10 μm waist diameter and a 2.25 cm waist length, and each measurement was repeated five times to en-sure repeatability. Speckle pattern images recorded during the experiments were analyzed using a convolutional neural network (CNN). The sensing process was performed through deep learning, and the CNN performance was evaluated. The trained CNN model demonstrated high classification accuracy across differ-ent fiber types and wavelengths. At 635 nm, step-index multimode fibers (SI-MMFs) outperformed graded-index multimode fibers (GI-MMFs). Among SI-MMFs, fiber with a larger core diameter exhibited better performance than fiber with a smaller core diameter. Similar trends were observed in graded-index fibers with different core diameters. Experiments conducted at 1550 nm confirmed that SI-MMFs consistently achieved superior performance compared to GI-MMFs. Moreover, larger core diameters led to improved CNN-based sensing accuracy. These findings demonstrate the effectiveness of deep learning for speckle-based RI sensing and highlight the influence of fiber type and core diameter on detec-tion performance.
Keywords: Refractive Index, Tapered Optical Fiber, Speckle Pattern, CNN, Deep Learning

Luan Nguyen, Tran Luu

Enhancing Learning Effectiveness and Satisfaction Through Game-Based Learning in Higher Education

FPT University, Viet Nam
Abstract: In modern education today, integrating advanced technologies into education is becoming increasingly common, and researching the impact of technology on learning is essential. This study will focus on exploring aspects surrounding learning motivation and the effectiveness that technology brings through understanding and analyzing the game-based learning (GBL) design framework. In higher education, teaching and learning methods that provide students with the most multifaceted opportunities for self-development require educators and institutions to focus on deeper development of flexible and unconstrained curriculum and teaching design frameworks. This allows students to feel comfortable and unpressured by their studies. With the GBL model, this is considered the basis for combining it with traditional teaching methods to create learning motivation and participation, thereby training the ability to adapt and update trends quickly and effectively. Despite growing interest, there is still limited empirical evidence on how design factors can influence learning outcomes and student satisfaction with their experience of the model throughout their studies. Insights from qualitative research have emphasized the importance of a clear alignment between game mechanics and learning objectives. The results of the study will partially clarify the factors and thus provide the correct directions for learning thru the GBL model and applying it in practice, applying existing theories and models to enhance the superiority of the GBL model,

and providing information most relevant to the needs of students and educators when they need additional input to strengthen and develop the model to become increasingly appropriate.

Keywords: Game-Based Learning (GBL), Learning Effectiveness, Student Satisfaction, Motivation and Engagement, Educational Technology

Luan Nguyen, Tran Huynh

AI-Based Smart City Applications: Student Experiences and Usage Challenges

FPT University, Viet Nam

Abstract: This study investigates university students' experiences and challenges in using AI-based applications within smart city environments. Drawing on survey data from 181 participants, the research explores patterns of adoption, perceived usefulness, ease of use, and barriers to effective engagement. Findings indicate that while students recognize the potential of AI technologies to enhance urban living, issues such as limited digital literacy, data privacy concerns, and usability difficulties hinder optimal utilization. The study contributes to understanding user-centered factors influencing AI adoption in smart cities and provides insights for policymakers and developers to design more accessible and effective solutions.

Keywords: Artificial Intelligence (AI), Smart City Applications, Technology Acceptance, Student Experience, Usage Challenges, User Perception

Thao Nguyen, Luan Nguyen, Vui Tang

Fake News and Students: from Perception to Behavioral Response

FPT University, Viet Nam

Abstract: Fake news has become a critical challenge in digital environments, particularly for university students who consume news primarily through social media. This study investigates Vietnamese university students' perception of fake news, their credibility evaluation processes, and behavioral responses to misinformation. Using a quantitative survey of 206 students, the study examines relationships among Perception of Fake News (PFN), Perceived Credibility (PC), Social Media Usage (SMU), Critical Detection (CD), Media Literacy (ML), and Behavioral Response (BR). Findings indicate that students exhibit moderate-to-high awareness of misinformation and frequently verify online content before sharing. Results highlight the significance of media literacy and critical evaluation in shaping responsible digital behaviors. Implications for educational interventions and future research directions are discussed.

Keywords: Social Media, Fake News, University Students, Media Literacy, Digital Behavior

Thao Nguyen, Luan Nguyen

Multitasking in Learning: The Impact of Social Media Use on Student Concentration

FPT University, Viet Nam

Abstract: This study examines the impact of social media multitasking on university students' concentration within the Vietnamese higher education context. Using a quantitative approach, survey data were collected from 206 students and analyzed through descriptive statistics, reliability assessment, correlation, regression, and ANOVA. The findings indicate that high levels of social media usage and multitasking behavior are strongly associated with increased cognitive distraction, which in turn reduces students' ability to sustain focused attention during learning activities. Although students self-reported relatively strong concentration, regression results show that multitasking and distraction remain the strongest predictors of reduced academic focus. Perceived credibility and fake news awareness exhibit modest mitigating effects by promoting more critical information evaluation, thereby partially lowering susceptibility to distraction. ANOVA results reveal no significant differences in concentration across demographic groups, suggesting that digital multitasking has a broadly consistent effect. Overall, the study highlights the need to improve digital literacy and attention management skills to support more effective learning in a technology-rich environment
Keywords: Social Media Multitasking, Student Concentration, Digital Learning, Cognitive Distraction, Academic Performance

Urfat Nuriyev, Khadija Hidayatova, Bora Bugra Sezer

Blockchain-Enabled Post-Quantum Session Establish-Ment for Constrained IoT Devices

Karabakh University, Azerbaijan
Baku State University, Azerbaijan
Ege University, Türkiye

Abstract: The integration of Internet of Things (IoT) systems with 6G communication infrastructures and critical applications requires decentralized trust, auditability, and low operating overhead. However, rapid advances in quantum com-puting increasingly render commonly used public-key security mechanisms vulnerable to the harvest-now, decrypt-later (HNDL) threat. This study presents a post-quantum-compliant and auditable session establishment frame-work for resource-constrained IoT devices. The session key is derived from the Module-Lattice-Based Key-Encapsulation Mechanism (ML-KEM) encap-sulation output using a context-dependent key derivation function, enabling quantum-resistant key establishment between the device and the server. Application traffic is protected with the lightweight Ascon-128a AEAD, which provides end-to-end confidentiality and integrity by binding the CoAP and option fields as associated data. Authentication is realized via zk-STARK proofs, achieving verifiability without exposing sensitive credentials. Block-chain overhead is reduced through an event-based smart contract (EBSC) approach, while dynamic authorization revocation is enforced during new session setups by checking the latest on-chain authorization state. Experi-mental results indicate that the

proposed design balances quantum security and performance.
Keywords: İnternet of Things (IoT), Post-Quantum Security, Lightweight Cryptography, Blockchain, Zero Knowledge-Proof

Bensu Melis Orhan, İrem Kayaarslan
A Search and Rescue Robot for Under Rubble Victim Detection Using Thermal and Sensor Based Systems
Baskent University, Türkiye
Abstract: In the critical hours following a natural disaster, achieving a rapid situational assessment is required for the search and rescue operations carried out after natural disasters, especially in collapsed structures. The proposed robotic system provides Simultaneous Localization and Mapping (SLAM), utilizing the Robot Operating System (ROS2) to monitor and detect victim signatures. Furthermore, durability is enhanced through its specialized robotic platform and track-type system. Within our integrated design, we combined 2D LiDAR and thermal sensor using a fusion strategy. This allows the robot to perform spatial mapping while simultaneously detecting survivors by analyzing temperature differen-tials in its surroundings. Furthermore, a USB camera was integrated to provide the operator with a re-al-time visual perspective. Data from all integrated sensors alongside me-chanical motion control are centralized within the RViz2 framework, offer-ing a unified operational dashboard for comprehensive visualization. Communication is

maintained via a high bandwidth TCP/IP network over a Wi-Fi module, ensuring seamless telemetry and real time sensor data stream-ing. For humanitarian support, the robot incorporates a walkie-talkie voice link alongside a servo mechanism designed to deliver essential life support supplies to trapped individuals. Experimental evaluations demonstrate that the system's performance in spatial reconstruction and thermal signature de-tection remains resilient against environmental noise. The integration of ROS2 and RViz2 ensures a scalable, modular, and professional solution for modern disaster response initiatives.
Keywords: Search and Rescue Robotics, ROS2, Sensor Fusion, SLAM, Thermal Imaging, Disaster Response

Yasin Ortakci, Caner Ozcan, Esmanur Alican

Machine Learning Insights into Europe's Energy Future: Trends and Regional Variations

Karabuk University, Türkiye

Abstract: This study examines the European energy transition from 1990 to 2023 and forecasts future trends (2024-2033) using Ember's extensive electricity data and advanced machine learning techniques. It covers 37 countries in its de-tailed analyzes, taking into account bioenergy, coal, gas, hydropower, nuclear, other fossil fuels, other renewables, solar and wind. The study examines how Linear Regression, Random Forest Regressor, Decision Tree Regressor, K-Nearest Neighbors Regressor (KNN) and Support Vector Regression (SVR) predict energy

production at the national level. The performance of the models was evaluated by the root mean square error (RMSE) and R-squared (R^2) values. Random Forest (R^2=0.8, RMSE=50) and Decision Tree (R^2=0.78, RMSE=52) models were found to be the most successful models as they provided low error (RMSE) and high fit (R^2). Detailed country-specific results, including comparative model performance and visualizations, show significant projected increases in renewable energy and corresponding decreases in fossil fuels, although the pace of transition varies significantly across coun-tries. It also contributes to the effective climate change mitigation policy development and energy strategies by shedding light on the determining parameters of the energy transition and regional differences in Europe.
Keywords: Energy Consumption, Renewable Energy,
Fossil Fuel, Machine Learning, Regression

Yasin Ortakci, Buse Sariçayir, Caner Ozcan
A Comparative Study of Word Embedding Techniques for Turkish Sentiment Analysis
Karabuk University, Türkiye
Abstract: This paper presents a comparative analysis of three different word embed-ding techniques—TF-IDF, Word2Vec, and FastText in the context of Turkish sentiment analysis. Each method offers a unique trade-off between computa-tional efficiency, representational richness, and classification accuracy of Turkish text. TF-IDF, a frequency-based approach, is computationally inexpensive but neglects word order and contextual

information. Word2Vec gen-erates context-aware embeddings capturing semantic relationships but remains context-independent for individual words. FastText further refines word representation by incorporating subword information, which is particu-larly advantageous for morphologically rich languages like Turkish. The performance of these embedding methods was evaluated using four different classification models (Logistic Regression, Decision Tree, Random Forest, and Support Vector Machine) on the Winvoker Turkish sentiment analysis dataset. Our experimental results show that Word2Vec achieves the highest accuracy with Logistic Regression. These results contribute to a better under-standing of the strengths and limitations of various word embedding tech-niques for sentiment analysis in morphologically rich languages.
Keywords: Sentiment Analysis, Turkish text, TF-IDF, Word2Vec, FastText, Embedding Models

Samat Osmonov, Balnur Kubanychova, Al Khan
AI-Based Personal Assistant as an Intelligent Control System for User Workflows in Desktop Environments
INAI, Kyrgyzstan
Abstract: The proliferation of digital tools and applications has paradoxically increased cognitive load, as users struggle to manage workflows across disparate desktop applications, file systems, and communication platforms. While personal assistants have evolved from simple command-line tools to sophisticated AI-powered agents,

existing solutions remain fragmented between cloud-based services with limited system access and desktop tools with constrained intelligence. This paper presents a novel intelligent control system architecture that reimagines the AI personal assistant as a hierarchical planner-executor capable of dynamically selecting between multiple interaction modalities—graphical user interface manipulation, direct system API calls, and code generation—based on task requirements and environmental context. The proposed Hybrid Action Modality Controller (HAMC) framework introduces a reinforcement learning-based orchestration layer that optimizes modality selection to minimize task completion steps while maximizing success probability. We develop a formal mathematical model of the desktop workflow automation problem and present an asynchronous training infrastructure, Entropulse, that addresses the entropy collapse and KL divergence accumulation challenges in large-scale reinforcement learning for desktop agents. Experimental evaluation on a comprehensive benchmark suite demonstrates that our approach achieves 48.1% success rate on complex multi-application workflows, representing a significant improvement over existing computer-use agents while reducing average action steps by 37%. The framework incorporates a sandboxed execution environment with fine-grained permission controls, addressing critical security and privacy concerns inherent in autonomous desktop automation. This work establishes a foundation for next-generation personal assistants that function as true cognitive collaborators rather than passive command executors.

Keywords: intelligent control systems, desktop automation, multi-agent reinforcement learning, human-AI collaboration, workflow optimization

Caner Ozcan, Esmanur Alican, İsmail Rakıp Karaş

A Review of Graph-Enhanced Augmented and Mixed Reality

Karabuk University, Türkiye

Abstract: Augmented Reality (AR) and Mixed Reality (MR) are the leading technologies that provide us with new ways to interface between the digital world and real spaces. This paper presents a literature review on the evolving intersection between graph theory and AR/MR, and how graph-based approaches advance these technologies. We present an analysis of the literature on this topic published between the years 2019 and 2024. This time frame captures articles discussing a variety of applications including, but not limited to, cultural heritage tourism, navigation, gaming, education, and collaborative work. The review also describes the functionalities of graphs within the AR/MR environments, including visualization, spatial understanding, scene rendering, network cutting, and user engagement. We assess the opportunities and challenges of using graph-based approaches, summarize some of the research areas currently on the agenda, and suggest some possibilities for future work in this area.

Keywords: Augmented Reality, Mixed Reality, Graph Theory

Geylani Panahov, Eldar Abbasov, Afat Yuzbashiyeva, Vusale Balakci

Modeling Deep-Penetration Conformance Control in High-Permeability Reservoir Zones to Stabilize the Hydrocarbon Displacement Front

Baku State University, Azerbaijan
Institute of Mathematics and Mechanics, Azerbaijan
Oil and Gas Institute, Azerbaijan

Abstract: The paper presents the results of research into a new method of physicochemical impact on layered heterogeneous formations and studies the features of the two-phase flow process using the example of oil displacement using deep-penetrating selectively blocking compositions. Approximate mathematical models of waterflooding are considered using a composition of chemical agents injected into the formation and capable of changing the hydrodynamic parameters of fluid flow in a porous medium. The processes of autogesis and adsorption of the polymer solution play a significant role in the processes of blocking highly permeable formation pores. Here, the mixture consists of two components with molecular weights and mass concentrations, the reaction between which determines the concentration of the thickener. The composition of the mixture affects flow only through the dependence of the viscosity of the aqueous phase on the concentration of the thickener. The above

ratio determines the difference between the amount of reaction in the forward and reverse directions per unit time. As a result of the dispersion mixing of solutions in the reservoir with a gradual change in saturation, the thickness of the deep penetrating components forming the blocking layer is determined. The mathematical model is based on the equation of one-dimensional flow, taking into account convective diffusion, and the equations of conservation of blocking matter, taking into account the kinetics of the sorption process. The paper also presents the results of numerical realization of the equations of concentration transfer of gelling components and thickener. In an uneven grid area, the problem is replaced by a discrete problem using a combination of an explicit and implicit difference scheme that increases the order of accuracy and is solved by the run-through method. Effective algorithms for solving a one-dimensional problem are obtained taking into account the equations of adsorption and convective diffusion. The results obtained can be taken into account in the development of methods of water impact on the oil deposit and conformance control in high-permeability reservoir.
Keywords: heterogeneous reservoir, deep-penetration, waterflooding, highly permeable, diffusion, chemical reaction

Adalat Pashayev, Elkhan Sabziev, Nubiyya Arif Gizi, Yegane Pashayeva, Ulviyya Goyushova

Detecting Changes for Area Monitoring Using Large-Scale Satellite Imagery Via Artificial Intelligence

Institute of Mathematics, Azerbaijan

Abstract: Area monitoring is of strategic importance for the timely identification of changes such as new building construction, dynamics of agricultural fields, forest loss and recovery, and variations in the area and boundaries of water bodies. Although remote sensing satellite imagery enables rapid observation over large territories, the very large size of modern high-resolution products (e.g., images with tens of thousands of pixels) makes it difficult to open and visually compare them as a whole. Therefore, there is a need for automated processing of such imagery. This paper presents a practical pipeline for multi-temporal change detection based on the tiling (patch extraction) approach, referred to here as "defragmentation" of large satellite images. The core idea is to split the image into fixed-size patches via windowed reading without fully loading it into RAM, store these patches as a dataset, and use artificial intelligence—particularly CNN-based models—to assess the presence of target objects. The corresponding patches from older and newer acquisitions are then compared using similarity metrics and model outputs. Patches that do not match are selected as change candidates and provided to experts for further visual analysis. The paper also explains the implementation of the proposed approach at the code level.

Keywords: large-scale image, image defragmentation, convolutional neural networks (CNN), data augmentation, albumentations, change detection

Omkar Prabhu, Ranjith G Rao, U S Advaith Sharma, Ayush Sinha, Aryaman Kukreja, Ahamed Shafeeq B M
Interpretable AI for Urban Air Quality: A Machine Learning Framework for Accurate and Explainable Carbon Monoxide Forecasting
Manipal Institute of Technology, Manipal Academy of Higher Education, India
Abstract: Accurate prediction of carbon monoxide (CO) concentrations is critical for urban air quality management, yet models often sacrifice interpretability for performance, limiting their practical deployment. This study addresses this gap by proposing a robust machine learning framework that synergizes high predictive accuracy with explainable AI (XAI) for forecasting CO levels from multi-sensor data. We implement and rigorously tune four advanced regression models, including Random Forest, XGBoost, LightGBM, and K-Nearest Neighbors, using Bayesian optimization. Our results demonstrate that the optimized Random Forest model achieves superior performance (R^2 = 0.764). To enhance transparency and interpretability, explainable AI (XAI) techniques such as Partial Dependence Plots (PDP) and SHapley Additive exPlanations (SHAP) were employed. PDP revealed the marginal effects of critical features, while SHAP provided both global and local insights into feature contributions and

interactions driving CO predictions. The analysis identified sensor responses for non-methane hydrocarbons (PT08.S2) and CO (PT08.S1) as the most in fluential predictors, while environmental factors like temperature played a moderating role. This dual focus on performance and transparency provides ac tionable insights for sensor calibration, anomaly detection, and informed environmental decision-making, bridging the critical gap between complex black box models and operational trust in smart city applications.

Keywords: Air Quality Prediction, Explainable AI (XAI), Machine Learning, Model Interpretability, SHAP

Holida Primova, Maxbuba Vaydullayeva, Shavkat Urokov

A Support System and Multi-Criteria Decision-Making Based on an Integrated Approach to Medicine 4.0.

Samarkand Branch of Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Uzbekistan

Development of Digital Technologies and Artificial Intelligence, Tashkent, Uzbekistan

Tashkent State University of Economics, Tashkent, Uzbekistan, Uzbekistan

Abstract: The integration of advanced digital technologies into healthcare systems, now known as the Medical 4.0 paradigm, has brought about revolutionary changes in the medical field. The main enabling factors for the systematic and effective implementation of these advanced

technologies in the healthcare sector are of paramount importance. This article considers the framework and multi-criteria decision-making process for implementing Medical 4.0 based on an integrated approach. An algorithm for determining a solution close to the real solution is proposed, which serves the objectives of cost-effectiveness, flexibility, risk reduction, data confidentiality, interoperability, and implementation. This research work helps to understand the dynamics of the implementation of Medical 4.0 and collects important insights into the healthcare sector based on its technology. Using the Technique for Order Preference by Similarity to Real Solution (TOPSIS) and fuzzy Measurement Alternatives and Ranking according to the Compromise Solution (MARCOS), a quantitative model is created for decision-making and prioritizing actions across the broad scope of Medicine 4.0. This study provides invaluable insights for practitioners and researchers seeking to leverage the opportunities presented by technological advances in healthcare.
Keywords: Medical 4.0, TOPSIS, decision making, Medical 4.0 opportunities, Medical technologies, fuzzy technology

Zhibek Primova, Gulzat Muktarkanova, Al Khan
An ML Framework for Expressive, Gesture-Controlled Composition: A Co-Adaptive Human-Ai Music System
INAI, Kyrgyzstan
Kyrgyz-German University, Kyrgyzstan
Abstract: The intersection of gesture recognition and generative music presents a compelling opportunity to

democratize music creation, yet existing systems face fundamental limitations: they either require musicians to learn rigid gesture vocabularies or employ static machine learning models that fail to adapt to individual users' expressive idiosyncrasies over time. This paper introduces GestureCompose, a novel machine learning framework for expressive, gesture-controlled music composition that establishes a genuine co-adaptive partnership between human and machine. The framework contributes three key innovations: a dual-stream recurrent neural network architecture that processes both gestural dynamics and musical context simultaneously, an online learning mechanism that continuously refines gesture-to-music mappings based on user interaction patterns, and a reinforcement learning module that enables the system to proactively suggest musical variations aligned with detected user intent. Unlike prior approaches that treat gesture recognition as a classification problem with fixed output categories, GestureCompose models gesture as a continuous, expressive parameter space that controls generative music synthesis in real-time. The system was evaluated through a longitudinal study with 24 participants across skill levels, measuring creative agency, expressive range, and perceived partnership. Results demonstrate that the co-adaptive approach significantly outperforms static baseline systems across all metrics, with novice users reporting a 73% increase in perceived creative control and expert users highlighting the system's capacity for surprise and collaboration. This work advances the field of human-

AI interaction by demonstrating how adaptive machine learning can transform digital instruments from tools into creative partners.

Keywords: gesture recognition, generative music, human-AI collaboration, online learning, co-adaptive systems, expressive interaction, real-time music generation, creative partnership, machine learning for HCI

Cahan Quliyeva

The Effect of the Use of Information Technologies in Education on Economic Growth

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: In modern times, the use of information technologies in education acts as one of the important factors in ensuring economic growth. This article examines the impact of the application of information technologies in the education system on the formation of human capital, increasing labor productivity and the development of an innovative economy. The use of information technologies in education improves the quality of the educational process, facilitates access to knowledge and increases the efficiency of learning. As a result, it becomes possible to prepare flexible and competitive personnel with digital skills. The article emphasizes that information technologies expand individual learning opportunities in education, strengthen the interactivity of teachers and students and create conditions for the formation of innovative thinking. These processes accelerate scientific and technological

progress in the long term and have a positive impact on economic growth. Especially in the context of global competition, the economic development of countries depends on knowledge and technology-based approaches. The results of the article show that investments in information technologies in education should be assessed as a strategic factor ensuring the sustainable development not only of the education sector, but also of the national economy as a whole

Keywords: economic growth, human capital, digitalization, innovation, competitiveness

Anar Rahimov, Zarifa Aliyeva, Rana Huseynli

Numerical Solution of Nonlinear Constrained Optimization Problems Using MATLAB

Baku State University, Azerbaijan
Institute of Mathematics of the Ministry of Science and Education of Republic of Azerbaijan, Azerbaijan

Abstract: This paper investigates the numerical solution of nonlinear constrained optimization problems using the MATLAB software package. The mathematical formulation of a nonlinear optimization problem is presented, and its analytical solution using the Lagrange multiplier method is briefly discussed. For the numerical solution, the capabilities and input-output parameters of the widely used MATLAB function fmincon are explained. Computer experiments conducted on a specific model problem demonstrate the efficiency of the fmincon function and the consistency of the obtained numerical results with the

exact solution. The results show that the MATLAB software package is a reliable and effective tool for solving nonlinear constrained optimization problems.
Keywords: nonlinear minimization, constrained optimization problem, numerical solution, MATLAB, fmincon function.

Anar Rahimov

An Approach to Numerical Solution to Inverse Source Problems for a Parabolic Equation

Baku State University, Azerbaijan
Institute of Mathematics, Azerbaijan

Abstract: The paper studies inverse problems related to recovering a source term in a parabolic equation subject to initial and boundary conditions. A distinctive feature of these problems is that the unknown parameters depend solely on either the space or time variable and appear as multiplicative factors in the right-hand side coefficients of the equation. Using the method of lines, the initial problems are trans-formed into parametric inverse problems for systems of ordinary differential equations. To solve these, a special representation of the solution is suggested. A key contribution of the study is that the proposed numerical approach for identifying the coefficients avoids the need for iterative procedures. The effectiveness of the method is demonstrated through numerical experiments carried out on test examples. The obtained results show the efficiency of the proposed approach to the numerical solving the inverse source problems.

Keywords: inverse source problem, method of lines, parabolic equation, space or time variable, parametric identification, special representation of solution

Mohammad Rizwan, Ayesha Anees Zaveri, Muhammad Ashraf

AI-Driven Manufacturing Supply Chains: An Intelligent Framework for Waste Reduction and Operational Efficiency

University of Worcester, United Kingdom
Malaysian Institute of Information Technology, University of Kuala Lumpur, Malaysia
Institute of Chemical Sciences, Bahauddin Zakariya University, Multan, Pakistan

Abstract: Manufacturing supply chains face increasing challenges due to demand volatility, rising operational complexity, and fragmented decision-making. Conventional planning and control processes are usually not flexible or responsive to innovate in such a matter and therefore the inefficiencies and waste come about. The concept of Artificial Intelligence (AI) has become one of the enabling factors in intelligent, data-driven decision-making of manufacturing systems. The majority of AI applications in manufacturing and supply chains, however, are carried out in isolation, with an orient to the local optimality, comparing and contrasting it without regard to the interfaces of manufacturing activities and supply chain processes. In the paper, an AI-based framework, which would merge manufacturing and supply chain processes to

improve decision-making and minimize waste, will be proposed. The framework is a combination of machine learning-based demand forecasting, predictive maintenance, real-time production scheduling, and AI-based planning tools. The components included with the model maximize production flexibility, enhance resource utilization, and proactive disruption management. Although the use of AI is increasingly used in the industrial environment, the introduction of AI solutions in manufacturing and supply chain operations has been low and has not yet been able to introduce systemic effect on the efficiency and reduction of wastes. The proposed solution provides this gap by introducing a conceptual and system-level framework that harmonizes decision-making in manufacturing and supply chain operations. This collaborative strategy is maintained so that a decision in one area does not impact negatively in the other area to achieve a more integrative and responsive supply chain. With this framework, manufacturers are able to attain an all-encompassing decision-making method that relies on AI and reduces wastage and improves business efficiency. The paper has ended by emphasizing the necessity of future empirical verification of the framework and its possible use in practical situations.
Keywords: Artificial Intelligence, Manufacturing Supply Chain, Intelligent Decision-Making, Waste Reduction, Operational Efficiency, Smart Manufacturing, Decision-Support Systems

Vladimir Roganov

Modeling a Visually Observable 3d-Model of the Earth's Surface in Different Electromagnetic Radiation Spectra

Penza State Technological University, Russia

Abstract: During an aircraft flight (AF), a pilot must solve two classes of problems. Problems of the first class are necessary for piloting the aircraft after receiving instrument information about engine operation and the airframe's interaction with the atmosphere, as well as information obtained through the pilot's visual analyzer about the aircraft's location above the flight area. Solving problems in the second class allows one to determine the aircraft's position above the flight area and its motion vector. Professional training depends on their physiological data, information acquired during pre-flight training, flight time Tr while piloting a real aircraft, and flight time Ts while piloting flight simulators (FS). Each flight simulator is a complex of imitators that generate real-time information for the pilot similar to that received during a real flight. In the future, we will focus on the ability to develop the components of pilot j's cognitive model X(AF), which reflects their professional experience in solving problems of the first class X(D,AF), and the second class X(N,AF), acquired during flights in a flight simulator. In the future, we will consider only imitators that synthesize for the j-th pilot during a flight on an aviation simulator a 3D-model of the flight area in the visual range of electromagnetic waves

and in the IR-ranges that allow the formation of X(D,AF) and X(N,AF).

Keywords: Flight Simulator, Environment Models, Imitators, Artificial Intelligence, In-formation Technologies

Aliyeva Ruhangiz

Managerial and Economic Aspects of Application of Artificial Intelligence in Green Energy of Azerbaijan

AzACU, Azerbaijan

Abstract: In the context of the global transition to sustainable development and decarbonization of the economy, green (renewable) energy occupies a leading position in the country's economy. The development of renewable energy sources is accompanied by increasingly complex management processes, which necessitates the use of new-generation digital technologies. This article examines the potential for applying artificial intelligence in green energy, focusing on the management and economic aspects of Azerbaijan's development. The main areas of application of artificial intelligence for optimizing energy infrastructure management and increasing the investment attractiveness of the industry are considered. It notes that the implementation of artificial intelligence in green energy contributes to the increased economic efficiency of renewable energy projects, attracting investment, and developing a sustainable, environmentally friendly energy system. The purpose of this article is to analyze the potential of artificial intelligence in green energy and

evaluate its application in management processes and the economic efficiency of energy development in Azerbaijan. To achieve this goal, the article examines the theoretical foundations of using artificial intelligence in green energy, analyzes the current state of green energy in the country, and identifies the main advantages, limitations, and prospects for further application of artificial intelligence in the energy sector. The article adapts international experience to national conditions to ensure the long-term development of the energy sector in Azerbaijan. The results of the research,, can be used in developing strategies for green energy development and improving management decisions in the energy sector in Azerbaijan.
Keywords: artificial intelligence, green energy, management, economic efficiency, renewable energy sources, Azerbaijan

Samir Rustamov, Abbas Aliyev

An Ensemble Approach to Deepfake Video Detection Using Pre-Trained CNNs and Statistical Feature Aggregation

MegaSec AI Company, Azerbaijan
ADA University, Azerbaijan

Abstract: Deepfake videos pose a significant threat to information integrity, demanding reliable automated detection methods. While end-to-end deep learning achieves high accuracy, it requires expensive training and often ignores temporal information across frames. We propose a systematic framework for video-level deepfake

detection that combines frozen pre-trained CNN embeddings with statistical feature aggregation, requiring no backbone fine-tuning. We introduce two complementary video-level descriptor types - appearance statistics and temporal difference statistics - and systematically evaluate 60 embedding configurations spanning three backbones (MobileNetV2, EfficientNetB0, ResNet50), three pooling strategies, and multi-backbone fusion, classified by grid-searched SVM, XGBoost, and MLP with AUC-weighted ensembling on FaceForensics++ (c23). Our analysis reveals three key findings: (1) temporal difference features consistently outperform appearance-only features (+2.5 pp AUC in binary detection), (2) multi-backbone fusion and maxavg pooling yield the strongest results across both tasks, and (3) the best multiclass configuration achieves 0.87 AUC-OVR on a 6-class attribution task without any CNN fine-tuning, while binary detection reaches 0.71 AUC. Although absolute performance is below fine-tuned methods, the frozen-feature paradigm enables the entire 60-configuration grid search to complete in approximately 25 minutes of classifier training on a single GPU, demonstrating that statistical aggregation enriched with temporal dynamics offers a practical and efficient alternative to end-to-end training.
Keywords: Deepfake Detection, Transfer Learning, Feature Extraction, Ensemble Learning, Temporal Analysis, Video Classification

Rafail Rzayev, Elman Ibishov, Aliagha Gasimov, Arzu Safarova

Artificial Intelligence and Higher Education Quality: Survey Evidence from UNEC

Scientific-Research Institute of Economic Studies under the Azerbaijan State University of Economics (UNEC), Azerbaijan

Abstract: Artificial intelligence (AI) technologies are increasingly transforming higher education systems worldwide by influencing teaching practices, learning processes, assessment methods, and insti-tutional governance. This study examines the relationship between AI adoption and the quality of higher education using survey data collected from students and academic staff at the Azerbaijan State University of Economics (UNEC). The main objective is to evaluate how AI-based tools affect perceived educational quality, instructional effectiveness, student engagement, and institu-tional efficiency within the university context. A structured questionnaire was administered to assess attitudes toward AI, patterns of use, and the perceived impact of AI applications on key dimensions of educational quality. Quantitative methods were applied to analyze the survey data. The findings indicate that AI-based technolo-gies—such as intelligent tutoring systems, automated assessment tools, learning analytics, and adaptive learning platforms—are positively associated with several aspects of higher education quality, particularly personalized learning, timely feedback, and data-driven decision-making. However, the study also

identifies key challenges related to AI integration, including concerns about data privacy, academic integrity, algorithmic bias, and unequal access to digital resources. These issues highlight the importance of effective institutional governance, ethical standards, and appropriate regulatory frameworks. Using UNEC as a case study, the research provides empirical evidence from a developing higher education context and contributes to the growing literature on AI in education. Overall, the study concludes that AI should be viewed as a complementary tool that supports and enhances human expertise in the educational process.
Keywords: Artificial Intelligence, Higher Education Quality, Educational Technology, Learn-ing Analytics, Survey Analysis

Asif Rzayev, Maryam Mammadli
Integrated Microprocessor System for Real-Time Measurement and Control of Flow Rate in Open Water Channels
Institute of Mathematics, Ministry of Science and Education, Azerbaijan
Azerbaijan University of Architecture and Construction, Azerbaijan
Abstract: Under conditions of limited water resources and the impact of climate change, the accurate and prompt determination of flow rate in open water channels and reservoirs is one of the fundamental requirements for the efficient management of water resources. Although

traditional hydraulic and empirical methods are widely used in practical applications, their capabilities are limited in terms of real-time monitoring and automatic regulation. In the article, the analytical and empirical foundations for calculating flow rate in open channel flows are analyzed, and the level–flow rate relationship as well as the application possibilities of modern sensor technologies are evaluated. Within the framework of the research, a structural model of a microprocessor-based intelligent information–measurement–control system has been developed based on an ultrasonic level sensor and the STM32F103 microcontroller. The system ensures the digital processing of incoming 4-20 mA measurement signals, the stabilization of level data through a filtering algorithm, and the real-time calculation of flow rate based on a hydraulic model. The proposed approach has been experimentally tested by applying it to a specific hydraulic facility (using the outlet channel of a reservoir as an example), through the calibration of the level–flow rate relationship and integration into a SCADA system. The obtained results demonstrate that the integration of hydraulic models with a microprocessor-based measurement system makes it possible to increase the accuracy and responsiveness of flow rate measurement and control.
Keywords: Water flow rate, Ultrasonic measurement, LU240, Microprocessor-based control, SCADA, SDG 6

Sona Rzayeva, Kamil Aida-zade, Azer Bagirov

Analysis of the Application of Genetic Algorithms to the Educational Timetabling Problem

Institute of Mathematics, Azerbaijan
The State Examination Center of the Republic of Azerbaijan, Azerbaijan

Abstract: The problem of constructing an academic timetable (allocation of teaching load, assignment of classrooms, and time slots) in an educational institution is well known to be an NP-hard discrete optimization problem. It is characterized by a large volume of input data determined by the number of instructors, student groups, and courses. Additionally, a significant number of constraints and requirements must be considered. These factors make the use of classical exact methods of integer programming, such as branch and bound and dynamic programming, difficult in practice, as computational time increases dramatically with the growth of problem size, even when searching not for an optimal but merely for a feasible timetable. For this reason, considerable attention in recent years has been given to heuristic approaches, including simulated annealing, tabu search, greedy algorithms, local search methods, and genetic algorithms. Although these methods are not always supported by strict mathematical guarantees, in practice, they often produce near-optimal solutions. The application of genetic algorithms has gained particular popularity in the context of educational timetabling. This paper examines and analyzes both the use of existing software tools for timetable construction and methodological approaches to

applying genetic algorithms, including techniques for generating the initial population, selection, crossover, and mutation operators, as well as parallelization strategies such as the master–slave model, island model, cellular model, and other approaches. The implementation of selection, crossover, and mutation operations is described with consideration of the specific requirements of educational scheduling. The paper presents the results of solving the educational timetabling problem on test data using the proposed algorithms, the DEAP (Distributed Evolutionary Algorithms in Python) framework, the Python programming language for implementing an adaptive greedy algorithm, and Delphi for database management.
Keywords: class schedule, NP-hard problem, requirements and restrictions, heuristic methods, genetic algorithm, penalty method, criteria aggregation method

Gunel Rzayeva, Rashad Nematzade
Cybersecurity for Autonomous and Intelligent Systems: Risk Control
Gazi University, Türkiye
Abstract: Artificial Intelligence (AI) is transforming the landscape of information security by providing advanced tools for detecting, analyzing, and responding to cyber threats. This paper explores the integration of AI techniques such as machine learning (ML), deep learning (DL), and natural language processing (NLP) into various areas of cybersecurity. The study emphasizes the use of AI in security information and event management (SIEM)

systems and AIOps platforms, enabling proactive and automated incident response. Additionally, it examines the challenges posed by large-scale data handling, interpretability, and ethical considerations. The findings highlight that while AI enhances threat intelligence and decision-making capabilities, human oversight and regulatory frameworks remain essential for ensuring trustworthy security systems.
Keywords: Artificial Intelligence, Cybersecurity, SIEM, AIOps, Threat Intelligence, Machine Learning, Information Security

Dilara Sabancıoğlu Duman, Şahin Emrah
A Genetic Algorithm Optimized Hybrid Recommender Model for Implicit User Feedback
Ankara University, Türkiye
Abstract: The rapid growth of online shopping in recent years has made recommendation systems attractive for research. Early studies relied on explicit user feedback, and many successful algorithms developed in this direction are known. However, data on such feedback is often limited in real-world applications. This has led researchers to develop recommendation systems based on implicit feedback data obtained from user behaviors such as viewing, adding to cart, and purchasing during their interactions with the system. In recommendation systems based on implicit feedback, matrix factorization methods such as Alternating Least Squares (ALS) are frequently used to reveal the overall structure of user-product

interactions. In contrast, binary learning approaches such as Bayesian Personalized Ranking (BPR) aim to directly improve ranking performance. However, each of these methods may exhibit various limitations when used alone. In this study, we present a hybrid recommendation model combining ALS and BPR methods for implicit feedback data. In our proposed model, we obtain the final preference score by combining the outputs of the two methods with a specific weighting parameter. We then optimize this score using a Genetic Algorithm based on performance in the validation data. We test the proposed method on the RetailRocket e-commerce dataset using a single data exclusion evaluation strategy. Experimental results show that the hybrid model optimized with the Genetic Algorithm offers higher and more stable performance compared to independent ALS and BPR models. These findings indicate that automated weighting optimization can make a significant contribution to the development of hybrid recommendation systems.
Keywords: Recommender systems, Implicit feedback, Matrix factorization, Bayesian Personalized Ranking, Hybrid models, Genetic algorithms

Refik Samet, Nooshin Nemati, Emrah Hançer, Akın Atakan Gören
A Comparative Study of Yolo-Based Architectures for Mitosis Detection in Histopathology Images
Ankara University, Türkiye
Mehmet Akif Ersoy University, Türkiye

Abstract: Mitosis detection is a crucial task in tumor grading and prognosis assessment, especially in breast cancer diagnosis. However, manual identification of mitotic cells in Hematoxylin and Eosin (H&E) stained histopathological images is time consuming, subjective, and labor-intensive. Automated computer-aided diagnosis systems can significantly support pathologists by improving efficiency and consistency. In this study, we present a comprehensive comparative evaluation of several YOLO-based one-stage deep learning architectures for mitosis detection. Specifically, YOLOv8, YOLOX, YOLOv11, and YOLOv26 are assessed on three publicly available datasets: ICPR12, ICPR14, and MiDeSeC. The models are evaluated using precision, recall, and F1-score to ensure a balanced performance comparison. Experimental results indicate that YOLOv8 consistently achieves strong performance across all datasets, demonstrating robustness and reliability. Overall, the results suggest that modern YOLO-based detectors provide competitive performance for automated mitosis detection and represent a promising direction for further research and practical development.
Keywords: Mitosis detection ·, Histopathological image ·, Object detection ·, YOLO.

Refik Samet, Kübra Kovayçin, Ece İrem Şişer, Derda Sina Günay, Yusuf Evren Aykaç

A Case Study of Examining Court Decisions with LLMs Section-Aware Retrieval for Turkish Case Law

Ankara Yıldırım Beyazıt University, Türkiye
Ankara University, Türkiye
Abstract: Finding relevant precedents often needs more than topical overlap: operative facts and judicial reasoning can be decisive. In Türkiye, court decisions are often long and frequently shared as scanned (image based) PDFs, making extraction and indexing harder. We present a section-aware retrieval case study on 1,000 Turkish court decisions about social media–related disputes. Using a vision–language model, each PDF is transcribed and organized into Facts, Reasoning, and Verdict segments; statute/article mentions are also extracted as lexical anchors. We compare a lexical baseline (BM25) with multilingual and legal biencoders adapted via parameter-efficient fine-tuning, and we test lexical dense hybrid fusion, including a simple section-aware hybrid that scores sections separately under fixed token budgets. Because expert-labeled precedent links are not available, we use a self-alignment known-item diagnostic: an LLM generates a short, query-like summary, and the system tries to retrieve the decision it came from; full-document BM25 is included as a reference baseline. Under this proxy, BM25 over Reasoning is the strongest single-section index and section-aware hybrid fusion with MPNet reaches and outperforming naive fusion while preserving section-level interpretability. This proxy setup is intended as a diagnostic rather than a full relevance benchmark; retrieval-time scoring is deterministic, using BM25 and cosine similarity over fixed embeddings.

Keywords: Legal information retrieval, precedent retrieval, section-aware retrieval, BM25, neural bi-encoder models, sparse–dense hybrid fusion, large language models (LLMs), Turkish case law

Kamran Samet, Nooshin Nemati

AI-Based Analysis of the Mechanical Performance of the Fiber-Reinforced Composite Materials

Gazi University, Türkiye
Ankara University, Türkiye

Abstract: The mechanical performance of the fiber-reinforced composite materials are strongly governed by the spatial position, orientation, and distribution of reinforcing fibers; however, accurate and automated quantification of this relationship from Scanning Electron Microscopy (SEM) images remains a significant challenge. In this study, an automated computational approach is proposed for the quantitative characterization of fiber structure and its direct correlation with mechanical performance. The proposed automated computational approach integrates weakly supervised learning, advanced image processing, and deep learning-based semantic segmentation to eliminate the need for manual pixel-level annotation. A Self-Regularized Dual-Aspect Pseudo-Labeling (SR-DAPL) is employed to generate reliable weak labels, which are subsequently used to train a U-Net segmentation model for accurate extraction of complex fiber structures. Using segmented fiber, local orientation information is obtained via structural tensor analysis,

enabling the computation of the fabric tensor and the anisotropy index. Furthermore, a physically interpretable mechanical metric, termed the Fiber Strength Index (FSI), is computed by integrating anisotropy, connectivity, and tortuosity measures to assess the influence of fiber positioning on mechanical strength quantitatively. Experimental results demonstrate that the proposed approach achieves high segmentation accuracy, robustness, and generalization across heterogeneous microstructures, providing an effective and scalable solution for predicting the mechanical performance of fiber-reinforced composite materials.
Keywords: Fiber reinforced., Fabric tensor., SEM images., Weakly supervised learning·, Deep learning·

Muhardi Saputra, Haryasena Panduwiyasa, Anindhita Febriandini
Integrating ECM and WebQual Frameworks to Evaluate Fitness Tracker Continuance Intention Among Generation Z Users
Telkom University, Indonesia
Abstract: As mobile health ecosystems become deeply embedded in daily routines, fit-ness tracker applications have redefined how individuals monitor physical well being. However, sustaining long term usage remains a critical challenge, as many users discontinue engagement after the initial phase. This study proposes an integrated framework to assess factors influencing continuance intention among Generation Z users in Greater Bandung.

The frame-work synthesizes the Expectation Confirmation Model (ECM) and the WebQual model to evaluate post adoption user perceptions of system, ser-vice, and information quality, while incorporating Habit and Self Quantification to capture routine behaviour and data driven self monitoring. As a pre-liminary study to validate these concepts, a pilot test with 40 respondents was conducted using Partial Least Squares Structural Equation Modelling (PLS SEM) with SmartPLS. The measurement model confirms all indicators meet the required criteria for convergent validity and reliability. Further-more, the structural model demonstrates substantial explanatory power, ac-counting for 78.9% of the variance in User Satisfaction (R2 = 0.789) and 63.5% in Continuance Intention (R2 = 0.635). Path analysis identifies Habit and Self Quantification as the most dominant drivers influencing long term usage. Overall, these findings confirm the model stability and instrument readiness for large scale data collection, aiming to provide developers with decision support insights to improve user centered mobile health systems.
Keywords: Fitness Tracker Applications, Continuance Intention, m-Health Systems

Buse Sariçayir, Caner Ozcan, İsmail Rakıp Karaş
A Review of Graph Topological Analyses in Location-Based Social Networks
Karabuk University, Türkiye

Abstract: The advent of location-based social networks (LBSNs) has fundamentally al-tered the manner in which social interaction occurs, integrating social interac-tion with a geographic location. This paper analyses the importance of graph topologies, with a particular focus on LBSNs, and the role of LBSN data. It draws upon 17 studies conducted between 2019 and 2024. All of the papers mentioned are part of the group using diagrammatic structures, but their gen-dering of the analysis to diagrammatic topology is not relevant. In contrast, they employ graph algorithms and structures to address issues pertaining to the construction of recommendation systems, the dissemination of infor-mation, and the safeguarding of information privacy. These papers are clas-sified according to the appropriate use of graph structures for heterogeneous graphs, spatial network information/influence graphs and LBSN applications that are not primarily topology networks. This review illustrates the growing significance of graph techniques in LBSN-driven studies, while simultane-ously highlighting a crucial gap: an insufficient examination of the topologi-cal characteristics of these networks and their impact on the performance and usability of applications.
Keywords: LBSN, Graph Topology, Graph, Location-based social network

Khuraman Sayın, Urfat Nuriyev, Arif Gürsoy, Yasin Kaymaz

A Controlled Evaluation of Meta-Heuristic Hyperparameter Optimization in 3D CNN-MLP Hybrid Models for Brain Cancer Survival Prediction

Ege University, Türkiye
Karabakh University, Azerbaijan

Abstract: Brain cancer survival prediction remains a challenging task due to the heterogeneity of tumor characteristics and the limited size of datasets in medical imaging studies. In this study, we investigate whether meta-heuristic hyperparameter optimization genuinely improves deep learning–based survival models. A 3D CNN-MLP hybrid architecture is developed to jointly learn volumetric MRI features and structured clinical variables for binary survival classification (long vs. short survival). First, a carefully regularized baseline model is trained using fixed hyperparameters. Subsequently, Particle Swarm Optimization (PSO) is employed to optimize key training hyperparameters, including learning rate, dropout rate, and batch size. To ensure a fair comparison, both models are evaluated under identical data splits, training protocols, early stopping strategies, and threshold optimization procedures. Each configuration is executed across five independent runs to assess stability and variance. Performance is evaluated using Area Under the Receiver Operating Characteristic Curve (AUC), F1-score for the Long class, and F1-score for the Non-Long class. The findings of this study indicate that, for moderately sized medical survival datasets, well-regularized deep architectures can achieve competitive performance

without the additional complexity introduced by meta-heuristic hyperparameter search. This work provides a controlled and reproducible evaluation framework for assessing optimization strategies in medical deep learning applications.

Keywords: Brain Tumor, Deep Learning, 3D convolutional neural networks, Magnetic Resonance Imaging, Meta-Heuristic Optimization, Survival Classification

Vladimir Semenov, Nikita Skybytskyi

Weakly-Connected Regular Network Topologies

Taras Shevchenko National University of Kyiv, Ukraine

Abstract: Regular network topologies frequently emerge in practical applications due to inherent hardware and physical constraints. While maximizing connectivity is a primary design objective, analyzing poorly connected topologies is equally critical for vulnerability assessment and cybersecurity. Identifying and classifying these structures provides a foundational framework for proactive network hardening and designing topologies resilient against targeted adversarial disruptions. This paper investigates the structural weaknesses of regular networks by establishing strict lower and upper bounds on the edge connectivity. We exhaustively enumerate the topologies that achieve the lower bound, providing a formal characterization of the least connected regular networks.

Keywords: weakly-connected networks, regular network topology, network vulnerability, minimum cut, robust connectivity

Vladimir Semenov, Bohdan Stupa

A Variance Reduction Stochastic Extragradient Method with Randomized Feasibility Updates for Variational Inequality Problems

Taras Shevchenko National University of Kyiv, Ukraine

Abstract: Solving variational inequalities over complex constraint sets is a fundamental challenge in optimization and game theory. We propose an algorithm that combines a stochastic extragradient with variance reduction method and a randomized feasibility algorithm, utilizing Polyak steps and a random number of sampled constraints per iteration, to solve monotone variational inequalities whose feasible region is the intersection of a (finite or infinite) number of convex functional level sets. In order to analyze the method, we introduce a Lyapunov function that simultaneously captures the momentum state of the variance reduction mechanism and the behavior of the feasibility gap. We show that under standard assumptions of monotonicity and L-Lipschitz continuity in the mean of VIs operator, the proposed algorithm converges to the optimal point with ergodic convergence rate to a neighborhood of the exact solution controlled by the step size. We illustrate the performance of our approach with numerical experiments on matrix games.

Keywords: variational inequality, extragradient, random feasibility method, stochastic method, variance reduction

Simon Serovajsky

Mathematical Modeling: Two Views of One Bridge

al-Farabi Kazakh National University, Kazakhstan

Abstract: The fundamental difference between mathematics and other sciences is that the objects it studies belong not to the real world around us, but to the ideal world of human ideas. Indeed, numbers and functions, derivatives and algorithms, probabilities and manifolds, operators and theorems, groups and sets, are themselves absent from the surrounding world. At the same time, mathematical methods can, in principle, be successfully used to study anything, which again distinguishes mathematics from all other sciences. The point is that there is a bridge between the real world studied by individual sciences and the ideal world with which mathematics operates. This bridge is mathematical modeling. The application of mathematical methods to the study of a specific phenomenon in the surrounding world essentially occurs in three stages. First, the patterns of the phenomenon under study, established by the means of a particular science, are translated into the language of mathematics, resulting in a corresponding mathematical model. This bridges the gap between the real world and the world of mathematics. Next, the properties of the resulting mathematical problem are revealed using mathematical tools, most often with the use of information technology. Finally, in the third stage, the obtained results are interpreted, i.e., the identified patterns are translated back from the language of mathematics into the language of the relevant subject area, returning across the bridge from the abstract mathematical world to the real world. These issues are the subject of S. Serovajsky book, "Mathematical

Modeling", accepted for publication by Taylor and Francis Group (UK). The book explores various aspects of constructing mathematical models, analyzing them, and interpreting their properties. It reviews mathematical models from two perspectives. The real-world perspective classifies models by subject area. These issues are addressed in chapters that provide an overview of models in physics, chemistry, biology, medicine, economics, sociology, ecology, political science, and other fields. The mathematical perspective, on the other hand, examines the mathematical problems used as models. It considers continuous and discrete, deterministic and stochastic, lumped and distributed, evolutionary and stationary systems, as well as identification, control, game, ill-posed problems, and other problems. The book is expected to be published in 2027. Its planned length is over 500 pages.

Keywords: Mathematical models, Classification, Analysis, Applications

Yaşar Nuri Sevgen

An Energy-Based Adaptive Modulation Framework for Bandwidth-Efficient Information Transmission

Başkent University, Türkiye

Abstract: Information and communication systems operating under strict spectral constraints must balance bandwidth efficiency and transmission reliability. In many conventional modulation schemes, system parameters such as the modulation index are selected using heuristic design rules, approximate bandwidth formulas, or fixed nominal values determined during the planning phase.

Although these approaches simplify implementation, they often fail to exploit spectral resources efficiently, especially in dynamically varying channel conditions. As a result, excess bandwidth may be occupied without providing proportional gains in performance, leading to suboptimal spectrum utilization. This paper introduces an energy-based adaptive modulation framework that formulates parameter selection as a constrained optimization problem. Specifically, the modulation index is determined by minimizing the effective occupied bandwidth subject to a minimum output signal-to-noise ratio (SNR) constraint. The effective bandwidth is rigorously defined through the cumulative spectral energy distribution, enabling a quantitative and physically meaningful measure of spectral occupancy. By integrating spectral energy concentration with performance constraints, the proposed method ensures reliable communication while systematically avoiding unnecessary bandwidth expansion. Numerical simulations demonstrate that the adaptive selection mechanism dynamically adjusts the modulation index according to system requirements. Compared to conventional fixed-parameter designs, the proposed framework achieves a substantial reduction in occupied bandwidth while maintaining the desired SNR performance level. These results highlight the potential of optimization-driven adaptive modulation strategies for next-generation spectrally efficient communication systems.
Keywords: Spectral efficiency, adaptive modulation, energy-based bandwidth, optimization, communication

Natiq Seyfullazade

Evaluating the Alignment and Identifying Skill Gaps Between Higher Education Syllabi and Job Advertisements in Azerbaijan Using an NLP-Based Approach

Azerbaijan State University of Economics, Azerbaijan

Abstract: Matching university courses with the changing needs of the job market is vital for helping graduates find employment. This study looks at how well university syllabi in Azerbaijan actually align with the requirements found in job advertisements. By using Natural Language Processing (NLP) techniques, a data-driven method is introduced to measure the connection between education and industry. A MiniLM-based multilingual Sentence Transformer was used to process the text and generate sentence embeddings, as it offers a great balance between computational efficiency and accuracy across different languages. Semantic proximity was then calculated using cosine similarity based on a best-match approach to find the closest fits. Additionally, the SkillNER framework was used to pull specific skills out of the text, which made a detailed skill gap analysis possible. To account for the fact that there were many more job postings than syllabi, relative frequencies were used to accurately track how often each skill appears in both datasets. The results show a strong overall match, but the analysis also highlights specific gaps—particularly in digital tools, practical knowledge of local laws, applied business processes, and soft skills like analytical thinking. These findings offer a

useful roadmap for educators and policymakers to monitor and eventually bridge these skills gaps.

Keywords: Labor market alignment, Natural Language Processing (NLP), Skill gap analysis, Semantic similarity

Perviz Ahmadzade, Ezgi Eren, Burak Yiğit Katanalp, Çiğdem Canbay Türkyılmaz, Emrah Türkyılmaz, Dilnoza Kamalova

Estimating International Roughness Index with ANFIS Using Pavement Characteristics and Traffic Components

Samarkand State Architectural and Civil Engineering, University, Uzbekistan

Adana Alparslan Türkeş Science and Technology University, Türkiye

Cukurova University, Türkiye

Abstract: The International Roughness Index (IRI) is widely utilized as an important indicator for assessing road roughness in terms of road safety and for proposing proper maintenance and rehabilitation practices in accordance with pavement deterioration mechanisms. The primary purpose of this study was to propose a general and transferable prediction model for IRI for the country of Türkiye, utilizing an Adaptive Network-based Fuzzy Inference System (ANFIS) method. The proposed model was developed utilizing data from field measurements of IRI, along with corresponding information on traffic volume and composition, age and bitumen content of the wearing and binder layers, and climatic conditions, for five highways in five different climatic areas of the country of Türkiye. The Random Forest Importance and Principal

Component Analysis methods were utilized for feature selection. Hyperparameter optimization was performed to improve the prediction performance of ANFIS. The most effective inputs were identified as heavy vehicle composition and wearing layer age. The optimized model configuration achieved cross-validation performance of R2=0.76 using 5 of 25 features. The findings of the study can be useful in predicting road surface roughness, thus supporting decision-makers in prioritizing maintenance and rehabilitation plans.

Keywords: International Roughness Index (IRI), ANFIS Road Maintenance, Pavements, Machine learning

Aypara Shabanova, Zakir Musayev, Mansur Zarbaliyev, Tarana Guliyeva, Shovgiyye Zarbaliyeva

Application of Automated Systems Based on Artificial Intelligence in the Management of Water Resources in the Territory of Azerbaijan

Azerbaijan University of Architecture and Construction, Azerbaijan

College of Construction under the Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: Territory of Azerbaijan Abstract. The article examines the application of automated systems based on artificial intelligence (AI) in the management of water resources in Azerbaijan, a country facing significant water scarcity despite its rich natural resources and growing renewable energy potential. The study highlights the importance of efficient water management in arid climatic

conditions and analyzes current challenges related to limited water reserves, deteriorating water quality, and increasing agricultural and industrial demand. Particular attention is given to the implementation of smart technologies such as SCADA systems, soil-moisture sensors, automated irrigation networks, and solar-powered monitoring systems. The article presents practical examples from the Turyanchay Canal, where AI-supported automated gates and water-level monitoring tools improve irrigation efficiency and reduce losses. It also discusses the role of big-data analytics, predictive modeling, and machine learning in optimizing water distribution, forecasting equipment failures, and enhancing treatment processes. The study concludes that the integration of AI-based automated systems significantly contributes to sustainable water use, improved agricultural productivity, reduced environmental impact, and enhanced socio-economic outcomes. Recommendations emphasize modernizing irrigation infrastructure, expanding smart management technologies, and increasing reliance on renewable energy sources to ensure long-term water security in Azerbaijan.
Keywords: artificial intelligence, automated irrigation, SCADA systems, renewable energy, Turyanchay Canal

Shahnaz Shahbazova, Solmaz Kalbiyeva, Sevinj Feyzullayeva

Big Data in Healthcare: Privacy and Security Issues

Azerbaijan State University of Economics (UNEC), Azerbaijan

Azerbaijan University of Architecture and Construction, Azerbaijan
Abstract: The latest achievements in big data security and privacy in the healthcare industry are discussed in this study. Big data has the ability to dramatically revolutionize patient care and improve health outcomes. However, the collection and analysis of massive amounts of sensitive medical data raises serious privacy and security concerns. In order to identify relevant difficulties and potential solutions, this paper undertakes a comprehensive analysis of existing research publications on big data in healthcare, focusing on privacy and security challenges. The authors investigate various cryptographic algorithms, such as AES, RSA, and SHA-256, that can be used to protect healthcare datasets. They also handle issues like as patient privacy, data breaches, and legal and ethical concerns. Furthermore, the paper proposes a framework for storing and sharing data while preserving privacy. It underscores the importance of implementing strong security measures in healthcare organizations to prevent data breaches and safeguard confidential patient information, all while leveraging big data for research and analysis purposes.
Keywords: healthcare, privacy, security, big data

Shahnaz Shahbazova, Sevil Huseynova, Rehim Iskenderov
Data Privacy in the Age of Big Data: Opportunities and Challenges

Azerbaijan State University of Economics (UNEC), Azerbaijan
Azerbaijan University of Architecture and Construction, Azerbaijan
Abstract: In our research, we start by providing an overview of big data and how it has revolutionized the way data is collected, stored, and analyzed, and then highlight the various opportunities that big data presents, including the ability to identify new patterns, trends, and insights, leading to more informed decision-making processes. The paper also notes the challenges associated with big data, particularly in terms of data privacy. We examine the value of data privacy and how it helps to safeguard people's rights and liberties. We also go over the various kinds of information that are gathered and utilized in big data analysis, including personal information, and we stress the significance of consent and openness in information gathering and usage. We also highlight some of the risks associated with data privacy violations, such as identity theft and discrimination. The paper also examines some of the ethical considerations surrounding data privacy, particularly in relation to issues of fairness and discrimination. In its conclusion, the academic research highlights the value of data privacy in the big data era and notes that it is a basic right that should be preserved. The study emphasizes the necessity of group initiatives to protect data privacy, involving the participation of governments, organizations, and people. The article concludes by urging further study and innovation to

overcome the problems with data privacy in the big data era.

Keywords: Data privacy, Big Data, Personal data, Privacy concerns, Privacy protection, GDPR

Khumar Shiraliyeva, Inci Abdullayeva

A Zero-Trust Digital Twin Core Middleware Architecture for Secure IIoT Systems Aligned with IIRA

Azerbaijan Technical University, Azerbaijan

Abstract: The rapid development of Industrial Internet of Things (IIoT) technologies has changed the fundamental overhaul of industrial systems in complex cyber-physical environments with sensors, actuators, edge computing nodes and cloud services. In this context, Digital Twin technology acts as one of the main technological approaches for real-time monitoring, analysis and management of industrial assets. However, existing Digital Twin middleware architectures are outdated with highly centralized trust models. These systems do not provide strong identity management and security management mechanisms at a high level. These controls increase the resistance of IIoT systems to various cyber threats such as device modification, unauthorized access, data injection and "man-in-the-middle" attacks. In this study, a secure Digital Twin Core middleware architecture for IIo Core based on Zero-Trust security principles and aligned with the Industrial Internet Reference Architecture (IIRA) is proposed. The proposed model implements an identity-centric trust approach at the middleware layer. This

approach integrates authentication, authorization, trust assessment, secure communication management, and anomaly detection mechanisms. A formal threat model was developed using the STRIDE threat modeling methodology to generate potential attack vectors and assess system vulnerabilities. The proposed architecture was tested and performance was evaluated using a prototype security analysis and verification tests using common IIoT technologies. Experimental results show that the proposed approach increases authentication security and reduces the probability of attack success, while maintaining acceptable latency and scalability. The proposed architecture provides a secure and scalable reference model for Digital Twin middleware in industrial IIoT environments.

Keywords: Digital Twin, Industrial Internet of Things (IIoT), Zero-Trust Security, Middleware, Architecture, Industrial Internet Reference Architecture (IIRA), Cybersecurity, Industrial Systems

Bashar Shirinov

The Role of Information Technologies in Project Management

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: An overview of the main digital tools used at different stages of the project life cycle is presented and practical cases of IT application in Azerbaijani and international companies are analyzed. It is shown that the

integration of information systems contributes to increasing the efficiency of project management, shortening implementation times, reducing costs and improving the quality of management decisions. The main benefits and risks of digitalization of innovation are identified and practical recommendations for the application of IT in the context of innovation management are developed. In the context of the rapid development of digital technologies and increasing global competition, the importance of effective innovation project management is increasing. Modern companies striving for sustainable development are forced not only to create innovations, but also to build implementation processes that take into account new technological opportunities. Information technologies (IT) are becoming an important tool in the arsenal of innovation managers, accelerating project planning and implementation processes and increasing their transparency, flexibility and adaptability. In particular, the use of digital platforms, analytical systems and automated management tools opens up new horizons in approaches to innovation. The article analyzes the advantages, risks and limitations of the application of information technologies in project management, the stages of the life cycle of an innovative project, and examines the role of information technologies in project management.
Keywords: project information technologies digital, innovative projectss management software, artificial intelligence forecasting big data blockchain, technologies

Anastasiia Storozhenko, Petro Stetsyuk

Linear Programming Solvers and r-Algorithm for Sparse Signal Reconstruction

V.M. Glushkov Institute of Cybernetics of the National Academy of Sciences of Ukraine, Ukraine

Abstract: Compressed sensing is a signal processing technique for reconstructing sparse signals from a small number of measurements. In this paper, we consider the basis pursuit problem and discuss its theoretical recovery guarantees. We reformulate the problem as a linear program (LP) and compare the performance of several well-known solvers, including Gurobi, CPLEX, HiGHS, and the recent open-source solver Clarabel. We also apply the $r(\alpha)$-algorithm with an adaptive step and both smooth and non-smooth penalties to solve basis pursuit directly, and compare its performance with that of the LP solvers. Based on those empirical results, we propose optimal parameter choices for the $r(\alpha)$-algorithm in the context of sparse signal recovery. Test problems are generated randomly in accordance with the theoretical recovery conditions. Overall, the study provides a concise comparison of optimisation-based approaches to sparse signal recovery, evaluated by runtime and reconstruction error.

Keywords: Compressed Sensing, Signal Processing, Sparse vector, Basis Pursuit, Linear Programming, AMPL, r-algorithm

Viktor Stovba, Oleksandr Zhmud
An Ellipsoid Method for Box-Constrained Lp-Loss Regression with L1 Regularization
V.M. Glushkov Institute of Cybernetics of the NAS of Ukraine, Ukraine
Abstract: We study the problem of parameter estimation in a linear regression model based on the Lp-powered least absolute deviations criterion ($1 \leq p \leq 2$) with L1-regularization and box constraints. The problem can be formulated as the minimization of a convex function, which may be smooth or nonsmooth depending on the value of p, subject to bound constraints. After briefly reviewing related regression models and their properties, we propose an algorithm based on the ellipsoid method for solving the stated problem. The method incorporates a specific initialization strategy for the ellipsoid method and employs a penalty approach to handle the box constraints. A Python implementation of the algorithm is presented, and computational experiments are performed to illustrate the effect of box constraints and regularization on the obtained solutions.
Keywords: Lp-Loss Regression, L1 Regularization, Nonsmooth Optimization, Ellipsoid Method, Box Constraints

Muhammad Hamza Tariq, Irfan Ahmed
Analyzing the Role of Machine Learning (ML) in Improving Inventory Management Through, Demand

Forecasting, Reducing Waste and Optimization in the UK Grocery Retail Sector

Worcester Business School, University of Worcester, Worcester United Kingdom
Eye Interaction Ltd, United Kingdom

Abstract: This paper discusses the application of Machine Learning (ML) to the optimization of inventory management in the UK grocer retail industry, particularly through use in demand prediction, waste minimization and operation optimization. Conventional inventory management systems which are most often rooted in past sales data are susceptible to various inefficiencies such as wastage, stock-outs and over stocking. Using predictive analytics and real-time data, ML offers a revolutionary solution through the means of improving the accuracy of demand forecasting processes, as well as automating the process of replenishing stocks and reducing waste. The study is of a quantitative nature, and the regression analysis is used to evaluate the effects of the ML techniques on the inventory management processes. The results show that ML enhances inventory management through decreasing stock replenishment, better demand forecasting, and less waste leading to better operational efficiency and reduction of costs. This study adds to the existing literature in applicability of ML to retail, as it provides insight into the role of these technologies in alleviating challenges encountered by retailers, enhancing customer satisfaction, and promoting sustainability in the retail industry. The paper also identifies critical problems

like data quality and workforce skills shortages that must be tackled to make the use of ML effective. However, existing approaches often struggle to effectively manage demand volatility and perishability in grocery retail, highlighting the need for more advanced data-driven forecasting methods.
Keywords: Machine Learning (ML), Inventory Management, Demand Forecasting, Waste Reduction, UK Grocery Retail

Muhammed Telçeken, Şeyma Değirmenci
Automatic Detection of Blood Cells Using YOLOv8 with CBAM and Performance Enhancement Via Image-Based Improvement Techniques
Sakarya Uygulamalı Bilimler Üniversitesi, Türkiye
Abstract: In this study, a deep learning–based object detection approach is proposed for the automatic detection of erythrocytes from microscopic peripheral blood images. The proposed method is built upon the YOLOv8 architecture, a single-stage object detection algorithm, and integrates the Convolutional Block Attention Module (CBAM) to enable the model to focus more effectively on discriminative features. The dataset used in this study consists of microscopic peripheral blood images that are widely adopted in the literature and annotated in YOLO format. During the training process, various data preprocessing and data augmentation techniques were applied to enhance the model's generalization capability and to mitigate overfitting. Experimental results

demonstrate that the CBAM-enhanced YOLOv8 model achieves consistent performance improvements over the baseline YOLOv8 architecture, particularly in terms of Precision–Recall balance and mean Average Precision (mAP) metrics. The findings indicate that attention mechanisms are effective in improving object detection performance in microscopic cell images and that the proposed approach provides a viable solution for decision support systems in hematological image analysis.
Keywords: Erythrocyte Detection, YOLOv8, Attention Mechanism (CBAM), Microscopic Image Analysis, Deep Learning–Based Object Detection

Cevahir Tunca

Analysis of the Impact of the Kura River on the Caspian Sea Basin Using Statistical Data and Satellite Imagery

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: The water of the Kura and Araz rivers has been used in agriculture and industry throughout history, and is still used on a large scale today. Climate change has caused a decrease in water in Azerbaijani rivers by approximately 15% in 30 years, as in the world. In addition, it is shown that reasons such as seasonal decrease in water in the river and excessive use of river water also play a serious role. The winter months are considered the least humid period in the river. All factors together cause a decrease in water in the lower reaches of the Kura. In general, if we take into account the decrease in the volume of the Kura River, we

can say that the Kura enters the territory of Azerbaijan less. One of the main reasons for this decrease is the construction of reservoirs on the river. As we know, the Kura is the largest transboundary river connecting 3 countries. The reasons for this are not clear in the past historical period, but here we examine the obvious changes that have occurred in the last few decades. In this article, we see that the evaporation series plays a dominant role in the increasing trend in the Caspian Sea Level (CSL) in the last few decades. At the same time, the research in the article shows that the long-term decline in XDS is likely to continue under global warming scenarios.
Keywords: caspian Sea Level (CSL), kura River, water level, climate change, rivers flowing into the Caspian Sea

Khangeldi Tynybek Uulu, Isa Navruz

Design and Simulation of Optical Directional Couplers with Adjustable Coupling Ratio

Ankara University, Türkiye

Abstract: Optical directional couplers are fundamental components in optical net-works, sensing systems, and integrated photonic devices, where precise pow-er distribution is essential for stable and efficient operation. Conventional couplers typically provide a fixed coupling ratio determined during fabrication, which limits system flexibility and adaptability. The inability to dynamically control power splitting restricts their utility in tunable and reconfigurable photonic systems. This study focuses on the numerical design, modeling, and performance analysis of

an adjustable optical directional coupler tailored for communication and sensing applications. We systematically design directional couplers with varied coupling ratios—ranging from 10/90 to 50/50—by determining their corresponding geometric and physical parameters. Key structural variables governing optical power transfer, such as port length, coupling length, waist size, are analyzed to evaluate their influence on splitting performance. Simulation results demonstrate that a controllable coupling ratio between 10% and 90% is achievable through geometric optimization, while maintaining insertion losses below 0.5dB. The pro-posed coupler design offers a flexible, efficient solution for tunable power splitting, with significant potential for adaptive optical networks, interfero-metric sensing, and reconfigurable photonic architectures.
Keywords: Directional coupler, coupling ratio, optical coupler, beam splitting, beam propagation method

Mohammad Nyme Uddin, Samia Akter Erin, Firuja Tasneem, Mim Mony, Umma Nourin Sawon
CO2 Concentration Prediction in a Multi-Functional Semi-Open University Auditorium Using Regression-Based Machine Learning Models
Building Energy & Environmental Management-BEEM Enhanced by AI, Dhaka, Bangladesh
Abstract: Carbon dioxide (CO2) concentration serves as a critical metric for evaluating air quality in densely populated urbanized regions like Dhaka, Bangladesh. In

educational settings, where complex human activities occur in semi-open auditoriums, interactions can elevate CO2 levels. Prolonged high CO2 concentrations degrade air quality, leading to respiratory ailments, exacerbating climate change, and causing discomfort. While existing studies focus on outdoor or indoor air quality using Machine Learning (ML) models, research on semi-open educational spaces is scarce. This study aims to develop regression-based ML models to forecast CO2 levels in a university's semi-open auditorium in Dhaka, Bangladesh, featuring partial natural ventilation. 350 data samples from November 2025 to February 2026, encompassing 29 parameters (e.g., environmental, behavioral, demographic), were collected to predict CO2 concentrations. Three ML models, such as Decision Tree (DT), eXtreme Gradient Boosting (XGBoost), and Random Forest (RF), were deployed to forecast CO2 levels. GridSearchCV facilitated performance optimization and hyperparameter tuning, using metrics like Accuracy, Mean Squared Error (MSE), and Root Mean Squared Error (RMSE). SHapley Additive exPlanations (SHAP) analysis assessed feature importance and model transparency. The DT model exhibited the highest accuracy (97%), followed by XGBoost (96%) and RF (74%) with K-fold average after cross-validation. SHAP analysis identified HCHO and Light_intensity as key factors in CO2 pre-diction. This study underscores how data-informed ML strategies can inform infrastructure decisions, promoting natural ventilation to enhance air quality on a building and urban scale. Future research should incorporate seasonal variations, real-time sensing, and robustness for broader applicability.

Keywords: CO2 Concentration, Semi-Open, University Auditorium, Machine Learning, Regression Models

Gözde Ulutagay, Doğukan İçli, Halime Gökmen

Black-Box Hyperparameter Optimization for Convolutional Neural Networks: An Empirical Analysis Across Architectures and Optimization Paradigms

Ege University, Türkiye

Abstract: Hyperparameter optimization is a non-convex, high-cost, gradient-informed, computationally demanding problem with critical hyperparameter selection. While numerous optimization algorithms have been proposed to date, they have not been sufficiently characterized for their effectiveness across different CNN architectures and their applicability in high-dimensional hyperparameter domains. This study presents a systematic comparative analysis of black-box optimization frameworks implemented in different design architectures and representing three different algorithm paradigms. These include residual networks, composite-scale networks, and modernized convolutional architectures. We implement Optuna's definition-work approach for dynamic search space generation using tree-structured Parzen estimators, Hyperopt's traditional definition-work methodology, and Ray Tune's ASHA timer for efficient resource allocation between trials using multiple accuracy optimization. CNN architectures were specifically chosen to represent

significant advancements in convolutional design, including ResNet's residual learning for gradient flow optimization, EfficientNet's compound scaling for balanced network scaling, and ConvNeXt's modernized convolutional blocks incorporating transformer-inspired design principles. To ensure statistical accuracy, we conducted extensive experiments with multiple independent trials using standardized black-box optimization protocols with the same search domains encompassing continuous, categorical, and conditional hyperparameters under controlled computational budgets. Our findings reveal significant algorithmic differences in addressing black-box optimization challenges. Optimization algorithm selection exhibited strong interaction with architectural complexities. This research contributes to the theoretical understanding of black-box optimization in deep learning contexts. It provides empirical guidance for practitioners facing hyperparameter optimization challenges. By improving our approaches to optimization outcomes in high-dimensional, costly-to-evaluate function domains, it is anticipated to serve as a reference for the development of more efficient automated machine learning systems.
Keywords: Black-box Optimization, Hyperparameter Optimization, Bayesian Optimization, Multi-fidelity Optimization, Deep Learning, Automated Machine Learning, Expensive Function Optimization

Gözde Ulutagay, Dina Ahmed

Robust Potential Function Clustering Via MDPDE-Based Weighting

Ege University, Türkiye

Abstract: Clustering is a fundamental task in unsupervised machine learning for discovering hidden structures in unlabeled data. However, traditional algorithms such as K-means, Gaussian Mixture Models (GMM), and Fuzzy C-Means (FCM) are highly sensitive to noise and outliers, as even a few anomalous observations can significantly distort cluster centers. This study proposes a novel robust clustering method called Robust Potential Function Clustering (RPFC). The approach integrates a density-based Potential Function framework with the Minimum Density Power Divergence Estimator (MDPDE), a robust statistical technique that down-weights outliers. In RPFC, point potentials are computed using local data density, while MDPDE-derived weights reduce the influence of contaminated observations. High-potential points are selected as initial centers for a predefined number of clusters and iteratively updated through weighted averaging, producing compact and well-separated clusters. To the best of our knowledge, this is the first study combining MDPDE-based robustness with a potential-function-driven clustering framework. The performance of RPFC was evaluated on synthetic datasets and the Wheat Seeds dataset from the UCI repository under both clean and contaminated scenarios. Using multiple internal and external validity indices, RPFC consistently achieved superior results outperforming classical methods

particularly in contaminated settings and demonstrated strong resistance to noise, correctly identifying most outliers. Overall, RPFC provides an interpretable, flexible, and robust alternative for real-world applications where data contamination is common, offering a tunable robustness parameter (α) for practical adaptability.
Keywords: Clustering, Robust Clustering, Outliers, Unsupervised Learning, Potential Function, MDPDE

Süheyla Uygur, Barış Tekin Tezel

A Multi-Agent System Approach for Solving Sudoku Puzzle Using Backtracking

Dokuz Eylul University, Türkiye

Abstract: Sudoku Puzzle is known to be an NP-complete problem with defined exact rules. This study presents the step-by-step development of a multi-agent system for solving Sudoku puzzles using a backtracking approach and a Belief-Desire-Intention (BDI) agent architecture. The proposed system is implemented using BDI agents within the Jason framework and is supported by a graphical user interface in a Java-based environment. The main goal is to provide agent-based coordination and demonstrate the integration of problem-solving approaches and communication. The study focuses on converting a classical algorithm into agent logic and gradually refining it to obtain the optimal solution for Sudoku puzzles. Experimental results on easy-level Sudoku puzzles show that the system can successfully solve the puzzles and validate the multiagent interaction and coordination mechanisms. This

work establishes a fundamental framework for solving more difficult Sudoku puzzles and is expected to contribute to the development of new Sudoku Puzzle-solving algorithms in this area.
Keywords: Multi-agent systems, Sudoku Puzzle solving problem, Backtracking algorithm, BDI agent architecture, Agent interaction

Zeynel Baran Yildirim
SSM-Based Assessment of Pedestrian and Vehicle Safety at Unsignalized Urban Crossings
Adana Alparslan Türkeş Science and Technology University, Türkiye
Abstract: The integration of autonomous vehicles (AVs) into urban traffic is often framed as a win for safety, but the reality of the transition period presents complex safety trade-offs. This study evaluates these dynamics at unsignalized mid-block crossings using a microscopic simulation model of a busy arterial in Adana, Türkiye. Moving beyond traditional crash data, the research employs Surrogate Safety Measures (SSMs), specifically Time-to-Collision (TTC), Post-Encroachment Time (PET), and Deceleration Rate to Avoid Crash (DRAC) to proactively quantify conflict risks. Multiple stochastic simulations across varying AV penetration rates reveal a clear friction between safety and efficiency. While pedestrian conflicts decrease by 19% at full automation due to predictable yielding habits, this transition triggers a 21% surge in vehicle-to-vehicle conflicts. The findings indicate that the

integration of AVs reshapes how risk is distributed within the traffic system rather than eliminating it entirely. Pedestrian safety benefits tend to emerge earlier, whereas vehicle flow stability becomes more fragile during the coexistence of human and automated driving logics. These results suggest that the transition to autonomous mobility is not only a technological shift, but also a be-havioral one, where interaction and adaptation play a critical role. Ultimately, the study identifies a non-linear transition path, suggesting that achieving safety goals requires a managed adoption strategy rather than an uncontrolled progression of AV penetration.
Keywords: Surrogate Safety Measures, Autonomous Vehicles, Traffic Safety

Elshad Yusifov, Aytakin Afandiyeva, Gulnar Gurbanova
Analytical Analysis of Big Data in the Innovative Development of Industry in Azerbaijan
Azerbaijan University of Architecture and Construction, Azerbaijan
Abstract: The article examines the role of big data analytics in promoting the development of innovative industry in Azerbaijan through the analysis of technological innovation expenditures and innovation performance indicators for 2020-2024. The study is based on official statistical data provided by the State Statistical Committee of the Republic of Azerbaijan and applies comparative, dynamic and structural analytical methods to assess trends in innovation activity in industrial sectors. The results show

that although the production of innovative products demonstrates positive dynamics, expenditures on technological innovations are unstable and unevenly distributed across sectors. The manufacturing industry continues to play a leading role in innovation activity, while the decline in the self-financing ability of enterprises is a significant problem for continuous technological modernization. Financial constraints, high economic risk and limited innovation potential are identified as the main obstacles hindering the development of innovation. The study shows that analytical approaches based on big data increase evidence-based decision-making and the efficiency of resource allocation, and support institutional development in the industrial sector. The results obtained in the article also provide a practical contribution to the understanding of innovation management in developing economies and to strengthening innovation policy, technological competitiveness, and sustainable industrial transformation in Azerbaijan.
Keywords: Big Data Analytics Industrial, Innovation
Digital Transformation, Industry 4.0 Azerbaijan Economy

Adnan Kutay Yüksel, Feyza Toktaş, Mehmet Serdar Güzel

Mapping the Safety Boundaries of Medical AI: A Mechanistic Failure Analysis of Pneumonia Detection Ensembles Under Severe Domain Shift

Ankara University, Türkiye

Abstract: Automated pneumonia detection faces critical barriers due to domain shift and AI "brittleness." This study introduces a triple-ensemble framework (VGG16, ResNet50V2, MobileNet V2) utilizing a robust 1,047-image validation partition and balanced loss weighting. While achieving 91.99% internal accuracy, the research distinguishes itself by pivoting to a failure-mode analysis through independent external validation, where performance collapsed to 51.00%. A primary advantage of this work is the systematic exposure of diagnostic unreliability via Grad-CAM mapping, which identifies "shortcut learning" anchored to non-pathological hospital artifacts rather than anatomical signatures. Furthermore, the study provides empirical evidence of representational collapse; targeted few-shot adaptation yielded negligible recovery defining the definitive limits of shallow adaptation. By transitioning from performance maximization to mechanistic failure analysis, this research advances the literature with a reproducible framework for mapping safety boundaries in medical AI. These advantages provide a necessary roadmap for identifying boundary conditions of trust, advocating for deep-adaptation strategies in heterogeneous healthcare environments. It moves the discourse beyond "accuracy-chasing" toward a trust-centered methodology essential for deploying safety-critical medical systems.

Keywords: Deep Learning, Representational Collapse, Ensemble Learning, Pneumonia Detection, Domain Shift,

Transfer Learning, Few-Shot Limits, Explainable AI, Clinical Robustness, Shallow Adaption

Enrico Zacchei, Md. Munir Hayet Khan
Advanced Modelling of Chloride Penetration in Concrete Considering Time- and Space-Dependent Diffusivity
University of Salamanca (USAL), Spain
INTI International University (INTI-IU), Malaysia
Abstract: For reinforced concrete structures, corrosion of reinforcing steel bars induced by chloride ions represents a recurring durability risk. Chloride ion diffusion is commonly described by Fick's laws, which are strictly applicable only when the diffusivity is assumed to be constant in both time and space. Under this assumption, the diffusion process and the associated exposure scenario can be greatly simplified. In this paper, a more comprehensive, non-constant, multifactorial diffusivity model is proposed, accounting for, among others, the effects of temperature, deformation, and damage. Given that the diffusivity varies in time and space, numerical solutions are required. For this purpose, the Runge–Kutta method is implemented for both 1D and 2D models, and the results are plotted using Her-mite polynomials. The boundary conditions relevant to this application are calibrated to solve the governing partial differential equations under randomly fluctuating diffusivity. The results demonstrate that traditional approaches significantly underestimate chloride

concentrations at certain depths, particularly for long-term exposure scenarios.
Keywords: Diffusion model, Chloride ions, Corrosion, Advanced analyses, Structural engineering

Enrico Zacchei, Zhiyuan Wang
Clustering-Based Post-Processing of Experimental Data for Double (insulating) Glass Units
University of Salamanca (USAL), Spain, Spain
Tongji University, Shanghai, China, China
Abstract: Double glass units (DGUs) consist of glass plates separated by a gas-filled cavity sealed by perimeter spacers. The glass plates resist to applied loads, whereas the enclosed gas mainly contributes to thermal and acoustic insulation in buildings or other structures. Load transfer between the plates occurs through a load-sharing mechanism that is difficult to quantify, particularly regarding its influence on out-of-plane vertical deflections. Although this phenomenon has been recently investigated experimentally, a major challenge of laboratory testing is the post-processing of large outputs. To address this issue, this study employs the k-means clustering algorithm as a data-driven tool for experimental data analysis. The objective is to identify optimal clusters that provide accurate approximations and enable direct relationships between elastic stiffness and out-of-plane deflections. The results show that k-means clustering produces reliable stochastic ap-proximations, allowing the generation of deflection maps for both the upper and lower glass plates.

Compared with traditional manual or analytical post-processing methods, the proposed approach offers an efficient and robust alternative for estimating stiffness values and glass deflections.
Keywords: k-means, DGU, mechanical deflections, structural analysis

Yahya Zakrya Khan, Hakan Kutucu, Isa Avcı
A Study of Multi-Model Comparison for an Explainable IoT Intrusion Detection System Using Particle Swarm Optimization-Based Feature Selection
Karabük University, Türkiye
Abstract: The rapid growth of Internet of Things (IoT) networks expands the attack sur-face and challenges intrusion detection because traffic is heterogeneous and strongly imbalanced. This study benchmarks four Machine Learning (ML) models and four Deep Learning (DL) architectures on the CICIoT2023 dataset using a two-stage protocol. The baseline stage trains models on the full feature set, without feature selection or resampling. The proposed stage applies binary Particle Swarm Optimization (PSO) to reduce redundancy and uses the Syn-thetic Minority Over-sampling Technique (SMOTE) to balance the training data. Performance is evaluated using accuracy, precision, recall, macro F1, specificity, and prediction time per sample. Baseline results indicate that high accuracy can mask the weak detection of minority classes, with XGB providing the most balanced baseline performance in terms of recall and macro F1 score. After the proposed

pipeline, RF achieves an accuracy of 0.987165, precision of 0.987346, recall of 0.987165, macro F1 of 0.987179, and specificity of 0.998166, while maintaining a prediction time of 0.061275 milliseconds per sample. Explainability utilizes SHapley Additive exPlanations (SHAP) and Local Interpretable Model-Agnostic Explanations (LIME) to interpret the best model, highlighting IAT, statistical flow descriptors, and Transmission Control Protocol (TCP) flag counters as key drivers, and demonstrating that remaining errors concentrate near overlapping feature regions. Overall, the pipeline en-hances robust, class-balanced detection and supports transparent analysis for practical IoT deployments.
Keywords: IoT intrusion detection, Feature Selection, Class Imbalance, XAI, Particle Swarm Optimization

Liu Zekun, Alexey Bezrodnyy, Arina Shelyugina

A Bio-Inspired Neural Network for Energy Supply and Transportation System

Belarusian State University, China
Belarusian State University, Belarus
Saratov state university, Russia

Abstract: Optimizing of energy supply when considered as service nets is essential for improving efficiency of many complex human-machine systems or cyber-physical ones. This study continues to develop a bio-inspired, cause-and-effect-based neural network approach tailored to such systems. Drawing from biological principles of causality and adaptation, the proposed method-ology involves three

key evolutionary steps: (1) constructing a traditional linear programming model; (2) developing a BP neural network-based fore-casting and scheduling model; and (3) applying a particle swarm optimiza-tion algorithm to optimize the initial weights and thresholds of the neural network, yielding the hybrid architecture. Some mathematical derivations are provided for each method, along with simulation experiments evaluating the performance of all three models in energy demand forecasting. The re-sults demonstrate that the model achieves good-enough prediction accuracy and convergence stability, highlighting its potential for real-world energy system optimization. and it also demonstrates some potential for real-time scheduling and robust decision-making in complex human-machine systems of practically any kind, as these systems often exhibit a net-like structure.
Keywords: supply, Transportation system, Neural network, Particle swarm optimization, Bio-inspired algorithm

Javanshir Zeynalov, Yigitcan Cakmak, Ishak Pacal, Maftun Aliyev, Leyla Ibrahimova, Hasan Nacafov
Automated Tomato Leaf Disease Classification Using Deep Learning: A Comparative Performance and Efficiency Analysis of CNN and Vision Transformer Architectures
Nakhchivan State University, Azerbaijan
Igdir Universty, Türkiye

Abstract: Tomato (Solanum lycopersicum) is a globally vital horticultural crop whose pro-duction is severely threatened by various diseases. Traditional disease diagnosis methods, relying on manual inspection, are often slow, subjective, and error-prone, highlighting the urgent need for a rapid and accurate automated system. This paper presents the development and evaluation of a deep learning-based sys-tem for the classification of ten tomato leaf classes using the PlantVillage dataset. We present a comparative analysis of four state-of-the-art architectures using transfer learning: DenseNet169, MobileNetV3-Small, ResNet50, and Vision Transformer (ViT-Base). The models were compared on accuracy, precision, re-call, and F1-score and also evaluated based on the computational efficiency with the number of parameters and GFLOPS as markers of computational efficiency. All the models showed excellent performance with DenseNet169 performing the best with a state-of-the-art accuracy of 0.9996 and F1-score of 0.9996. While both accuracy and F1-score were equal between DenseNet169 and ViT-Base, DenseNet169 was identified as the best model as it had the highest combination of optimal performance and total computational efficiency with both fewer pa-rameters and lower cost (GFLOPS) than ViT-Base. In summary, these results confirm that deep learning, specifically with the DenseNet169 architecture, is a viable and innovative tool for automating plant disease management and support-ing sustainable agriculture and food security worldwide.

Keywords: Deep learning, Tomato leaf diseases, Plant disease classification, Transfer learning

Vladimir Zubov

On the Experience of Simultaneous Identification of the Volumetric Heat Capacity and the Thermal Conductivity of a Substance

Federal Research Center "Computer Science and Control" of the Russian Academy of Sciences, Russia

Abstract: The study of nonlinear heat transfer problems is very important for practice. When studying new materials, the problem of simultaneously identification the temperature-dependent thermal conductivity and volumetric heat capacity of substance based on the results of experimental observations of the dynamics of the temperature field in an object arises. This problem was considered in both one-dimensional and three-dimensional cases. The consideration is based on the first boundary value problem for a one-dimensional and three-dimensional unsteady heat equation. Both the given temperature field and the given heat flow at the boundary of the object were considered as experimental data. The inverse coefficients problem is reduced to a variational problem. Formulas for calculating the gradient of the cost functional are obtained. The results of the solution of the formulated problem are presented and discussed.

Keywords: Optimal Control, Inverse coefficients problem, Thermal Conductivity

Onur Mert Çeldir, Efendi Nasibov
Comparative Analysis of Evolving Fuzzy Systems for Anomaly Detection in Streaming IoT Data
Dokuz Eylül University, Türkiye
Abstract: The rapid proliferation of IoT devices and the limited security measures that can be implemented on devices with low processing power have led to numerous security issues. Traditional intrusion detection systems cannot adapt to concept drift in data that changes over time and to new types of attacks. This study compares the evolving Takagi-Sugeno Plus (eTS+) and evolving Takagi-Sugeno Anomaly Detection (eTSAD) models, which use Evolving Fuzzy Systems (EFS) to detect attacks in IoT networks. Using the Bot-IoT dataset, the performance of these models on streaming data was examined. According to the experimental results, both algorithms achieved high detection rates above 99.8%. In addition, it was found that the algorithms exhibited different behaviors on the same data. eTSAD created a total of 73 rules and adapted quickly to changes, while eTS+ generalized more with only 2 rules. The results of the study show that EFS performs well on streaming data, but it was understood that these models require more complex test environments to demonstrate their true performance.
Keywords: Internet of Things, Anomaly Detection, Evolving Fuzzy Systems, Network Security, Online Learning, Bot-IoT Dataset

Batuhan Çelikbaş, Oguz Findik

Forex Price Prediction After Economic News with Boomerang Strategy and Machine Learning

Karabuk University, Türkiye

Abstract: The Forex (Foreign Exchange) market is the largest and most liquid market in the global financial system; its daily trading volume reaches trillions of dollars. This market has a complex structure with high volume and sudden changes in direction, where international currencies are priced against each other. Therefore, making short-term price predictions is an extremely challenging problem for investors and algorithmic trading systems. In this study, three different deep learning models (LSTM, GRU, and BiLSTM) were used comparatively together with the Boomerang Strategy based on technical analysis for short-term exchange rate prediction in the Forex market. The models input historical OHLC (Open, High, Low, Close) data and are trained to predict the price movement in the next minute. The models' predictions were analyzed for performance evaluation using Mean Squared Error (MSE), F1 Score, and price direction accuracy rate (%). The results revealed that the models achieved accuracy rates ranging from approximately 51% to 63% in predicting the price direction. These rates show that deep learning models have demonstrated significant success despite the difficulty of the short-term Forex prediction problem.

Keywords: Forex price prediction, Boomerang Strategy, LSTM GRU BiLSTM

Özge Nur Özaras, Asuman Günay Yılmaz, Vasif Nabiyev

Comprehensive Benchmarking and Hybrid Modeling of Deep Neural Networks for Tomato Leaf Disease Detection

Karadeniz Technical University, Türkiye

Abstract: Accurate and early detection of plant diseases is crucial for increasing agricultural productivity and reducing crop losses Although deep learning-based approaches have demonstrated promising performance in this domain, the comparative analysis of different architectures in terms of classification accuracy, computational cost, and generalization capability has not been sufficiently explored. In this study, a detailed comparative analysis of deep learning architectures is conducted for tomato leaf disease classification. Considering computational constraints and agricultural relevance, five classes—Healthy, Late Blight, Early Blight, Bacterial Spot, and Tomato Yellow Leaf Curl Virus (TYLCV)—are selected to represent fungal, bacterial, and viral disease categories while supporting cross-crop generalization. The classification performances of several Convolutional Neural Network-based (VGG16, ResNet50, InceptionV3, Xception, EfficientNet-B3, MobileNetV2, ConvNext-Tiny, ConvNext Small), and Vision Transformer–based architectures (ViT-B/16, DeiT-S, Swin-T, CoAtNet-0, MaxViT-Tiny) are evaluated. These models are compared using multiple evaluation metrics, including classification accuracy, F1-score, number of parameters, and training time. Experimental results reveal that different architectures exhibit complementary strengths depending

on the disease type and model capacity. Based on these observations, a hybrid model that combines the best performing two models (CoatNet-0 and Swin-T) is proposed. The results demonstrate that the proposed hybrid approach achieves a more balanced performance than CNN or ViT models, benefiting from both local feature extraction and global contextual modeling. Overall, this study provides a systematic evaluation of deep learning architectures for tomato leaf disease classification and highlights the potential of hybrid CNN–Transformer models for developing robust and generalizable solutions.
Keywords: Convolutional Neural Network, Vision Transformer, Leaf Disease Classification

Berna Özbaşaran, Gözde Ulutagay

Revisiting the Kwon Index for Fuzzy Cluster Validation: A Hybrid Mahalanobis–Euclidean Approach

Ege University, Türkiye

Abstract: in fuzzy clustering, internal validity indices play a critical role in determining the optimal number of clusters; however, their behavior is strongly influenced by the underlying distance metric. While the Fuzzy C-Means (FCM) algorithm is typically based on the Euclidean distance, this metric ignores correlation structures and non-spherical cluster geometries, which may lead to misleading compactness evaluations. This study investigates the effect of replacing the Euclidean metric with a Mahalanobis-based formulation for the distance metrics of internal validity indices within the fuzzy

clustering context. The proposed formulation adapts the classical Kwon index by incorporating local covariance structures into the compactness term, allowing for the detection of non-spherical cluster shapes. Furthermore, the separation component is modified to utilize the global Mahalanobis distance, ensuring that the overall correlation structure of the dataset is respected. In this way, the index becomes capable of capturing cluster-specific dispersion patterns without altering the optimization behavior of FCM. Extensive experiments were conducted on benchmark datasets from the UCI repository and on simulated datasets generated with scenarios designed specifically to test robustness against varying degrees of noise and outlier contamination. The results show that the proposed approach provides more reliable model selection, particularly for datasets with correlated variables and elongated clusters, while maintaining comparable performance in spherical scenarios. These findings highlight that the choice of distance metric in validity assessment is not merely a computational detail but a factor that fundamentally reshapes the interpretation of fuzzy partitions.
Keywords: Unsupervised Machine Learning, Fuzzy clustering, Internal cluster validity, Kwon index, Mahalanobis distance

Merve Özkan, Refik Samet, Yusuf Evren Aykaç

Lexicon-Augmented Explainable Aspect-Based Sentiment Analysis for Azerbaijani Finance and Business Text

Ankara University, Türkiye
Ankara Yıldırım Beyazıt University, Türkiye

Abstract: Aspect-based sentiment analysis (ABSA) for Azerbaijani has received limited attention, and finance / business text introduces domain terms whose polarity can be context-dependent. We study a Finance / Business Azerbaijani ABSA dataset with ∼27.2K aspect-level instances (≈18 tokens on average) and examine whether the SentiAzNet polarity lexicon can complement a multilingual transformer. Using XLM-RoBERTa as the base encoder, we integrate lexicon cues in two lightweight ways: (1) concatenating token-level polarity features and (2) adding an attention bias towards lexicon-matched tokens. We also define SentiAzNet-Fin through a small set of finance-specific polarity overrides. Lexicon coverage is sparse (3.17% of tokens; ∼38% of instances have ≥1 hit), so the lexicon acts as an optional cue rather than a primary signal. Across 5-fold cross-validation, the attention-bias model with SentiAzNet-Fin reaches 0.769 accuracy and 0.738 macro-F1, improving over vanilla XLM-R by 3.6 macro-F1 points (McNemar $p < 0.001$). For analysis, we compare SHAP attributions, attention saliency, and lexicon hits; agreement between these signals tends to coincide with higher correctness. We further summarize frequent errors such as sarcasm, neutral–negative ambiguity, mixed sentiment, and code-switching.

Keywords: Aspect-Based Sentiment Analysis, XLM-RoBERTa, Financial Sentiment Analysis, Sentiment Lexicon, Explainable AI, SHAP, Attention

Süleyman Nurullah Adahi Şahin, Abdulkadir Ozden, Hakan Kocaman, Abdurrahman Korkmaz, Cem Özkurt

Mapping Mobility Justice: A Deep Learning and GIS-Based Framework for Micro-Scale Sustainable Mobility Policy Assessment

Sakarya University of Applied Sciences, Türkiye
Giresun University, Türkiye

Abstract: The development of inclusive and sustainable transport policies demands accurate, spatially detailed data on the built environment and mobility in-frastructure—particularly at the neighborhood level, where daily mobility patterns and access disparities are most visible. This study proposes MiS-Har (Micro-Scale Sustainable Mobility Index), an integrated analytical framework that leverages deep learning-based object detection and Geo-graphic Information Systems (GIS) to systematically evaluate the sustainable mobility potential of urban micro-regions. High-resolution satellite and aerial imagery are processed using convolutional neural networks to automatically detect physical features such as buildings, green areas, paved sur-faces, pedestrian and bicycle networks. These are subsequently combined with GIS-based public transport bus stop yielding a multi-dimensional in-dex formulation. The index incorporates weighted parameters related to population density,

infrastructure provision, and land use patterns. A pilot implementation in Adapazarı District (Sakarya, Türkiye) demonstrates the model's ability to reveal intra-urban mobility inequalities and provide spatial evidence for transport-oriented development strategies. MiSHar represents a policy-responsive, survey-independent, and scalable approach to mobility diagnostics. By integrating AI-powered spatial analytics with urban planning principles, it offers a valuable tool for local governments seeking to target infrastructure investments, design equity-focused interventions, and align with European and global sustainable mobility goals.
Keywords: Sustainable mobility index, Deep learning, GIS, Micro-scale analysis

Hidayat Kerimov, Tarana Quliyeva

Computer Graphics as a Tool of Scenario-Based Design

Azerbaijan University of Architecture and Construction, Azerbaijan

Abstract: The paper examines the transformation of architectural design in the transition from fixed layouts to scenario-based thinking. It analyzes the evolving role of computer graphics—shifting from a tool for visual representation of form to a means of modeling spatial behavior over time. The study substantiates the necessity of accounting for functional variability, user scenarios, and operational dynamics as key parameters of modern design. It demonstrates that the digital model is no longer a final project illustration but rather an experimental

environment for hypothesis testing, conflict identification, and predicting the consequences of design decisions. Particular attention is paid to the development of new professional competencies for architects working in conditions of environmental uncertainty and usage variability. The conclusion emphasizes that scenario-based design and computer graphics contribute to the reimagining of architecture as a dynamic system oriented not only toward form but toward the life processes within it.
Keywords: Scenario-based Design, Computer Graphics, Digital Modeling, Architectural Form, Spatial Behavior, Functional Dynamics, Digital Design Tools, Scenario Simulation, Professional Responsibility, Design Thinking

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Abstracts

Gulchohra Mammadova
Telman Aliev
Kamil Aida-zade (Eds.)

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Site:
itta.cyber.az

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itta2026conf@gmail.com

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