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DETERMINING THE CAPABILITIES OF GENERATIVE ARTIFICIAL INTELLIGENCE TOOLS TO INCREASE THE EFFICIENCY OF REFACTORING PROCESS

pages 6–11

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The object of research is a source code refactoring facilitated and proctored by generative artificial intelligence tools. The paper is aimed at assessing their impact on refactoring quality while determining their practical applicability for improving software maintainability and efficiency.

The problem addressed in this research is the limitations of traditional rule-based refactoring tools, which require predefined rules and are often language-specific. Generative AI, with its advanced pattern recognition and adaptive learning capabilities, offers an alternative approach. However, its effectiveness in handling various refactoring tasks and its reliability remain undisclosed.

The research involved multiple experiments, where four AI tools – ChatGPT, Copilot, Gemini, and Claude – were tested on various refactoring tasks, including code smell detection, efficiency improvements, decoupling, and large-scale refactoring.

The results showed that Claude achieved the highest success rate (78.8%), followed by ChatGPT (76.6%), Copilot (72.8%), and Gemini (61.8%). While all tools demonstrated at least a basic understanding of refactoring principles, their effectiveness varied significantly depending on the complexity of the task. These results can be attributed to differences in model training, specialization, and underlying architectures. Models optimized for programming tasks performed better in structured code analysis, whereas more general-purpose models lacked depth in specific programming-related tasks.

The practical implications of this research highlight that while Generative AI tools can significantly aid in refactoring, human oversight remains essential. AI-assisted refactoring can enhance developer productivity, streamline software maintenance, and reduce technical debt, making it a valuable addition to modern software development workflows.

Keywords: AI-driven refactoring, code quality improvement, automated code smell detection, generative AI tools, software optimization.

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DEVELOPMENT OF AN APPROACH TO CHAT-BOT PERSONALIZATION WITH GENERATIVE ARTIFICIAL INTELLIGENCE WHEN REALIZE AN ONLINE ASSISTANT

pages 12–19

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The object of research is the interaction in the "human – machine" system during the user's interaction with generative artificial intelligence. The relevance of the research topic is due to the need to provide assistance to users in a narrow professional topic. To implement the goal set in the work, a model of operator decomposition was developed using the "Goals, Objects, Methods, and Selection rules" GOMS technology, taking into account the multi-level cognitive functions of a person. For this purpose, microoperators were used, which are responsible for combining various actions to find an answer to a question. A model with the decomposition of the operator μ was developed, which is responsible for cognitive functions when creating a request during human interaction with a chatbot based on artificial intelligence. The work used interaction with the ChatGPT chatbot.

The proposed decomposition algorithm was used as the basis for the online assistant plugin. The implementation is made in JavaScript, which allows it to be used on any sites and portals. The main components of the plugin are the interface for entering a query, a multi-level search mechanism on the site and in connected specialized libraries. The API integration of the plugin with ChatGPT was implemented.

As a result of the work, a study was conducted to experimentally determine the values of action and movement operators that are related to human mental activity and algorithmized in the online assistant. According to the results of the experiment, it was taken into account that for a chatbot, queries using foreign language signs and symbols and queries in the user's usual natural language are equivalent. To communicate with ChatGPT using the plugin, it is necessary to adhere to uniqueness and clarity when forming narrowly professional queries. The result was obtained that when querying in natural language on a topic familiar to the user, the online assistant adapts to the requirements more slowly. But at the same time, the speed of finding an answer and its formulation is accelerated. The problem of personalizing the online assistant was solved. This became possible thanks to the analysis of user behavior through the detailing of the query by micro-operators in the GOMS model. This allows to personalize the online assistant without user registration, only based on its behavior when forming a request.

The proposed approach can be used to create online assistants for the implementation of highly specialized complex projects on web platforms.

Keywords: plugin, GOMS model, operator decomposition, cognitive functions, natural user language.

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INTELLIGENT ENERGY CONSUMPTION FORECASTING AND MICROGRID STATE ASSESSMENT USING MACHINE LEARNING AND FUZZY LOGIC

pages 20–26

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The object of research is the processes of generation, consumption and storage of electricity in microgrids with renewable energy sources. They are characterized by the certain parameters and together determine the state of the energy microgrid. The task of assessing the state of the microgrid, which is relevant for maintaining its stable operation, can be solved using machine learning methods.

Time series of data, which are created as a result of monitoring energy microgrids and contain indicators of their operation, were used as input dataset. Since microgrids operate in variable conditions, the ability of energy microgrids to meet the demand for electricity is characterized by uncertainty, and to assess the state of microgrids, there is a need for adaptive methods that can process inaccurate and incomplete data. Traditional methods of statistical analysis and deterministic algorithms do not provide sufficient accuracy in forecasting, which creates risks of incorrect management of energy resources. To solve this problem, this study uses a combination of machine learning and fuzzy logic, which allows not only to forecast the load, but also to adaptively assess the state of energy assets in real time.

The essence of the obtained results is to create models for the information technology of assessing the state of microgrids, which integrates BiLSTM for forecasting electricity consumption and a fuzzy logic system for determining the state of the microgrid. The use of a neural network approach allows to take into account time dependencies in electricity consumption, while fuzzy logic classifies the state of the microgrid based on the battery charge level, current solar energy generation and forecasted load. The features of the obtained results are the integration of several approaches, which provides expansion of analytical capabilities and the formation of a comprehensive assessment of the energy balance in conditions of uncertainty and variability of input data.

The obtained results confirm the effectiveness of the proposed approach and its practical applicability in the tasks of monitoring and controlling microgrids. Experimental tests on real data showed that the BiLSTM model provides a mean absolute error (MAE) of load forecasting at the level of 18.15 W, a root mean square error (RMSE) of 20.74 W, and a mean absolute percentage error (MAPE) of 5.0%. The fuzzy logic-based assessment system classified the state of the microgrid with an accuracy of 93.2%, which indicates its ability to interpret situations with potential energy deficit. The developed models allow for timely detection of unstable operating modes, formation of solutions for load balancing, reduction of the load on batteries, and prevention of energy losses.

Keywords: time series, microgrids, load forecasting, state estimation, machine learning, BiLSTM, fuzzy logic.

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DEVELOPMENT OF A METHOD FOR DETERMINING THE DEPENDENCE OF BUSINESS COMPETITIVENESS ON MOBILE COMMUNICATION TECHNOLOGY

pages 27–32

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The object of this research is the factors that significantly influence the competitiveness of enterprises operating in the modern high-tech society. The paper examines the business environment that actively uses modern mobile communication technologies.

The relevance of this research stems from societal concerns associated with modern mobile communication technologies (3G, 4G, 5G) and the rapid development of 6G, which may pose potential risks. These risks can impact businesses that rely on such technologies in their operations.

This paper proposes an approach to determining the dependence of business competitiveness on mobile communication technologies based on game theory. Performance matrices were constructed, and risk analysis was carried out according to the criteria of Wald, Savage, and Hurwitz. Potential operational strategies were analyzed in the context of environmental states, considering responses to market fluctuations and unpredictable factors. The influence of specific factors on enterprise competitiveness was assessed under conditions of complete uncertainty.

To compare the impact of mobile communication technologies, a simulation model in C# was developed. The study considered 240 enterprises in the market of the Republic of Kazakhstan. Two scenarios were compared: the use of 4G versus 5G technology. The results were visualized as a model ranking enterprise based on the impact of mobile communication technology. A distinctive feature of the study is the identification of environmental states, which served as a basis for grouping risk factors by their influence on competitive position. The minimax and maximin principles were applied to describe enterprise behavior in a competitive environment. The simulation model was split up. The simulation model revealed skewed gains and shortcomings in the competitiveness of enterprises that were monitored.

The proposed approach can be applied to business growth projects, marketing strategy enhancement, and automation of tasks aimed at improving competitiveness in enterprises across all forms of ownership. It is also applicable to banking and credit institutions in the justification and optimization of lending policies.

Keywords: risk matrix, efficiency matrix, Hurwitz criterion, Sevige criterion, Wald criterion.

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DEVELOPMENT OF A SECURE STORAGE ARCHITECTURE FOR DIGITAL EVIDENCE

pages 33–43

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The object of the study is the process of generating, transmitting, and storing memory dumps within digital forensics. The problem being addressed is the insufficient level of security of existing methods of transmitting and storing digital evidence, which can lead to their compromise, loss of authenticity, and inadmissibility in court proceedings.

As a result of the conducted research, an architecture for secure storage of digital evidence was developed, providing protection at the stages of acquisition, transportation, storage, and further analysis of memory dumps. A cross-platform Python script for automated memory dump acquisition was proposed, as well as a mechanism for secure transportation of evidence using cryptographic protection through the SCP protocol and authentication. The effectiveness of the combined use of SSH encryption, creation of file system containers in "read-only" mode, mandatory logging of all actions with digital evidence, and an integrated hash-checking mechanism for data integrity verification was demonstrated.

The effectiveness of the proposed approach was assessed based on process modeling in a test environment. In particular, the collected memory dumps were transferred using a custom Python script using a "safe corridor" from the Kali Linux virtual machine to the Caine virtual machine to the created container in "read-only" mode. The integrity of the files after transportation and storage was checked using a hash sum comparison.

A distinctive feature of the proposed model is a comprehensive approach to digital evidence protection, combining technical and organizational measures to ensure the authenticity and integrity of data. This allows solving the problem of compromising digital evidence and guarantees its judicial admissibility. The results obtained are explained by the implementation of cryptographic methods and compliance with digital forensics standards.

The proposed methodology can be used in the practice of law enforcement agencies, forensic experts, as well as in the development of national standards for the preservation of digital evidence. The storage model complies with international security standards and can be adapted to the specific requirements of judicial proceedings in Ukraine.

Keywords: digital forensics, memory dumps, cryptographic protection, cross-platform Python script, file system containers, "read-only" mode.

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AI-DRIVEN TOOLS IN MODERN SOFTWARE QUALITY ASSURANCE: AN ASSESSMENT OF BENEFITS, CHALLENGES, AND FUTURE DIRECTIONS

pages 44–54

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Traditional quality assurance (QA) methods face significant challenges in addressing the complexity, scale, and rapid iteration cycles of modern software systems and are strained by limited resources available, leading to substantial costs associated with poor quality.

The object of this research is the quality assurance processes for modern distributed software applications. The subject of the research is the assessment of the benefits, challenges, and prospects of integrating modern AI-oriented tools into quality assurance processes. Comprehensive analysis of implications was performed on both verification and validation processes covering exploratory test analyses, equivalence partitioning and boundary analyses, metamorphic testing, finding inconsistencies in acceptance criteria (AC), static analyses, test case generation, unit test generation, test suit optimization and assessment, end to end scenario execution. End to end regression of sample enterprise application utilizing AI-agents over generated test scenarios was implemented as a proof of concept highlighting practical use of the study. The results, with only 8.3% flaky executions of generated test cases, indicate significant potential for the proposed approaches. However, the study also identified substantial challenges for practical adoption concerning generation of semantically identical coverage, "black box" nature and lack of explainability from state-of-the-art Large Language Models (LLMs), the tendency to correct mutated test cases to match expected results, underscoring the necessity for thorough verification of both generated artifacts and test execution results.

The research demonstrates AI's transformative potential for QA but highlights the importance of a strategic approach to implementing these technologies, considering the identified limitations and the need for developing appropriate verification methodologies.

Keywords: quality assurance, testing, end-to-end test automation, test case, SDLC, AI, AI agents, LLM.

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DEVELOPMENT OF A PREPROCESSING METHODOLOGY FOR IMBALANCED DATASETS IN MACHINE LEARNING TRAINING

pages 55–61

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The object of the study is an imbalanced dataset of credit card transactions, where fraudulent cases represent only 0.18% of the total. One of the most problematic places is the inability of standard machine learning models to correctly detect rare fraud events, often resulting in high false-negative rates. This occurs because the models focus on the majority class, which leads to biased outcomes and undetected fraud. The presented analyses used a structured preprocessing pipeline to address this issue. It includes scaling of numeric values to eliminate bias, stratified sampling to preserve class proportions, random undersampling to balance the dataset, and outlier removal to reduce noise. These steps were applied before training three classification models: logistic regression (LR), K-Nearest Neighbors (KNN), and support vector classifier (SVC). The obtained results show that all models performed well in both cross-validation accuracy and ROC-AUC metrics, with SVC achieving the best ROC-AUC score of 0.9787. This is because the proposed preprocessing pipeline has many features customized to the characteristics of imbalanced data, in particular the combination of data balancing with careful filtering of noise and redundancy. This provides the possibility of achieving robust performance when detecting minority class events. Compared with similar known preprocessing workflows, it provides the following advantages: better class separation, reduced model bias, and improved generalization on unseen data. The results are especially relevant for financial institutions, where fraud detection must be both timely and accurate. The approach offers a practical method for improving security systems without requiring complex or high-cost infrastructure. It can also be adapted for use in other domains where rare events must be detected from large datasets. In future research, the pipeline can be extended by integrating synthetic sampling techniques such as SMOTE or GANs. Additional experiments with real-time streaming data will further validate the robustness of the proposed methodology.

Keywords: imbalanced classification, fraud detection pipeline, stratified sampling, outlier removal, support vector classifier.

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SYSTEMS AND CONTROL PROCESSES

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BENCHMARKING OF TRANSFORMER-BASED ARCHITECTURES FOR FALL DETECTION: A COMPARATIVE STUDY

pages 62–70

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The object of this research is transformer-oriented deep learning architectures designed for fall detection based on sensor data. One of the main issues identified during the audit of traditional solutions is the excessive computational complexity of standard transformers, which hinders their effective use on resource-constrained devices and in real-time applications. The study involved the use of Temporal Convolutional Transformer, Performer, Multiscale Transformer, LSTM Transformer, Informer, Linformer, and the classical Transformer. Each of these models incorporates advanced mechanisms for attention implementation and processing of both short- and long-term dependencies in input sequences. The Temporal Convolutional Transformer achieved the best results, demonstrating a test accuracy of 99.79% and a peak accuracy of 100% after 50 epochs. This success is attributed to the proposed approach's effective combination of convolutional operations with self-attention, which significantly accelerates the extraction of key features and enables robust handling of short- and long-term temporal dependencies. Convolutional layers help filter out noise from sensor data and reduce computational costs compared to classical transformers. This allows for the deployment of such solutions in real-world edge scenarios without sacrificing fall detection accuracy. Compared to traditional methods, the proposed models offer higher performance and improved resource efficiency – critical factors for implementing real-time fall detection systems. Additionally, the performance of the aforementioned models was evaluated under various operating conditions, including scenarios with low bandwidth and limited energy efficiency. The results confirm that optimized transformer architectures successfully solve the fall detection task while remaining efficient for portable and embedded systems with constrained memory.

Keywords: transformer-based fall detection, temporal convolutional transformer, sensor fusion with barometer data, edge deployment for healthcare AI.

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CONCEPTUAL FOUNDATIONS OF THE SWARM EMPLOYMENT OF UNMANNED AERIAL VEHICLES AS INTELLIGENT MEANS OF ELECTRONIC WARFARE

pages 71–80

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The object of research is the process of functioning of a swarm of unmanned aerial vehicles (UAVs), equipped with artificial intelligence technologies, as intelligent means of electronic warfare (EW). The main attention is focused on their interaction and efficiency of functioning, their adaptive capabilities in a dynamically changing and complex electromagnetic environment.

One of the key problems is ensuring reliable, stable and flexible coordination of swarm actions in conditions of electromagnetic influence of enemy radioelectronic means (REM). Coordination of swarm actions and measures should include continuous monitoring of the spectrum, timely adaptation to enemy countermeasures.

To solve this problem, it is proposed to create an adaptive swarm architecture that implements the principles of decentralized control using machine learning algorithms, a multi-agent approach and software-configuration architecture of radio systems (SDR). The developed approach is based on the application of cognitive strategies for interaction between UAVs and the formation of a dynamic network structure that is self-repairing in the event of damage or interference.

The proposed conceptual approach allows for significantly increasing the effectiveness of influencing the enemy's REM environment through dynamic spatial-temporal distribution of interference, taking into account the tactical situation and spectral characteristics of threats.

It is envisaged to integrate strike and reconnaissance UAVs into a single swarm structure with autonomous coordination of actions, which expands the functionality of the swarm from the placement of multi-frequency interference to the detection, tracking and neutralization of critically important objects.

This approach provides a high level of autonomy, adaptability and survivability of unmanned platforms in difficult conditions of electronic warfare, and also creates the prerequisites for significantly increasing the effectiveness of combat operations in a modern high-tech environment by integrating reconnaissance and strike functions and EW means into a single information system.

Keywords: swarm, obstacles, technologies, system, efficiency, integration, algorithm, methods, countermeasure, control.

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DEVELOPMENT OF A MODEL OF COMPREHENSIVE ASSESSMENT OF ENTERPRISE BANKRUPTCY RISK LEVEL

pages 81–87

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The object of this study is the process of assessing the risk level of enterprise bankruptcy based on a comprehensive analysis of both quantitative and qualitative characteristics of its business processes. The problem addressed in this work concerns the improvement of bankruptcy risk prediction models. Existing approaches suffer from several significant drawbacks. In particular, the BR model lacks sufficient flexibility. It requires strict preliminary ranking of influencing factors and relies on formalized weighting systems. This limits the individualization of the analysis and reduces the accuracy of the assessment.

The essence of the obtained results lies in the development of a model of comprehensive assessment of enterprise bankruptcy risk level (MCAEBRL). This model implements a comprehensive analysis of the enterprise's business processes using both quantitative and qualitative characteristics. Ranking of factors is not mandatory. Instead, the model uses actual normalized weights determined by experts. It supports flexible rating scales for various indicator types, enables fuzzification of data to handle linguistic evaluations of indicators, and allows a group of experts to be involved to enhance the objectivity of the results.

The importance of the obtained results is explained by the features of the MCAEBRL construction. A process-based and integrated approach was used to analyze the enterprise's activities. A multi-level hierarchy of business processes was employed, as well as quantitative and qualitative indicators for their characterization. Assessments were conducted using broad rating scales. The model uses fuzzy set theory to handle both precise and imprecise data.

The proposed model can be practically applied to assess the financial stability of enterprises across various industries. It is especially useful in unstable economic environments. The model is suitable for working with data of different nature and accuracy levels. It can also be used in cases where expert knowledge needs to be taken into account, thus improving the objectivity of bankruptcy risk assessment.

Keywords: business processes, enterprise, bankruptcy risk, model, assessment, expert, fuzzy sets.

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DEVELOPMENT OF AN IMAGE SEGMENTATION METHOD FROM UNMANNED AERIAL VEHICLES BASED ON THE PARTICLE SWARM OPTIMIZATION ALGORITHM

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The object of research is the process of segmenting images from an unmanned aerial vehicle based on the particle swarm algorithm.

One of the most problematic areas in segmenting images from unmanned aerial vehicles is the reduction in the efficiency of known segmentation methods. In addition, most methods do not accurately recognize small objects that occupy a small part of the image.

The method of segmenting images from an unmanned aerial vehicle based on the particle swarm algorithm has been improved, in which, unlike the known ones, the following is performed:

– the source image is converted to the appropriate color space;

– the channel is selected for further analysis;

– the particle swarm is initialized on the source image in each channel selected for further analysis;

– the objective function is calculated for each particle of the swarm in the image in each selected channel;

– the current value of the objective function for each particle of the swarm is compared with the best value of the objective function in the image in each selected channel;

– calculating the velocity value and new location for each swarm particle in the image;

– moving each swarm particle in the image in each selected channel;

– determining the swarm particles with the best value of the objective function in the image in each channel;

– combining the channels and forming the resulting image.

During the study, it was found that the segmented image by the improved method based on the particle swarm algorithm has better visual quality compared to the known segmentation method. It was found that the improved segmentation method based on the particle swarm algorithm provides an average reduction in segmentation errors of the I kind by 11% and an average reduction in segmentation errors of the II kind by 9%.

Keywords: segmentation, unmanned aerial vehicle, swarm intelligence, particle swarm algorithm, k-means.

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