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Alfa BK Univerzitet

THE BOOK OF ABSTRACTS

**International Scientific and Professional Conference
“ALFATECH “
Smart Cities and modern technologies**



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Standardised Evaluation Protocol for Multi-Label Classification Models in Insurance Complaint Analysis

Kuan MADIYAROV¹, Olga SHVETS², Alexey LETOV³

Abstract: Multi-label text classification presents unique challenges in model evaluation due to imbalanced label distributions and overlapping categories. This paper proposes a standardized evaluation protocol for machine learning classifiers, emphasizing unified performance metrics and resource usage monitoring. The protocol defines common metrics (micro- and macro-averaged F1, Hamming loss) and procedures (threshold tuning, probability calibration) to assess model quality, alongside computational criteria like training time and memory footprint. We illustrate the protocol in an insurance customer complaint classification task, comparing a neural network, XGBoost, and SVM. All models achieve high overall accuracy on this multi-label task, but their trade-offs become evident under the unified evaluation: the neural network and XGBoost slightly outperform SVM in rare complaint categories and run an order of magnitude faster. The results demonstrate how the proposed protocol facilitates fair comparison by highlighting both predictive performance and efficiency. This standardized approach can be generalized to related applications, guiding practitioners in selecting models that balance accuracy and computational cost.

Keywords: Multi-Label Classification, Evaluation Protocol, Insurance Complaints, Computational Efficiency, Machine Learning.

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Density-Based Clustering of Textual and Numerical Data Using DBSCAN: Insights from Heterogeneous Datasets

Vojkan NIKOLIĆ¹, Sanja RAIČEVIĆ², Miraš MILAŠINOVIĆ³

Abstract: This paper examines the application of the density-based clustering algorithm DBSCAN to heterogeneous datasets comprising both textual and numerical data, with the aim of analyzing its behavior and applicability under different data structural characteristics. The study is conducted on two types of data: textual data derived from articles of the Criminal Code of the Republic of Serbia and numerical data related to traffic accident statistics for the period from 2015 to 2021. The textual data are processed using standard preprocessing techniques followed by TF-IDF vectorization, while the numerical dataset includes indicators such as the number of accidents involving material damage, the number of injured individuals, and the number of fatalities. The clustering results indicate that DBSCAN enables the identification of data groups based on density without requiring a predefined number of clusters, as well as the separation of instances that do not belong to dense data regions. When applied to numerical data, variations in cluster structure were observed depending on the selected parameter values. In the case of textual data, increased sensitivity to data representation and parameter selection was noted, primarily due to semantic similarity among the documents. Based on the conducted analysis, it can be concluded that the applicability of the DBSCAN algorithm largely depends on the structure and distribution of the data, as well as on the chosen feature representation. The paper emphasizes the importance of careful algorithm and parameter selection in the analysis of heterogeneous datasets and provides a foundation for future research focused on combining density-based clustering methods with more advanced text representation techniques.

Keywords: Clustering, DBSCAN, Textual Data, Numerical Data, TF-IDF, Density-Based Clustering

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Reframing Air Pollution Prediction: The Regression-Classification Dichotomy in Artificial Neural Networks

Goran KEKOVIĆ¹, Vladimir MIKIĆ², Miloš ILIĆ³, Rade BOŽOVIĆ⁴

Abstract: The problem of air pollution not only affects large urban areas and human health, but also threatens the entire environment, endangering flora and fauna, water, soil, ecosystems, contributing to climate change. For these reasons, this problem has attracted significant attention from researchers, and within the framework of real-time air pollution prediction and forecasting, artificial neural networks (ANNs) remain at the forefront. Typically, ANNs are used for regression tasks, although they are most effective in classification tasks. This paper examines the possibility of using Long Short-Term Memory (LSTM) neural networks as classifiers in real-time air pollution prediction tasks with PM_{2.5} particles. In parallel, the properties of these networks in air pollution regression tasks were also tested. The performance metrics of LSTM networks in classification tasks were overall accuracy and the confusion matrix, while for regression tasks they included the Mean Squared Error (MSE), Mean Absolute Percentage Error (MAPE), and Mean Absolute Error (MAE). The results indicate that the regression method is effective for air pollution assessment, whereas the classification method is suitable as an alarm system in cases of air pollution hazardous to human life.

Keywords: Air Pollution, Classification Method, LSTM Networks, PM_{2.5} Particles, Regression Method.

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Application of Data Mining Methods for Automated Access Detection in Smart Tourism Systems

Vladimir KRAGULJAC¹, Luka ALEBIĆ², Dejan VIDUKA³

Abstract: Smart tourism represents an important segment of smart cities and relies heavily on digital platforms and data analytics to improve the tourist experience and make decisions based on reliable information. Web analytics of tourist portals and destination information systems play a key role in assessing tourist interest, capacity planning and optimization of tourist flows. However, the presence of automated web traffic, generated by bots, can seriously undermine the validity of the collected data and lead to wrong analytical conclusions. This paper presents an approach to the detection of bot access in smart tourism systems based on the analysis of web server log files using data mining techniques. The methodological framework includes the preparation and transformation of log data, the generation of association rules, and the application of supervised classification algorithms to distinguish between human and automated behavior. The effectiveness of the proposed approach was evaluated using multiple classification models, where very high levels of accuracy were achieved on the basic data set, as well as satisfactory results on the independent test set. The obtained results confirm that it is possible to reliably identify bot access using standard attributes available in web log files, thus providing a reliable basis for smart tourism analytics and decision support in smart cities.

Keywords: Bot Detection, Data Mining, Smart Cities, Smart Tourism, Web Log Mining.

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AI in Learning C Programming: Ally or Trap?

Luccas SVICERO LINS DE CARVALHO¹, Rogério APARECIDO CAMPANARI XAVIER², Angela TERESA ROCHETTI³, Anderson DUARTE BETIOL⁴, Luciana SARTORI MURARI⁵, Paulo CÉSAR MIORALLI⁶, Elson AVALLONE⁷

Abstract: Artificial Intelligence (AI) has emerged as a support tool in programming instruction, especially for beginners. This study investigated its role in C language learning, assessing its contribution to the development of skills or limitations in autonomous critical thinking. An experiment was conducted with high school students, divided into two groups: one with AI as a virtual tutor and the other with traditional teaching. The methodology included a literature review, analysis of the quality of the Prompts used with AI, practical experiments with Prompts, and questionnaires on the use and perception of the tool. The results showed that the AI group made fewer mistakes and completed tasks faster. However, signs of dependency and difficulty in explaining the corrections made by the AI emerged. Although effective in the short term, AI can become a trap if used without pedagogical mediation. It is concluded that its use must be planned with a focus on autonomy and critical thinking, acting as a complementary tool to the educational process.

Keywords: Artificial Intelligence, AI Tutor, AI Maker.

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AI-Based License Plate Detection as a Component of Safe City Infrastructure

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Abstract: The “Safe City” concept increasingly relies on intelligent video-surveillance systems to improve road safety and enable efficient urban management. One of the key components of such systems is automatic license plate detection, particularly at high-traffic urban intersections. This paper presents a multi-criteria analysis of two deep-learning-based approaches—Fast R-CNN and Fully Convolutional Networks (FCN)—for license plate detection within a “Safe City” framework. The study was conducted as a case study at the intersection of Mihajlo Pupin Street and Trešnjiog Cveta Street, where 605 vehicles were recorded over a one-hour period under ideal visibility conditions. The methodological framework is based on a hybrid decision-making model that combines the SWARA (Step-Wise Weight Assessment Ratio Analysis) method to determine criteria weights from expert judgments and the NWA (Normalized Weighted Aggregation) model for the final ranking of the analyzed algorithms. The evaluation criteria include detection accuracy (recall), localization precision (IoU), processing speed (FPS), computational efficiency, and operational stability of the system. Based on parameters reported in relevant literature and expert assessments, the expected number of successfully detected license plates was calculated for both algorithms. The results indicate a slight advantage of Fast R-CNN in terms of detection rate, while FCN achieves high spatial precision due to its segmentation-based approach. These findings support the selection of an optimal algorithm for deployment in “Safe City” systems and provide a foundation for further research in the field of intelligent transportation systems.

Keywords: Safe City, License Plate Detection, Fast R-CNN, FCN, SWARA, NWA, Multi-Criteria Analysis.

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Smart Urban Systems and Economic Development: A Multidimensional Perspective

Marijana JOKSIMOVIĆ¹, Marijana JOVANOVIĆ TODOROVIĆ², Zorica ĐURIĆ³

Abstract: The rapid advancement of smart urban systems has significantly transformed the dynamics of economic development in contemporary cities. By integrating digital technologies, data-driven governance, and intelligent infrastructure, smart cities aim to enhance productivity, innovation, and overall economic performance. This paper examines the relationship between smart urban systems and economic development from a multidimensional perspective, encompassing technological, institutional, social, and environmental dimensions. The study proposes a conceptual framework that explains how smart urban systems contribute to economic development through improved resource efficiency, innovation ecosystems, human capital development, and inclusive governance models. Using a mixed-methods approach, the research combines a review of relevant literature with an analysis of selected smart city initiatives to identify key drivers and outcomes of smart urban development. The findings indicate that cities implementing integrated smart systems experience positive economic effects, including increased competitiveness, attraction of investment, and enhanced entrepreneurial activity. Furthermore, the paper highlights the importance of governance capacity, stakeholder collaboration, and data interoperability in maximizing the economic benefits of smart urban systems. The study contributes to the existing literature by offering a holistic understanding of smart cities as complex socio-technical systems and provides policy-relevant insights for urban planners and decision-makers seeking to foster sustainable and resilient economic development.

Keywords: Smart Cities, Smart Urban Systems, Economic Development, Digital Transformation, Urban Innovation.

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Application of Information Technologies in Smart Cities: Transport, E-Waste and Environmental Protection

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Abstract: Within the framework of modern cities, Information and Communication Technologies (ICT) are intensively utilized to improve services for the urban population, while simultaneously reducing negative environmental impacts and thereby enhancing the quality of life. The subject of this paper aims to conduct research within three key sectors: public passenger transport using eco-friendly electric buses, the digitalization of electronic waste management processes, and environmental protection through the reduction of harmful gas emissions and the optimization of supporting economic processes. Special emphasis is placed on European Union legislation and the accompanying regulations of the Republic of Serbia that initiate these researched actions. Accordingly, the paper presents an analysis of the application of modern ICT from the perspective of benefits, advantages, and challenges, highlighting the legal frameworks that enable the development of smart solutions in urban environments, as well as harmonization with the regulations of neighboring countries.

Keywords: Electric-Powered Buses, Electronic Waste (E-Waste), Emissions, Information and Communication Technologies (ICT), Recycling, Transport.

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New Technologies in the Function of Smart Cities

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Abstract: Urban environments today face an increasing number of risks, starting from parking problems, traffic jams, pollution and increasingly frequent weather disasters, floods, heat waves, fires, extreme winters, etc. The current situation with floods in cities in Kosovo and Metohija in the era of digital transformation and technological progress, indicates the possibility of applying new technologies, i.e. adopting the concept of smart cities, in order to adequately respond to new weather disasters and situations, and thus improve the quality of life of its residents and become more efficient, sustainable and inclusive. However, despite all the benefits of applying new technologies in the literature, there is still not a sufficient number of scientific papers and research on this topic. In this research paper, based on the latest scientific literature, the concept of a smart city, supporting technologies, smart city models and their content components, i.e. functioning, as well as trends in the application of the concept of smart cities in our environment, will be presented and evolved. In this context, the process of transforming cities into smart cities will be explored, bringing with it positive changes in the everyday lives of citizens, examples of good practice and challenges that cities face on this path. The theoretical part of the research will present generations and models of smart cities, smart homes and their advantages and disadvantages, as well as differences compared to traditional cities. The research results show that in Serbia, not enough attention is still paid to the concept of smart cities. The empirical part will analyze aspects of the application of new sophisticated or smart technologies through surveys that determine the extent to which citizens are familiar with smart cities and what their attitude is towards new "smart" technologies. The results in practice show that cities on the path of transformation into smart cities use modern technology to create a better, safer and more sustainable environment for their citizens. Theoretical findings and research results indicate that the concept of smart homes and cities is still relatively unknown to citizens in our environment.

Keywords: Smart Cities, Smart Home, New Technologies, IoT.

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The Impact of the Digitalization of Urban Environments on Educational Inequalities

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Abstract: The idea of smart cities is based on introducing modern technologies to upgrade everyday life and to optimize the functioning of public services. However, in reality, such approaches confront the issue of digital inequality, which originates from the socio-economic conditions within the population. This research explores the digital divide in the education system, with a specific focus on the connection between technological resources and academic outcomes. The goal of the study is to pinpoint, using empirical data analysis, the key barriers preventing equal access to digital learning resources. The primary hypothesis of the paper is that spatial disparities, particularly living in peripheral and underdeveloped areas, have a negative influence on academic achievement because of inadequate information and communication technologies (ICT).

Keywords: Smart Cities, Digital Divide, Educational Inequalities, Urban Digitalization, E-Learning, Socio-Economic Status.

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Low-Cost IoT Water Quality Monitoring Station with Local Data Logging for Smart Environments

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Abstract: Within the concept of smart cities, continuous monitoring of water quality represents an important prerequisite for the sustainable management of water resources. This paper presents the design and implementation of a modular IoT measurement station for monitoring key water quality parameters, based on the ESP32 microcontroller. The system integrates sensors for measuring water temperature, pH value, total dissolved solids (TDS), and turbidity, along with local data visualization and offline storage of measurements on a MicroSD card in CSV format. Special emphasis is placed on the reliability of long-term operation and the collection of data suitable for further analysis and training of machine learning models. The proposed solution is low-cost, scalable, and easily adaptable for applications in smart cities, aquaculture, and environmental monitoring systems.

Keywords: Smart Cities, IoT, Water Quality Monitoring, ESP32, Machine Learning.

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The Role of Electronic Commerce in Sustainable Smart City Development

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Abstract: The sustainable development of smart cities increasingly depends on the integration of digital economic activities with urban infrastructure and governance models. Among these activities, electronic commerce (e-commerce) is a significant driver of economic change, technological innovation and the transformation of urban logistics systems. This paper analyses the role of e-commerce in the sustainable development of smart cities, with a particular focus on the economic, social, environmental, technological and institutional dimensions of sustainability. The research is based on a conceptual-analytical approach, which combines a systematic review of relevant literature with the development of a formalised methodological framework for assessing sustainability. An aggregated sustainability index, constructed on the basis of weighted dimensions and normalised indicators, is proposed, which enables a comparative analysis of different levels of e-commerce integration into smart city systems. The applicability of the framework is illustrated through a scenario analysis that includes low, partial and high levels of e-commerce integration. The results indicate that higher levels of integration significantly improve technological and economic sustainability, while environmental and institutional effects are largely conditioned by the quality of public policies, the regulatory framework and the coordination of relevant actors. The main contribution of the paper is reflected in the development of a formal conceptual model that positions e-commerce as an integral part of the smart city ecosystem and a strategic instrument for long-term urban sustainability, with a clear basis for future empirical research and evidence-based decision-making.

Keywords: Digital Economy, Electronic Commerce, Smart Cities, Smart Infrastructure, Sustainable Development.

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Mathematical Optimization of Combined Heat and Power Plant Operation Using the Elbow Method to Maximize Market Potential in The Day-Ahead Market

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Abstract: The EU electricity market, particularly the Day-Ahead (DA) market within the BSP SouthPool exchange, serves as a key platform for optimizing electricity production, consumption, and management. Electricity prices in this market are determined by the supply and demand for each individual time interval of the following day. After the end of operational state subsidies for continuous operation, the challenge was to maintain the economic efficiency of the combined heat and power (CHP) plant, which is still technically capable of continuous operation. However, market prices for gas and electricity without operational subsidies no longer justify continuous operation. An advanced operation optimization algorithm that analyzes published DA electricity prices was developed. It calculates the optimal operating time window for each day. The plant is activated only when market prices are high enough to make operation economically justified. Thus, under these conditions, the plant is used for maximum economic effect while controlling risks through carefully selected operating times. Annually, this amounts to just under 10% of the full continuous operating time. By introducing this dynamic operating regime, the continued operation of the CHP plant was ensured despite the expiration of subsidies.

Keywords: Day-Ahead Electricity Market, CHP Operation Subsidies, Operation Optimization Algorithm, Elbow Method, Dynamic Operating Regime, Operation Time Window.

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Integration of Cloud Computing and IoT Systems in the Development of Smart Educational Environments

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Abstract: The digital transformation of education emphasizes the role of smart educational environments facilitated by advanced digital technologies. This paper explores the role of Cloud computing and Internet of Things (IoT) technologies in smart learning environments based on perceived usefulness, technical security, infrastructure readiness, and decision support in educational institutions. The research framework regards Cloud computing and IoT as complementary technologies. The former provides computing services over the internet, whereas the latter enables interconnecting physical learning spaces. An empirical study on the topic used a structured questionnaire targeting students and employees of educational institutions who actively use digital technologies for education. The study collected 180 questionnaires. The study revealed a high level of familiarity with Cloud computing and positive attitudes towards the integration of Cloud computing and IoT technology. Factor analysis identified three factors: perceived usefulness, technical security and infrastructure, and decision support in smart educational environments. Although perceived benefits are significant, there are also some concerns about technical reliability and security. The study reveals that Cloud computing and IoT technology integration can enhance teaching quality, learning flexibility, and efficiency of educational processes, thus supporting the development of smart learning environments.

Keywords: Cloud Computing, Digital Transformation of Education, Educational Infrastructure, Internet of Things (IoT), Learning Analytics, Smart Classrooms, Smart Educational Environments.

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Artificial Intelligence as the Basis for Smart City Management: Automating the Identification of Regulatory Conflicts

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Abstract: This paper examines the use of artificial intelligence for the automated detection of legal conflicts as a key factor in managing a Smart City. The purpose of the study is to analyze existing experience and develop a concept for a hybrid intelligence system. The emphasis is on the practical application of AI. The study analyzes cases where machine learning and neural networks are already being implemented in law enforcement, from experimental systems in Shanghai to the use of language models by judges. Based on the analysis, a modular architecture of an expert system based on natural language processing (NLP) and deontic logic is proposed.

Keywords: AI in Law, Artificial Intelligence, Conflicts, NLP, Smart City.

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Digitalization of Payments in Smart Cities: Artificial Intelligence as a Factor of Economic Growth and Development

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Abstract: The paper analyzes the role of payment digitization and artificial intelligence as factors of economic growth and the paper analyzes the role of payment digitization and artificial intelligence as factors of economic growth and development in the context of smart cities, with a focus on the Balkan countries and specifically on Belgrade and Zagreb. The study is based on a mixed-methods approach that combines quantitative analysis of secondary data with qualitative interpretation of institutional and technological trends. Empirical findings indicate a continuous increase in cashless and digital payments, as well as the development of payment infrastructure in Serbia and other Balkan countries. Specifically, a comparative analysis highlights a higher level of digital maturity in Zagreb, while Belgrade records a faster growth of digital payment technologies. The results confirm that AI-supported digital payments contribute to greater efficiency of financial systems, lower transaction costs, and the strengthening of formal economic flows. In conclusion, the development of AI-supported digital payment systems represents an important factor for the sustainable economic development of smart urban environments and beyond.

Keywords: Digital Payments, Smart Cities, Artificial Intelligence, Digital Economy, Economic Growth, Financial Inclusion.

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Blockchain-Enabled Smart Digital Marketing: A Conceptual Evaluation Framework for Enhancing User Experience

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Abstract: The development of digital technologies and their application in business have led to the transformation of traditional marketing and the emergence of Smart Digital Marketing (SDM). SDM uses technology to build customer relationships; however, data collection raises concerns regarding security and transparency, creating a need for the improvement of SDM campaigns. The application of blockchain technology in digital marketing offers a potential solution by enabling secure data storage, immutability, and transparency - all aimed at improving User Experience (UX), trust, and engagement. Despite this potential, a systematic framework for evaluating the effects of integrating these two concepts on key UX dimensions, such as trust, engagement, and loyalty, is lacking. The aim of this paper is to present a conceptual evaluation framework for SDM strategies integrated with blockchain technologies, focusing on UX improvement. The framework operationalizes the relationship between specific strategies, corresponding blockchain mechanisms, and expected outcomes, alongside proposed evaluation criteria. Its main contribution lies in highlighting the systematic synergy between strategies and technology and emphasizing the interconnected nature of UX effects, which cannot be viewed in isolation. The proposed framework provides a methodological foundation for future empirical research and practical strategic application, enabling organizations to plan integrated, customer-centric campaigns.

Keywords: Blockchain Technology, Digital Transformation, Smart Digital Marketing, User Experience.

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Smart City or Digital Cage: Safety vs. Privacy in AI and IoT Monitoring

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Abstract: The accelerated tendency of artificial intelligence (AI) implementation and usage of Internet of Things (IoT) is transforming public safety approaches significantly. In addition, such development highlights additional concerns with privacy and freedom. Research in the paper covers how autonomous AI tools within real-time surveillance and biometric facial analysis. It is essential not to forget risk detection mechanisms and the balance between collective security and personal autonomy. The research uses hypothetical and sometimes existing scenarios with the AI solutions in smart cities. They are included in a survey, and the information has been collected by randomly chosen residents. It covers thought confrontation between machine generated or human decisions. Finally, solutions get spotlighted: Privacy by Design principles alongside human-in-the-loop methods, forming the basis for principled, quantitative smart city management. To wrap up, achieving lasting security in smart urban environments calls for accountable algorithms, firm legal guidelines, and protecting individual digital autonomy above all.

Keywords: Autonomous AI Agents, Data Privacy, Internet of Things, Smart Cities, Urban Security.

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Historical Development of Fourier Transform and Its Contemporary Application in Network Performance and System Security Analysis

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Abstract: Fourier Transform provides an effective framework for analyzing time-series data in technical and network systems. In modern digital infrastructures, metrics such as RTT, jitter, and packet loss directly impact the reliability of systems critical to public safety, including video surveillance and emergency communications. Time-domain monitoring is often insufficient for detecting periodic disturbances and slow degradations. Power Spectral Density (PSD) analysis enables identification of characteristic spectral signatures, where periodic packet losses appear as stable peaks and systemic degradation manifests as increased low-frequency energy. This frequency-domain approach enables earlier and more reliable anomaly detection, improving the stability and security of public digital infrastructures.

Keywords: Fourier Transform, PSD, RTT Analysis, Packet Loss, Network Anomalies, Public Safety.

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The Impact of Digital Transformations on Improving the Quality of a New – Innovative Product

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Abstract: In today's competitive and globalized world, innovations are essential for the survival of organizations, offering companies ideas to withstand environmental impacts and social challenges. Traditional methods of digital transformation primarily focus on the product itself or the technical system, but they rarely recognize or plan the product development process from the perspective of innovation. The aim of this paper is to present a qualitative model for product innovation. Digital transformations are analyzed as factors influencing the creation of a new, innovated product. Based on product design characteristics and the integration of information technologies into design technology, a qualitative model for product innovation has been developed. As innovation processes accelerate, managers must reassess the entire value creation chain, with digital transformation emerging as a continuous process of organizational adaptation to a changing social environment. The paper examines the specific impact of each digital technology on innovation revenues, while simultaneously exploring how these technologies influence different types of innovation within organizations.

Keywords: Digital Transformation, Innovation, New Product, Innovated Product, Product Quality.

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The Prototype of the Information Security System of Educational Institutions

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Abstract: This article presents a conceptual framework for designing an information system dedicated to monitoring and responding to potential threats within the educational environment. Unlike traditional approaches that focus on information security in terms of data integrity, this study focuses on the physical and social safety of the educational space through the lens of business process management. This perspective acknowledges that the complexity of modern educational ecosystems requires a shift from fragmented security measures to a holistic management paradigm. Efficiency of a security system is fundamentally limited if it is treated as a standalone technical add-on; instead, it must be deeply integrated into the institutional workflow to ensure seamless interaction between technology and human factors. To bridge the gap between theoretical safety requirements and practical implementation, the research employs a process-oriented methodology to map the daily operations of educational institutions, identifying specific vulnerabilities at each stage. By analyzing these workflows, the study highlights how automated monitoring can be harmonized with existing administrative routines without disrupting the core educational mission. The resulting model provides a scalable solution for transforming educational facilities into "smart" secure environments, balancing the need for rigorous safety standards with the requirement for an open and conducive learning atmosphere.

Keywords: Information System, Monitoring, Potential Threats, Educational Environment, Physical and Social Safety.

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Artificial Intelligence in Digital Systems for Documenting and Safeguarding Intangible Cultural Heritage

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Abstract: This article examines the theoretical and methodological foundations of applying artificial intelligence within digital information systems for the documentation and safeguarding of intangible cultural heritage. Proceeding from a heritological understanding of intangible cultural heritage as a processual, socially embedded, and contextually constituted phenomenon, the article critically interrogates the conditions under which digital technologies can support, rather than distort, the complexity of living cultural practices. The analysis addresses the paradigm shift in documentation theory, from static archival models toward process-oriented and participatory frameworks, and situates digital information systems within this broader theoretical reorientation. Particular attention is given to the methodological integration of artificial intelligence as an analytical instrument capable of processing large heterogeneous datasets, identifying structural patterns in performing practices, and enabling longitudinal comparative analysis. At the same time, the article systematically delineates the interpretative limitations of algorithmic models, arguing that the symbolic, social, and contextual dimensions of intangible cultural heritage remain beyond the operational reach of formalized data processing. The ethical challenges of algorithmic standardization, the reduction of variability, and the suppression of local meaning frameworks are examined as constitutive risks of technologically unreflective application. Drawing on participatory documentation models and community-centered approaches, the article proposes a framework in which artificial intelligence occupies a precisely defined, subordinate, and methodologically transparent role. At the same time, interpretative authority remains within the domain of expert heritological analysis and community dialogue. The conclusion affirms that the long-term sustainability of digital safeguarding systems depends not on technological sophistication, but on their capacity to remain open, participatory, and oriented toward the living dynamics of cultural practice.

Keywords: Intangible Cultural Heritage, Artificial Intelligence, Digital Documentation, Cultural Safeguarding, Digital Information Systems, Machine Learning, Ethical Frameworks, Cultural Sustainability.

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Application of Modern ICT Solutions in Strengthening the Public Safety of Smart Cities

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Abstract: The paper presents the establishment of infrastructure and advanced ICT services that would enable secure, reliable, and comprehensive mass collection, processing, analysis, exploitation, and storage of various types of data (alphanumeric, biometric, video material data, GIS data) within Public Security Services with all associated organizational elements, as well as the establishment of infrastructure for comprehensive data exchanges aimed at more effective crime prevention and offender detection. In the establishment of the modern IT system, IBM Kafka data stream was used, a platform for mass data collection from various sensor platforms. Through the application of such an IT-IoT system, the work of Public Security Service officers is optimized by providing access to all necessary services through a single workstation, which was not the case until now. This will significantly save future costs of purchasing and maintaining workstations for the needs of Public Security Services, Ministry of Internal Affairs.

Keywords: Integration, Services, Public Safety, Criminal Offense.

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A Fuzzy Multi-Criteria Framework for Cyber Threat Prioritization in Smart City IoT Systems: Sensitivity and Robustness Analysis

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Abstract: The fast growth of the Internet of Things (IoT) in smart city infrastructure has made cyber risk management much more complicated. Communication networks, energy distribution, healthcare, and transportation are among the vital urban systems increasingly susceptible to sophisticated cyberattacks that could have a detrimental effect on society. The subjectivity and ambiguity inherent in expert assessments are often inadequately captured by traditional deterministic risk assessment techniques. This article presents a fuzzy multi-criteria decision-making framework for assessing cyber threats in IoT systems for smart cities. Technical intensity, domain criticality, socio-ethical effect, operational resources, and architectural vulnerability are the five core criteria that make up the model. These criteria are further subdivided into seventeen sub-indicators. Uncertainty in expert judgments is addressed through fuzzy logic representation, enabling more realistic modeling of complex risk environments. The four representative cyberattack scenarios examined are data manipulation in monitoring systems, distributed denial-of-service attacks on urban sensors, ransomware attacks on hospital infrastructure, and data exfiltration from smart meters. Because of their significant socio-ethical and domain-critical impact, ransomware attacks on vital healthcare systems pose the greatest threat. In urban environments, the proposed framework provides a consistent, adaptable decision-support tool for strategic prioritization of cyber risk.

Keywords: Cyber Threat Prioritisation, Fuzzy Analytic Hierarchy Process, Internet of Things, Multi-Criteria Decision-Making, Sensitivity Analysis, Smart City Cybersecurity.

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Digital Shield of the City: Application of Artificial Intelligence in Predicting Infrastructure Collapse and Climate Hazards

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Abstract: As climate alteration continues to accelerate and intensify, the traditional smart city concepts are decreasingly fit for purpose. Urban areas now need smarter strategies to handle climate hazards. In this work, we analyze the role of artificial intelligence incorporated into urban simulation models that aim to explain how extreme weather events affect cities. It examines flood risks, urban heat effects, and air quality problems. This could help spot issues in water supply, electrical systems or air pollution sooner. We surveyed people about their feelings about safety. Survey questions included local risks, old infrastructure problems, trust in warning apps, and their emergency response habits. The results are clear, trust also matters, not just the technology. Both of them are essential for the functionality of digital resilience systems in crisis.

Keywords: Artificial Intelligence (AI), Climate Hazards, Early Warning Systems (EWS), Environmental Protection, Infrastructure Risk Prediction, Smart Cities, Urban Resilience, Public Perception & Trust.

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Impact of Meteorological Predictor Selection on Drought Forecasting Accuracy

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Abstract: Drought is one of the most critical climate-related threats, impacting water resources and agricultural systems. Precise short-term drought forecasting depends strongly on the selection of relevant meteorological predictors. This study examines the impact of various predictor combinations on the accuracy of one-month-ahead drought forecasting, utilizing the Standardized Precipitation Evapotranspiration Index (SPEI-1) as the goal variable. Hourly meteorological data from a station in Novi Sad, Serbia (2014–2020) were consolidated from daily to monthly values. Five predictive scenarios were assessed, encompassing precipitation and air temperature, as well as additional variables such as air humidity, wind speed, and surface soil moisture. The evaluation of forecasting performance was conducted with MAE, RMSE, and MAPE. The results indicate that the ARIMAX model consistently surpasses the LSTM model in all cases. The greatest significant enhancement occurs when surface soil moisture is incorporated, resulting in the lowest MAE and MAPE, but the whole predictor set offers the lowest RMSE with minimal further benefits. These findings validate that domain-specific predictor selection is essential for enhancing short-term drought forecasting and facilitates effective data-driven monitoring systems.

Keywords: Climate Analysis, Drought Forecasting, Meteorological Predictors, SPEI, Time Series.

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Asynchronous Counters Based on D Flip-Flops in IoT Systems for Smart City Applications: Operation and Delay Effects

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Abstract: This paper presents an overview and analysis of asynchronous (ripple) counters implemented using D flip-flops. The operation of the D flip-flop as a basic sequential memory element is briefly described, followed by an explanation of its role in counter design. The principle of cascading multiple D flip-flops to form an asynchronous counter is discussed, together with the resulting counting sequence. Particular attention is given to propagation delays, which cause non-simultaneous state changes across counter outputs and may lead to transient unwanted states. The advantages and limitations of asynchronous counters are analysed from a practical digital design perspective. The paper aims to clarify when asynchronous counters are suitable for use and which design considerations must be taken into account in real digital systems. In the context of smart cities, asynchronous counters are commonly used in low-power IoT sensor nodes, traffic monitoring units, smart lighting controllers, and simple urban measurement devices, where hardware simplicity and energy efficiency are critical. Understanding the impact of propagation delays is therefore essential for ensuring reliable operation in distributed smart city systems.

Keywords: D Flip-Flop, Asynchronous Counter, Ripple Counter, Propagation Delay, Internet of Things (IoT), Smart City Systems.

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Intelligent Real-Time Adaptive Learning: A Performance Analysis of Educational Systems

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Abstract: The paper presents a laboratory analysis of modern educational platforms from the aspect of intelligent adaptive learning in real time. The platforms were evaluated based on performance criteria that directly affect the possibility of quick and efficient adaptation during the teaching process. Measurements and analysis are focused on six key performance variables: adaptation latency, temporal granularity of adaptation, throughput of interactions, scalability, deterministic behavior and system resource efficiency. The research was conducted in controlled laboratory conditions, without the involvement of students, using standardized scenarios and measurement procedures. The results indicate that platforms designed for real-time work have an advantage in reaction speed and intensity of interaction, while mass education platforms show a higher degree of scalability. The findings indicate the importance of performance analysis in assessing the technical readiness of educational systems for use in the classroom environment. In this context, the results confirm the thesis that, according to the performance criteria of adaptive learning in real time, Digital Dialogue achieves results comparable to leading modern educational platforms.

Keywords: Adaptive Learning, Real Time, Educational Platforms, Interaction, Performance.

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Possible implications of IoT implementation on society

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Abstract: The main goal of this research is to gain a thorough understanding of the concept of the Internet of Things (IoT) and their applications in the function of improving the environment, preventing natural disasters and saving human lives through timely interventions. The Internet of Things is a relatively new technology with enormous potential that promises to make the world more efficient, smarter and more comfortable, and it can be said that these technologies and applications have found their way into society and are changing traditional methods in many areas of life and work. Key components of the IoT include sensors and actuators, network connectivity, data processing platforms, and applications for data analysis and visualization. IoT technology not only makes our daily lives easier, but also brings significant advantages in the so-called smart cities and industry. Based on several years of research into the latest literature, this paper presents great possibilities for the application of the Internet of Things in society. All these innovations contribute not only to greater practicality, but also to energy efficiency, which in the long run saves money and reduces the negative impact on the environment. Although the application of IoT in industry had a slow start, many understand that it is necessary for companies to see the need to adopt new and innovative technologies in their business plans. The research also includes a SWOT analysis of the functional application of IoT with a presentation of the number of IoT devices and a projection for the coming years. The research shows that one of the risks in the implementation of IoT is data privacy, which is addressed by ensuring it through data encryption, user authentication, and the implementation of security protocols and policies that limit access to sensitive information. The goal of the project is to provide a thorough understanding of how new technologies work together to create automated and efficient living spaces.

Keywords: Digital transformation, Internet of Things (IoT), Artificial Intelligence.

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Predictive Maintenance as a Strategic Pillar of Smart City Infrastructure

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Abstract: Predictive maintenance is a key mechanism for managing smart city infrastructure in conditions of high interdependence and cascading risks. Traditional reactive and time-based models are proving insufficient to ensure the reliability and continuity of public services. In this paper, predictive maintenance is analysed as a strategic tool based on the application of artificial intelligence, digital twins and data analytics for the early detection of degradation and the optimization of interventions. Special attention is paid to its role in preventing cascading failures and strengthening urban resilience. The paper points out the institutional and organizational limitations of implementation and emphasizes the need to integrate predictive maintenance into urban management and sustainable development.

Keywords: Predictive Maintenance, Smart Cities, Urban Resilience, Infrastructure Management, Artificial Intelligence.

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Evaluating Temporal Horizons in Air Pollution Prediction Using Gradient-Boosted Trees

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Abstract: Predicting particulate matter concentrations is crucial for understanding and managing air quality in smart cities. This study investigates the impact of temporal horizons on the accuracy of PM_{2.5} prediction using a Gradient-Boosted Trees (XGBoost) machine learning methodology. The research utilizes data from 34 SensEURCity network sensors in Antwerp, aggregated into a unified city-level PM_{2.5} signal. After careful data preparation and feature engineering (including temporal and lag features), the model was trained and evaluated using walk-forward cross-validation for four forecast horizons: 1, 3, 6, and 24 hours ahead. Results show a clear and monotonic increase in prediction error as the forecast horizon increases. Short-term forecasts (1–3 hours ahead) achieve substantially lower mean absolute error, while predictions beyond 6 hours exhibit significantly reduced accuracy. The 24-hour-ahead forecasts demonstrate the limitations of tree-based models for long-horizon air pollution prediction under constrained historical data. These findings provide practical guidance on the feasible temporal horizons for data-driven air quality forecasting in smart city environments and highlight the importance of aligning model choice with forecast horizon.

Keywords: Air Pollution Forecasting, PM_{2.5} Prediction, Time-Series Forecasting, Gradient-Boosted Trees, Low-Cost Sensors.

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Information Technology Security as The Foundational Framework for Smart Cities

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Abstract: Smart cities have emerged as innovative solutions to meet the complex demands of urban life. Information and communication technologies (ICT) are seen as the backbone of this transformation, integrating infrastructure, public services and environmental sustainability. Smart city developments involve the intensive use of information and communication technologies, opening up numerous security challenges. In this paper, we analyze the importance of information technology security as one of the key factors for successful and sustainable functioning of smart cities. Within ICT, information system security has become a cornerstone for building large-scale systems that support the implementation of smart cities. Artificial intelligence (AI) plays an increasingly important role in protecting information systems, as it can provide a faster and more efficient way to detect and resolve security threats. AI systems are designed to analyze large amounts of data to identify suspicious activities and detect threats before they become serious problems.

Keywords: Smart City, IoT Security, Cryptography, AI, Sensor Shield.

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Cybersecurity of Critical Infrastructure in Smart City

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Abstract: The security of the country, its economy, cities, and their citizens depends on the critical infrastructure, which is the most important part of the total infrastructure. Each subsystem within the critical infrastructure system provides services to other subsystems, and in this sense, they are characterized by a large number of interwoven, tight connections. By maliciously acting on one subsystem, a ripple effect is created that can grow so much that it threatens the security of the state itself. Therefore, the cyber security aspects of critical infrastructure are very important for researchers, government agencies, and professional individuals. The vision of a smart city should enable a better life for all its citizens and humanity as a whole. It presupposes the use of 4.0 technologies such as the Internet of Things, cloud computing, big data, and artificial intelligence. In past, critical infrastructure subsystems have relied to a greater or lesser extent on isolated and proprietary technologies. With the introduction of "things" into those subsystems, a new polygon is created that includes a large number of vulnerabilities that did not exist until that moment. This paper attempts to shed light on the cybersecurity aspects of critical infrastructure in smart city scenarios.

Keywords: Cybersecurity, Critical Infrastructure, Smart City, Internet of Things, Sensors.

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Communication Scalability Analysis of Federated Learning in Autonomous Vehicle Networks

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Abstract: Autonomous vehicles generate and exchange large volumes of data used to improve artificial intelligence models. Traditional centralized training approaches face challenges related to scalability, data privacy, and network communication load. Federated learning offers a potential solution by enabling distributed model training without transferring raw data. This paper analyzes the communication scalability of federated learning in autonomous vehicle networks. A simulation model is developed in which autonomous vehicles communicate with a central aggregation server using bidirectional TCP communication. The results provide insight into communication limitations in such systems and represent a basis for further research focused on optimizing communication protocols and improving distributed learning architectures.

Keywords: Autonomous Vehicles, Federated Learning, Communication Scalability, Distributed Machine Learning

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Implementing GitOps with ArgoCD and Kubernetes for Continuous Deployment of Smart City Microservices: A Case Study in Traffic Management Systems

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Abstract: Modern smart city initiatives, particularly in critical domains like traffic management, face significant operational challenges in deploying and updating complex, interconnected software systems. Traditional manual deployment methods and monolithic architectures result in slow update cycles, configuration drift, and unreliable rollback procedures—all unacceptable for real-time urban infrastructure. This paper presents a practical implementation of a GitOps-based DevOps pipeline to automate the deployment and management of a containerized, microservice-based traffic management platform. The authors propose a reference architecture utilizing Kubernetes as the orchestration layer, ArgoCD as the declarative GitOps operator, and GitHub Actions for continuous integration. The implemented case study, managing simulated traffic signal control and congestion detection microservices, demonstrates a 70% reduction in deployment time, enables near-instant rollback via Git history, and provides complete auditability of all changes. Results indicate that the GitOps paradigm, realized through this specific toolchain, provides the necessary reliability, speed, and compliance required for evolving smart city infrastructure. This work offers a reproducible technical blueprint for municipal IT teams seeking to operationalize agile, resilient urban services.

Keywords: DevOps, GitOps, Kubernetes, ArgoCD, Smart City, Microservices, Continuous Deployment, Traffic Management.

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Identifying a Minimal Feature Set for Accurate PM_{2.5} Prediction in Urban Sensor Network

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Abstract: Accurate prediction of fine particulate matter (PM_{2.5}) is essential for urban air quality assessment and public health protection. In recent years, machine learning models have been widely applied to PM_{2.5} forecasting, often relying on extensive sets of pollutant and meteorological variables. However, the necessity of using large input feature sets has rarely been systematically examined. This study investigates the extent to which accurate PM_{2.5} prediction can be achieved using a minimal subset of input features. Air quality and meteorological data from an urban sensor network in Antwerp, Belgium, were used to evaluate multiple combinations of temporal lag structures and auxiliary variables. Gradient boosting regression models were trained and validated using a rolling time-based cross-validation framework, with performance assessed using mean absolute error. Different feature configurations, ranging from lagged PM_{2.5} values alone to combinations including meteorological and gaseous pollutant variables, were systematically compared. The results demonstrate that competitive predictive performance can be obtained using a reduced set of input features, primarily based on temporal information from PM_{2.5} itself. These findings suggest that simplified models may offer an effective and computationally efficient alternative for PM_{2.5} forecasting in dense urban sensor networks, with potential implications for data availability, system robustness, and model deployment.

Keywords: PM_{2.5} Prediction, Air Quality Modeling, Feature Selection, Machine Learning, Urban Sensor Networks, Time Series Forecasting.

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Elements of System Management in Smart Buildings

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Abstract: Building Management Systems (BMS) form the foundation of smart building operations by enabling centralized monitoring and control of HVAC, lighting, energy, security, and safety systems. Based on standardized communication protocols, traditional BMS solutions improve operational efficiency and occupant comfort. However, limited interoperability, vendor dependency, and restricted scalability reduce their ability to integrate advanced analytics and cloud-based services, resulting in insufficient flexibility for data-driven management. The adoption of Internet of Things (IoT) technologies has significantly enhanced building monitoring through distributed sensors and wireless communication networks. IoT enables real-time data acquisition and improved system responsiveness. Nevertheless, challenges related to cybersecurity, privacy, network reliability, and device heterogeneity complicate system integration and long-term maintenance. Energy Management Systems (EMS) and artificial intelligence (AI) further advance smart building performance by supporting intelligent energy optimization and adaptive control. EMS facilitates demand response, renewable energy integration, and load forecasting, while machine learning methods enable energy prediction, fault detection, and self-optimizing strategies. Despite these benefits, many EMS platforms remain isolated from other subsystems, and traditional rule-based approaches lack adaptability. Moreover, AI-based solutions are often constrained by limited data availability, high computational requirements, and insufficient transparency, which may reduce user trust and practical applicability.

Keywords: Smart Buildings, System Management, IoT, Energy Efficiency, Automation, Building Management Systems.

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Artificial Intelligence in Education: Using ChatGPT to Generate Math Problems

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Abstract: This paper presents the findings of study on the application of ChatGPT for generating mathematical assignments in primary education. This research aimed to investigate the responses of pupils of varying ages to mathematics challenges devised by the teacher and those generated by artificial intelligence. Emphasis was made on variations in success, perceived difficulty, clarity of objectives, and pupil motivation in addressing both task types. The study encompassed kids from fifth to eighth grade, categorized into younger and older age cohorts. Pupils were administered two assessments, one devised by the instructor and the other produced by artificial intelligence. Upon completing both assessments, pupils completed a questionnaire regarding their attitudes. Studies indicate that artificial intelligence can enhance mathematics instruction, particularly for older pupils. Nevertheless, the findings underscore the need of pedagogical oversight and the necessity to tailor content according to pupil's age, as assignments produced by artificial intelligence are not invariably didactically suitable. The research findings indicated that artificial intelligence could serve as a helpful aid for educators; yet it cannot supplant their professional and methodological roles in mathematics instruction.

Keywords: ChatGPT, Mathematics Teaching, Motivation, Pupils Perception.

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Role of Data Integration Tools in Smart Sewer Scenario and Hybrid Cloud Environment

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Abstract: Traditional information systems in water and sewage companies cannot adequately respond to the business challenges posed by the modern business environment, urbanisation processes, and climate change. That is why these companies use Industry 4.0 technologies in the realisation of certain business scenarios. Usually, some of these companies have their own developed information systems in the past that were on-premise. It is possible that these systems may have lost their ability to evolve over time and become legacy systems. Legacy systems still contain huge business logic and support core business processes. There is a need to connect systems running on a public or private cloud and legacy systems that are on-premise through a hybrid cloud, so the role of integration tools is very important. In this paper, we will describe a scenario of smart sewerage that, by using integration tools, allows data to be loaded into the legacy system and thus ensures the automated creation of a business document as if it had been created manually.

Keywords: Data Integration, Smart Sewer, Hybrid Cloud, Legacy Systems, Smart City.

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The City as an Educational Tool: Cultural Infrastructure as the Wise Pillar of Smart Cities

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Abstract: Contemporary smart city models are based on information technologies, data analytics, and optimisation-driven approaches to urban governance. Smart technologies confined to efficiency, access and personalisation do not generate meaning, learning or collective wisdom. These capacities emerge through cultural interpretation, spatial experience, and the accumulation of cultural capital, as occurs within cultural and higher education institutions, heritage systems, and public spaces. The limitations of the prevailing smart city frameworks therefore lie in the persistent neglect of culture as a structural urban pillar, materialised through cultural infrastructure. Cultural infrastructure has nevertheless been a pioneer in technological experimentation, integrating new media, digital systems and interactive interfaces into architecture, exhibitions and public space and often anticipating their adoption within smart city agendas. Simultaneously, cultural institutions and their buildings have transformed, expanded, multiplied, and grouped into clusters, routes and networks, implicating public space and forming a complex urban system with unprecedented educational potential. Framing the city as an educational tool, this paper sets cultural infrastructure as an operational urban subsystem in the evolution of the smart city and society, in a structural completion that integrates technological, cultural, and spatial intelligence to support learning, urban culture, imagination and long-term urban resilience.

Keywords: Cultural Capital, Cultural Infrastructure, Intelligent City, Museums, Smart City, Urban Intelligence, Urban Learning, Wise City.

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Literature Review on Scalability in Microservice Architectures

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Abstract: Microservice architecture is a modern approach to the architecture and development of software systems that enable the development, deployment, and scaling of separate services. Although microservice architecture brings numerous advantages in terms of flexibility and maintainability, it also introduces new challenges related to scalability. The aim of this paper is to review, identify, and systematize existing approaches for evaluating the scalability of microservice architectures. The research was conducted as a literature review, with papers selected based on a clearly defined search strategy, keywords, clearly clearly defined key words, inclusion and exclusion criteria, and time frame. Papers published in relevant journals and conference proceedings were analyzed with a focus on applied methods, research objectives, types of scalability, validity, and ethical aspects of research. The results indicate that the most common scalability metrics are horizontality and independent scaling of microservices. The conclusion is that there is no single approach in evaluating the scalability of microservice architectures, because the choice of methods to use depends on the context, goals, and overall research.

Keywords: Microservice Architecture, Scalability, Literature Review.

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Integration of Modern Information Technologies Into the Teaching Process as a Factor of Economic Efficiency of the Education System

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Abstract: The integration of modern information technologies into the teaching process represents a significant factor in improving the economic efficiency of the education system. The application of digital platforms, learning management systems, and online instruction enables more rational use of educational resources, cost reduction, and increased productivity of the teaching process. The aim of this paper is to analyze the role of information technologies in education and their impact on the economic aspects of the functioning of educational institutions. The study is based on an analysis of relevant scientific literature in the fields of the economics of education and educational technologies. The results indicate that the systematic implementation of information technologies can contribute to sustainable development and the enhancement of the economic efficiency of the education system.

Keywords: Information Technologies, Teaching Process, Economic Efficiency, Education System, Modern Living Conditions.

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From Connected Devices to Cognitive Connectivity: Toward an Architecture for Hyper-Connected Intelligence Ecosystems

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Abstract: Contemporary digital transformation is entering a new phase in the evolution of connectivity—from the traditional Internet of Things (IoT) paradigm toward an integrated framework that incorporates the Internet of Body (IoB) and the Internet of Mind (IoM). This paper introduces the concept of Hyper-Connected Intelligence as both an architectural and functional model for the convergence of physical devices, biosensor systems, and cognitive interfaces into a unified ecosystem of adaptive intelligence. The proposed framework is based on a multilayer architecture comprising: (1) a smart device and sensor layer, (2) a biometric and physiological data acquisition layer, (3) a cognitive interface layer, (4) an edge/cloud AI analytics layer, and (5) a governance, security, and ethical regulation layer. The integration of these components enables the development of human-centered cyber-physical systems capable of contextual adaptation, real-time prediction, and process optimization. Special attention is given to the role of artificial intelligence in multimodal data processing, as well as to challenges related to privacy, cybersecurity, interoperability, and regulatory compliance. The paper further explores potential applications in healthcare, smart industrial systems, education, and personalized digital environments. The Hyper-Connected Intelligence concept represents a step toward a new generation of integrated intelligent ecosystems in which the boundaries between physical, biological, and cognitive domains gradually dissolve, establishing the foundation for adaptive, predictive, and self-regulating technological systems of the future.

Keywords: Hyper-Connected Intelligence, Internet of Things (IoT), Internet of Body (IoB), Internet of Mind (IoM), Cognitive Connectivity, Cyber-Physical Systems, Multimodal Artificial Intelligence, Edge–Cloud Computing, Human-Centered Intelligent Systems, Digital Ecosystems.

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PPG Signal Analysis - Neural Network Model Testing for Different Wavelets

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Abstract: The topic of this work is focused on the development of machine learning based on neural networks. This work aims to analyze the PPG signal and improve the concept of a neural network that performs prediction based on the PPG signal. The subject of analysis are signals, ie. biomedical signals obtained by the method of photoplethysmography - PPG signals. These signals provide important information about the internal state of organs, response to external stimuli, general condition, general health and the state of various other parameters and are an indispensable part of modern medical diagnostic practice. In this work, the concept of neural network is set up so that certain coefficients of wavelet transformed PPG signals are used as input data on the basis of which the predictions used in further analyzes of PPG signals will be made. Three different types of wavelets will be used for wavelet transformation of the PPG signal from the database. The focus of the work will be testing the neural network on wavelet transformed PPG signals. Wavelets that will be used in testing are db1, sym2, rbio3.3. These wavelets are built into libraries in the Python programming environment. Metrics suitable for regression networks and prediction of continuous values such as Mean Absolute Error and Mean Squared Error will be used for validation.

Keywords: Photoplethysmography (PPG), Machine Learning, Wavelet Transform, Data Processing, Neural Networks, Recurrent Neural Network, MAE (Mean Absolute Error), MSE (Mean Squared Error).

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Paradigms of Evolution and Challenges of Applying Industry 4.0

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Abstract: In this research paper, based on a successive review of relevant literature and scientific works, the concepts of modern industry 4.0 have been evolved. In this context, the evolution and purpose of industries from Industry 1.0 to Industry 6.0 will be presented. The available literature mainly deals with works that look at industries from only one point of view, most often positive and negative effects on business success. Special attention in this paper will be devoted to Industry 4.0, where the latest research and theoretical considerations indicate that the development of Industry 4.0 in the coming years is basically based on processes: automation, robotization, modularity, computerization and the use of smart devices to access processes from anywhere and at any time, connecting companies and business systems and finding the best solutions. The paper will explore all the advantages and weaknesses of the application of Industry 4.0, which according to research is no longer just a vision of the future - it is a reality in which business systems and organizations function almost independently, collect data, learn from their mistakes, predict failures and make correct business decisions faster and more precisely. As part of the discussion of the results, challenges that, according to research, can be encountered in practice during the process of introducing Industry 4.0 will be presented. For the purposes of the work, empirical research was conducted on a sample of companies and business systems from Serbia, and quantitative methodology was applied. Research in practice proves that it is possible to introduce the principles of Industry 4.0 into production and business systems with one's own resources and that in this sense it is extremely important to introduce inclusion, i.e. the widest possible application of these sophisticated technologies from the aspect of improving business processes and living and working conditions.

Keywords: Digitization, Industry 4.0, Internet of Things.

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STEM in Preschool Preparatory Groups - A Case Study

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Abstract: This study explores the application of STEM activities in a preschool preparatory group setting, focusing on promoting scientific inquiry, critical thinking, and hands-on learning for young children. STEM (Science, Technology, Engineering, and Mathematics) education is increasingly recognized for its role in developing skills essential for understanding and navigating the modern world. Through a series of structured STEM-based activities, children were engaged in experiential learning designed to foster curiosity, resilience, and problem-solving abilities. This case study provides insight into implementing STEM in early childhood education and highlights the potential for these approaches to build foundational skills and confidence in young learners.

Keywords: Application of STEM, Preschool Preparatory Group, STEM-based Activities Childhood Education, STEM Methodology.

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Resilience Assessment of Smart Sports Systems in Smart Cities

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Abstract: Digitization of sports facilities leads to a significant improvement of services, but also to an increase in the complexity of the system and its exposure to risks. Smart sports centers rely on IoT sensors, wireless networks, cloud and edge platforms, as well as AI algorithms to manage access, security and operational processes. At the same time, such systems become vulnerable to cyber-attacks, physical incidents and organizational omissions that can threaten continuity of business and visitor safety. The paper proposes a conceptual-quantitative framework for assessing the resilience of smart sports systems based on five criteria: cyber resilience, physical resilience, operational resilience, organizational resilience and adaptability/recovery. A composite resistance index was introduced, which is calculated as a weighted sum of normalized criteria values. The weighting coefficients and evaluations of the criteria were determined by an expert approach, and the evaluation was carried out through three scenarios: normal functioning, cyber incident and combined cyber-physical incident. The results show a significant drop in resistance index values in the disruption scenarios, with the combined incident having the lowest resistance index value. This framework enables a quantitative comparison of system resilience and the identification of critical points, which can help in planning protection measures and improving risk management.

Keywords: Critical Infrastructure, Cyber Security, IoT, Smart Cities, Smart Sports Systems.

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Hybrid Communication System in Smart Cities

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Abstract: Modern smart cities are built upon complex IoT (Internet of Things) ecosystems that integrate heterogeneous communication technologies to ensure reliable, scalable and secure data transmission. The hybrid communication system represents an architectural approach that combines multiple networking technologies, including 5G(5th generation network), LPWAN (Low-Power Wide-Area Network) and optical backbone networks, into a unified and adaptive system capable of responding to the dynamic demands of urban environments. This document analyzes traffic dynamic routing mechanisms as a distinct functional layer that enables adaptive data redirection according to current network load and available resources. Special emphasis is given to horizontal and vertical scaling of IoT systems as key architectural characteristics that allow infrastructure growth without performance degradation. Furthermore, the role of edge computing and cloud infrastructure is analyzed in maintaining operational continuity, efficiently distributing workloads and optimizing long-term system performance under varying traffic conditions. In addition, within the digital healthcare ecosystem of a smart city, pharmacies represent critical operational nodes that rely on the hybrid communication system for continuous, secure and real-time data exchange. Implementing a hybrid communication system in pharmacies enables electronic prescription processing, real-time therapy verification, automated inventory management, temperature monitoring of pharmaceutical storage and seamless integration with centralized healthcare databases.

Keywords: Digital Healthcare, Dynamic Management, IoT, 5G, LPWAN, Network scaling, Pharmacies.

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Registers in Modern Digital Systems and Smart Cities

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Abstract: Registers are fundamental memory components of digital systems, intended for fast and temporary storage and manipulation of binary data during program execution. Due to their high operating speed and direct connection to processor units, they play a key role in ensuring system efficiency, reliability, and deterministic behavior. Their application is particularly evident in microprocessor, embedded, and distributed systems that must process large volumes of real-time data. In the context of smart cities, registers represent an indispensable element of digital infrastructure, as they enable efficient processing of data collected by sensors, actuators, and management units. Such systems require high-speed processing, low latency, and reliable operation, which further emphasizes the importance of registers within the memory hierarchy. This paper discusses register architecture, functional characteristics, typical implementations, and modern trends, with a particular focus on their application in intelligent urban systems and on autonomous, adaptive, and energy-efficient solutions.

Keywords: Registers, Sequential Logic, Microprocessors, Embedded Systems, IoT, Smart Cities.

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Graph-Theoretic Models for Route Optimization in Smart Cities with Applications to Waste Disposal Systems

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Abstract: Smart cities rely heavily on sophisticated mathematical models to optimize complex urban systems that change over time. This paper presents a graph-theoretic framework for route optimization in intelligent urban systems, with particular focus on municipal waste disposal. We use weighted graphs where nodes represent locations, and the connections between them capture changing variables such as traffic intensity, energy consumption, and stochastic delays. We analyze the route optimization problem as a constrained combinatorial optimization task related to the Dynamic Vehicle Routing Problem (DVRP). To handle the computational complexity, we combined traditional shortest-path algorithms with approximation methods and smart search techniques in large networks. We study theoretical properties including complexity bounds, convergence behavior, and stability under time-varying edge weights. For waste disposal optimization, sensors monitoring waste bin fill levels help us assign priority scores to different collection points, transforming the problem into a time-constrained graph traversal task. This becomes a balancing act - we want to minimize travel costs while making sure we meet service requirements and do not overload the vehicles. Our findings show that these graph-based models can provide good enough solutions for real-time city logistics problems, supporting sustainable and computationally tractable infrastructure management.

Keywords: Smart Cities, Graph-Theoretic Framework, Dynamic Vehicle Routing Problem (DVRP), Route Optimization, Municipal Waste Collection.

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Implementation of Virtual Reality in Training Systems for High-Risk Occupations: Analysis of Cognitive and Operational Benefits

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Abstract: The application of Virtual Reality (VR) technologies in training employees for high-risk jobs represents one of the most significant innovative shifts in the field of occupational safety and professional development over the past decade. This paper provides a comprehensive analysis of the benefits of VR technology applications in the context of training for hazardous professions, based on a review of current scientific literature. The aim of this study is to systematize the key advantages of VR training in the domains of safety improvement, training efficiency, cost-effectiveness, and cognitive learning outcomes. Literature analysis indicates that VR enables the creation of immersive simulations of dangerous work environments while completely eliminating physical risk to trainees, thereby preparing workers for critical situations under controlled conditions. The interactive nature of VR training, coupled with the capacity for immediate feedback and unlimited repetition of exercises, leads to a deeper understanding of procedural knowledge and a more efficient transfer of skills into real-world work contexts. Economic analyses demonstrate that VR training, particularly with a larger volume of trainees, becomes more cost-effective than traditional methods. It achieves savings through the elimination of costs related to physical resources, travel, and instructor engagement, yielding a return on investment (ROI) of over 200% within a three-year period. Furthermore, the immersive experience and high level of engagement generated by VR positively influence trainee motivation, memory retention, and long-term consolidation of learned material. It is concluded that the integration of Virtual Reality into strategic workplace training frameworks is a necessary imperative for organizations striving for the highest standards of safety and efficiency in high-risk industries.

Keywords: Virtual Reality, Employee Training, High-Risk Jobs, Occupational Safety, Immersive Learning, Skill Transfer.

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Python-Based Traffic Signal Timing Optimization for Smart Intersections Using Discrete-Event Simulation

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Abstract: Urban intersections often act as mobility bottlenecks where small inefficiencies in signal timing can produce disproportionate delays, queue spillback, increased fuel consumption, and higher emissions. While adaptive signal control and connected-vehicle approaches are actively researched, many municipalities continue to rely on fixed-time timing plans due to budget, interoperability, and operational constraints. This paper proposes a reproducible Python workflow for fixed-time signal timing optimization at a single isolated intersection using discrete-event simulation. The workflow models stochastic vehicle arrivals and queue dynamics, evaluates candidate timing plans under uncertain demand, and selects signal phase parameters that minimize average delay while limiting queue growth. An experimental study on a controlled test scenario compares a baseline timing plan against an optimized plan obtained through simulation-based parameter search. Results show measurable improvements in operational performance, including reduced average delay and queue length and increased throughput. The paper's contributions include a reference simulation-and-optimization workflow suitable for municipal planning contexts, portable Python implementation excerpts that enable reproducibility, and an experimental evaluation demonstrating the effectiveness of simulation-based timing updates for practical smart mobility operations.

Keywords: Smart City, Urban Mobility, Traffic Signal Timing, Discrete-Event Simulation, Intersection Optimization, Stochastic Arrivals, Queueing Dynamics, Python, Simulation-Based Optimization, Fixed-Time Control.

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Face Biometrics as a Trust Enabler in the Smart Cities Concept

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Abstract: Smart cities increasingly rely on digital identity mechanisms to enable seamless access to urban services such as e-government portals, transportation systems, smart buildings, and public safety platforms. Among biometric modalities, face recognition stands out due to its contactless nature, scalability, and compatibility with existing camera infrastructure. However, large-scale deployment of face biometrics in smart city environments introduces critical challenges related to security, trust, and resilience against presentation attacks. Without robust safeguards, biometric systems become vulnerable to spoofing techniques such as printed images, replayed videos, or synthetic media. This paper explores face biometrics as a foundational trust enabler in smart city ecosystems, with a particular focus on liveness detection and biometric decision fusion. We analyze the role of passive and active liveness detection methods in mitigating presentation attacks under real-world urban conditions. Passive liveness infers authenticity from involuntary facial cues and texture analysis without user interaction, enabling frictionless citizen services. In contrast, active liveness relies on explicit user challenges, offering stronger security at the cost of increased interaction. Beyond individual techniques, the paper emphasizes the importance of fusion-based decision models. Smart city deployments operate in heterogeneous environments with varying risk profiles, sensor quality, and contextual constraints. We propose a conceptual fusion framework that combines face matching confidence scores, liveness indicators, and contextual signals into a unified decision threshold. Such fusion allows dynamic adaptation of security levels depending on service criticality. One example can be for differentiating access to public information kiosks from high-risk identity verification scenarios. The presented analysis aims to guide researchers, system architects, and policymakers in designing biometric solutions that balance security, usability, and trust, enabling scalable and responsible identity services in next-generation smart cities.

Keywords: Smart City, Face Biometrics, Liveness Detection, Passive Liveness, Score Fusion, Identity Verification, Trustworthy AI.

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Prime Factorisation for Fast Signal Processing

Dejan DJUKIC¹

Abstract: Ubiquitous spreading of smart methods in the widest range of domains today is being fueled mainly by the advances in generative pretrained artificial intelligence (AI). Nevertheless, whilst the AI can certainly give most detailed answers to most intricate questions, it is largely helpless for applications where numerical data need to be subjected to complex transformations. Yet, term smartness covers both resolution of linguistical, verbal issues, and operations with data involving significant mathematical reasoning. One of the classical methods used in data processing are fast signal processing algorithms, such as fast Fourier transform (FFT). In its most widely known form, FFT methods operate on data sets the sizes of which are powers of two (2 , 4 , 8 , ... , 256 , 512 , 1024 , ...). However, this may require either Procrustian forcing of data sizes, by filling data sets with synthetic, i.e. false, samples, or complete renouncing to fast forms of the data processing algorithms. One possible resolution of this difficulty is a reformulation of fast signal processing methods for data sets with non-binary sizes. The data size of an arbitrary data set is factorised into prime multipliers, and, for each prime factor, a fast version of a signal processing algorithm is formulated. This approach requires using methods for prime factorisation of numbers. Eratosthenes' sieve is an ancient, yet still widely used method for computing prime numbers. However, the same method may be easily adapted so that it may produce prime factorisations of non-prime numbers. In this work, two forms of Eratosthenes' method for prime factorisations have been presented. One of these forms is the classical Eratosthenes' sieve method. The other method, under a proposed name of Eratosthenes' mill, uses the same logic, but with the order of operations reversed. Although it has been shown that the classical version is faster, the alternative version of the factorisation method has significant advantages. It does not require a limit on the number table, as is the case with classical Eratosthenes' sieve. The alternative method is performed using uniform operations that are simple, and that can be applied in parallel. With a proper organization, most notably, with massive parallelisation of computations, the mill version may prove to be as fast, possibly faster, than the sieve version. With some additional computation, the alternative method may produce prime moduli of numbers, which may have a much wider application, e.g. in data coding or cryptography, and even in theoretical research of some domains of number theory.

Keywords: Fast Signal Processing, Data Processing Methods, Non-Binary Sized Data Sets, Spectral Signal Analysis, Prime Factorisation, Eratosthenes Sieve.

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Security In VoIP Networks

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Abstract: Voice over Internet Protocol (VoIP) is gaining more and more traction in everyday use, more options, better prices, flexibility and mobility are features that analog telecommunications systems cannot offer. Soon, VoIP technology will become mandatory for communication for all companies regardless of size, and with further development and integration of mobile with IP technology, we will get a perfect communication hybrid that will further determine the telecommunications market. New systems are being developed so that the entire database and the entire telecommunications system is integrated into the user's data center, and performs many other functions besides the call forwarding and switching. Calls are just one of the functions that IP technology enables, but in addition to calls themselves, this technology also enables video calls, conference calls and many multimedia functions. In order to prevent problems and unwanted attacks on the system, as well as to present possible threats that are present in every in order to minimize the number of attacks that can damage the system in various ways at any given moment, it is necessary to take certain actions to improve the security of VoIP networks.

Keywords: VoIP Protocol, IP Technology, Security in VoIP Networks.

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Database Performance Optimization for Smart City IoT Platforms

Miloš ILIĆ¹

Abstract: Smart city IoT (Internet of Things) platforms are foundations of software and data that connect urban sensing with the information systems supporting city services. These platforms depend on timely and reliable access to continuously produced sensor data, which makes the database layer a critical determinant of overall system responsiveness. Relational SQL databases remain a common choice because they combine strong integrity guarantees with predictable operational behavior and broad tool support. This paper explains how typical smart city IoT usage can lead to performance degradation in relational database backends. The impact becomes more pronounced as ingestion scales up, query workloads diversify, and historical data grows over time. The paper further examines how database-level decisions influence end-to-end latency, scalability, and operational cost, while highlighting practical directions to improve performance without sacrificing data quality and consistency. The contribution is a structured, SQL-focused set of recommendations that supports the design and long-term operation of smart city IoT platforms under realistic growth and workload variability.

Keywords: Database Optimization, SQL Databases, Smart City, Internet of Things (IoT), Performance Tuning.

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Healthcare Protection within the Concept of Contemporary Urban Development

Drasko DUBLJANIN¹, Andrijana BARAC², Aleksandar JEREMIC³, Danilo TIMOTIJEVIC⁴, Jaksa DUBLJANIN⁵

Abstract: With the rapid development of modern communication technologies, databases, servers, smart devices, and high-speed optical internet, contemporary cities are undergoing profound digital transformation. The next logical step in this evolution is the systematic implementation of advanced technological solutions within healthcare systems in order to enable faster, simpler, and more efficient access to medical information for both physicians and patients. The integration of smart healthcare platforms, electronic health records, AI-supported diagnostics, and interconnected medical infrastructures contributes to improved quality of care, optimized resource management, and enhanced public health monitoring within smart city environments. However, alongside these benefits, digital transformation introduces significant risks. Issues such as unauthorized access to medical data, cyberattacks, malicious software (malware), data breaches, and illegal data distribution represent serious threats to healthcare systems. Such vulnerabilities may compromise patient privacy, disrupt institutional operations, and entail criminal and legal liability. Therefore, the development of secure digital frameworks, robust cybersecurity protocols, and clear regulatory mechanisms is essential to ensure safe and sustainable implementation of smart healthcare solutions. The paper analyzes the role of digital healthcare within contemporary urban development, emphasizing both its transformative potential and the necessity of advanced data protection strategies in smart city ecosystems.

Keywords: Smart City, Smart Healthcare, Electronic Health Record (EHR), E-Health, Digital Health Card, Artificial Intelligence.

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Digital Literacy or Digital Maturity? Redefining Educational Standards in the Era of Smart Cities

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Abstract: In the era of smart cities, digital transformation is becoming a fundamental structural element of urban life. Infrastructures based on a large amount of data, artificial intelligence, and interconnected systems are transforming the management of resources, education, healthcare, and public services. However, dominant educational standards remain focused on the development of digital literacy – the ability to use tools, platforms, and software. This paper argues that the sustainable and humane development of smart cities requires a shift from the concept of digital literacy towards the concept of digital maturity, which entails the ethical, critical, and responsible use of technology. In the process of transitioning from digital literacy to digital maturity, education plays a key transformative role.

Keywords: Artificial Intelligence, Critical Thinking, Digital Ethics, Digital Literacy, Digital Maturity, Educational Standards, Interdisciplinarity, Responsible Use of Technology, Smart Cities, Sustainable Development.

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