



Book of Abstracts

Workshop on RECI 2024

November 6-8, 2024
Žilina, Slovakia



Preview

Previous *International Workshops on Reliability Engineering and Computational Intelligence* (RECI 2020 and RECI 2022) demonstrated a strong synergy between Reliability Engineering and Computational Intelligence but scientific differences remain. The third RECI workshop attempts to address further integration by (a) presenting papers on RECI topics, (b) panel discussions about future RECI research, and (c) a curriculum discussion for an international RECI curriculum. Since reliability engineering and computational intelligence include a wide range of scientific and engineering areas, the workshop will be divided into four parts:

- Main Conference
- Stream on Applications of RECI in Healthcare
- Stream on Environmental Risk Assessment
- Stream for PhD Students and Young Researchers (ACeSYRI)

Main Conference. The main conference focuses on all areas of synergy between two scientific domains that are reliability engineering and computational intelligence. Reliability engineering is an established domain that has a very good practical and scientific background for the analysis of the reliability of systems. Computational intelligence is relatively new in reliability engineering. But it has been an equally well-established branch of research with many groups over the world attempting to develop useful computational intelligence tools in different fields. Today, the continuous drive for digitalization causes reliability engineering and computational intelligence to merge. Combining the fields paves the way to progress in big data analytics, uncertain information evaluation, reasoning, prediction, modeling, optimization, decision-making, and of course, more reliable systems. Topics of interest include but are not limited to: Accident and Incident Analysis, Computational Intelligence for Risk Estimation, Data Mining and Knowledge Discovery, Digital Technologies for Reliability Engineering, Hardware and Software Solutions, Human Reliability Analysis, Mathematical and Computational Methods for Risk Analysis, Methods Based on Artificial Intelligence, Risk and Hazard Analysis, Software Solutions for Testing Fault-Tolerant Systems, Software Reliability, Trends in Reliability Engineering and Computational Intelligence, etc.

The main conference of the workshop is organized in accordance with the activities of projects “*Development of a New Approach for Reliability Analysis and Risk Assessment Based on Artificial Intelligence*” (reg. no. APVV-23-0033 supported by the Slovak Research and Development Agency) and “*New approaches of reliability analysis of non-coherent systems*” (reg. no. VEGA 1/0165/21 supported by the Ministry of Education, Science, Research, and Sport of the Slovak Republic).

The workshop RECI 2024 continues the ideas and achievements of the Reliability and Safety workshop, which was supported by the project “*Exchange Reliability and Safety Experience in the V4 region*” (Visegrad fund, reg.no. 22230200) and by the project “*New Methods Development for Reliability Analysis of Complex Systems*” (project reg.no. APVV-18-0027 supported by the Slovak Research and Development Agency).

Stream on Reliability Engineering and Computational Intelligence in Healthcare. The aim of the stream is discussion on relevant topics and trends in reliability engineering, data mining, and machine learning in healthcare, medicine, and biotechnologies. The possible areas include but are not limited to Biomedical Engineering, Biomedical Informatics, Computer-Aided Diagnosis, Education in eHealth and Telemedicine, Electronic Health Records and Medical Databases, Innovative eHealth, Precision Medicine, Applications and Products, Legal, Social, Ethical and Financial Aspects, Medical Image Analysis and Biomedical Visualization, Telemedicine, Telehealth and Remote Monitoring, etc.



The stream is organized in accordance with activities of the project “*University-Industry Educational Centre in Advanced Biomedical and Medical Informatics*” (reg.no. 612462-EPP-1-2019-1-SK-EPPKA2-KA supported by the European Union’s Erasmus+ programme). The workshop is also a post-project activity of “*Development of Methods of Healthcare System Risk and Reliability Evaluation under Coronavirus Outbreak*” (reg.no. APVV PP-COVID-20-0013), which was supported by the Slovak Research and Development Agency in years 2020 and 2021.

Stream on Environmental Risk Assessment. The stream focuses on applications of reliability analysis, machine learning and remote sensing in environmental risk assessment. Topics of the stream include Environmental Threats and Environmental Hazards, Geoprocessing and Geographic Information Systems, Land Degradation, Mathematical and Computational Methods for Risk Assessment, Mathematical Models of Environment, Remote Sensing, Use of Unmanned Aerial Vehicles in Environmental Risk Assessment, ArcGIS Application in Environmental Risk Assessment, Cartography and maps development, Risk Assessment in Environment, etc.



The stream is organized in accordance with the activities of the project “*Earth Observation for Early Warning of Land Degradation at the European Frontier (EWALD)*” (Horizon Europe, ID 101086250).

Stream for PhD Students and Young Researchers. The stream covers all topics of the RECI Workshop and provides an opportunity for students, PhD students, and young researchers to present their results based on the submitted abstracts.



The stream is organized in accordance with the post-project activities of “*The Advanced Centre for PhD Students and Young Researchers in Informatics*” (ACeSYRI) (Project EACEA.CBHE reg.no.: 610166-EPP-1-2019-1-SK-EPPKA2-CBHE-JP supported by the European Union’s Erasmus+ programme)

The organization of all workshops is supported by *IEEE Chapter of Reliability Society of the Czechoslovakia Section, the European Safety and Reliability Association (ESRA), the Slovak Research and Development Agency, and the Institute of Information Technologies*



Website of RECI 2024:

<https://reci.fri.uniza.sk>

Table of Contents

Preview	2
From High Reliability to Resiliency Engineering – The Future of Patient Safety.....	9
Reliability Importance Measures: from Local to Global.....	10
Electromobility Transformation: Challenges for Reliability Engineering	10
Defending Complex Systems Against Intentional Attacks and Natural Impacts	11
Some Dynamical Systems for Reliability Modelling and Estimation	11
Advanced Learning from Information in the Chemical Industry	12
Availability Models of a Recoverable Wireless Sensor Network for Forest Fire Monitoring System	13
An Asymmetrical Graph Siamese Network for One-Class Anomaly Detection of Engine Equipment with Multi-Source Fusion	14
2050 Futures in AI: Two Horizons	15
Application of a Bowtie Digital Twin: How a Mechanical Seal Looks Different from a Data Perspective.....	17
Two-Layer Model of Fake Information Classification Using Artificial Intelligence in Socially Oriented Systems.....	18
Bayesian Networks as Surrogate Models: An Application to Energy Systems Analysis.....	19
Experimental Overview of Techniques Used for the Management of Intermediate Results in Calculations with Decision Diagrams.....	20
Data Potential and Feasibility Study with Grid mean Algorithm	20
Evaluating Ground Impact Severity in Suborbital Vehicle Explosion Scenarios.....	22
Code Performance Evaluation with Modern AI Models and Fine Tuning.....	23
Estimating Electric Motor Temperatures with Machine Learning Models	25
Advanced Tools for Visualization and Animation in the Simulation and Computational Intelligence	27
Using Intelligent Approaches in Algorithms of Interpolation and Extrapolation of Short-Focus Electron Beams Boundary Trajectories by Root-Polynomial Functions.....	28
A Reinforcement Learning Algorithm based on Markovian Model for Server Reliability Assessment in IIOT System.....	29
Use of ROS2 in Conjunction with YOLOv8 Image Recognition System for Mobile Robot Control System.....	30
Lightweight Convolutional Transformer for Fault Diagnosis on Vibration Signal in Time-Frequency Domain	31
Overview of AI Applications in Electromechanical Systems.....	32

Damage Detection in Road Images By YOLOv9 and Transfer Learning	33
Comparison of Python and Octave as Tools for Developing Intelligent Systems.....	34
The Study of Hardware Resources Usage on Examples of Convolutional Neural Network Implementation.....	35
Digitalization of Urban Systems: Kazakhstan's Experience in Creating Smart Cities	35
Empirical Hardness of the AES Cipher.....	36
Testing Stability of Virtual Machines with Various Strategies of Resource Provisioning	37
Modelling Reliability of Multi-Purpose Synthesis System in Presence of Common-Cause Failures	38
Improving the Reliability of Automatically Generated Test Suites	39
Implementing 3MU Identification in Chaotic Environments	40
Parallel Numerical Simulators for Surrogate Modeling of Random Fields.....	41
Reliability and Maintainability of Technical Systems: Modularisation Versus Overall System. Case Study Electric Vehicles.....	42
Machine Learning Analysis of Potential Mobile APPS Threats on the Basis of Permissions	43
Research of Automated Control System of Gravity Enrichment Method of Chrome ORE	44
Sensitivity of Goal Function in R-Facility Interdiction Covering Problem and Systemic Risk.....	45
synTEXT4JSON: Framework for Generating Synthetic Data for Template-Filling Task	46
University Selection System, Problems and Solutions	49
Synthetic Data Generation for Enhancing Specialized Object Detection Models	50
Reducing the Impact of the Reproducibility Crisis on the Ranking of Binary Classifiers through the Examination of Performance Scores' Consistency.....	53
Comparison of Open APIs for the Data Collection on environment Indicator: A Case Study on Air Quality in Almaty, Kazakhstan.....	55
Modeling and Control of a Mobile Robot with Differential Drive Based on a Digital Twin Complete	56
Identification of Thematic Groups of Publication Corpora using Top2Vec.....	59
UAV Flight Planning for Solving Monitoring Problems	60
Using UAVs and Deep Neural Networks to Count the Number of Cars on City Roads	60
Testing Software for Error-Correcting Data Coding at the Processor Level.....	61
LLMAgentNet: A Collaborative Network of Autonomous AI Agents for Complex Task Execution ..	62
Fine-Tuning LLM for Code Style Analysis: An Approach Augmented with DFA	64
Flight Safety Calculations in a Computer Aided Flight Planning System.....	65
On the Use of Offline Reinforcement Learning Methods in Condition-based Maintenance.....	66
Exploring Social Dynamics and Stability Using Cellular Automata	67
Modeling and Optimization of Software Reliability using Fuzzy-Algorithmic Approach	68
Robust Bayesian Method for Step-Stress Accelerated Life Testing Data	69

A Development of Fuzzy Inference System for Modeling the Degradation of Light Emitting Diode	69
Synchronization of the Time Zones in the Temporal Database Environment Making Transparent Reliable Solution	70
Verification of Markov Model-Based Availability Assessment of Intelligent Diagnostic Systems Using Two Methodologies and Tools	70
Concept and Analysis of Segmentation Algorithms in Modern Intelligent Computer Vision Systems	71
Quantifying System Reliability based on Accelerated Life Test Data for Components.....	72
Solid Waste Detection During Monitoring of Urban Agglomerations using UAVs	72
Stages of Planning and Modeling the Bread Baking Process in the Context of Creating a Digital Twin	73
Stream on <i>Reliability Engineering and Computational Intelligence in Healthcare</i>.....	75
New Biotechnological Directions in Diagnostics and Treatment of Ischemic Cardiomyopathy	76
CRISPR: A New, Versatile Biotechnology.....	77
From Genome to Treatment: The Encode Project's Impact on Precision Medicine and Technological Innovations.....	78
Genetic Aspects of Hereditary Thrombophilia in Pregnancy.....	79
Technologies for Breast Cancer Diagnosis	80
Biotechnological Progress in Determining Genotypic Diversity and Mutation Profiles of Multidrug-Resistant Mycobacterium Tuberculosis.....	81
AI, Algorithmic Management and Teachers' Occupational Safety and Health	82
Application of Artificial Intelligence to Enhance the Reliability of Lightweight Cryptographic Systems in Precision Medicine	85
Biotechnological Transplantation of Hematopoietic Stem Cells with Mutation of the CCR5 Gene as a Way of Treating HIV Infection.....	86
Recent Progress for Determination of Association of Some Periodontal Microorganisms with PD-L1 and PD-1 Protein Expression.....	87
Medical Image Segmentation with Graph Reasoning	88
Investigating the Relationship between Lighting, Human Circadian Rhythms and Physiological Parameters	89
Integration of eHealth Competences into Health Students' Curriculum	90
Wearable Devices in Cardiovascular Medicine.....	91
Advances in Gene Therapy for Duchenne Muscular Dystrophy: Promising Strategies and Future Directions.....	92
New Bioengineering Technologies in the Diagnosis and Treatment of Multiple Sclerosis.....	93
Recent Biotechnologies to Assess Genetic Factors in Atherosclerosis.....	94

New Biotechnological Directions in Treatment of Cystic Fibrosis	95
Biotechnologies Improving the Diagnostic Establishment of Molecular Mechanisms Involved into Synaptic Dysfunction of Dopaminergic Neurons in Parkinson’s Disease.....	96
Simulation-based Approaches to Managing Infectious Disease Risks in Conflict Zones: Opportunities and Limitations	97
Biotechnological Development of Targeted Treatments based on a Tumor’s Specific Genetic Mutations in PARP Inhibitors	98
Optimization of Parameters for Modeling the Joint Spread of Tuberculosis and HIV Using an Integrated Approach	99
The Classification of ECG signals.....	101
Automatic Analysis of DNA Comets Using CNN.....	102
The preprocessing of ECG signals.....	104
Analysis of a Fragment of the Image to Identify the Effect Of Stress Caused by Heavy Metals on the Pigmentation of Leaves of Cereal Plants.....	104
Stream on <i>Environmental Risk Assessment</i>.....	106
A Method to Aggregate Interval-Valued Expert Estimates Taking into Account Their Reliability	107
Methodological Foundations of Multispectral Aerospace Images Informativeness Increasing.....	111
Geophysical Methods of Soil Fertility Mapping for Precision Agriculture Applications in Morocco	112
Forward Seismic Modeling and High-Resolution Seismic Imaging of the Phosphatic Series in the Gantour Basin (Morocco)	113
Eo-Based Early Warning System for Enhancing Responses to Land Degradation: Challenges and Solutions.....	114
Functional Block Configuration of EWS for Land Degradation Mapping/Prediction	116
Monitoring Changes in Agricultural Landscapes within the Areas of Municipal Solid Waste Dumps using Remote Sensing and GIS Technologies.....	118
Assessment of Land Degradation and Urbanization in ARID Environments through SDG 11.3.1 and 15.3.1 Indicators	119
Siltation of Recent Large Dams in the Marrakesh-Safi Region, Morocco: Analysis of Factors Influencing Sediment Yield using the RUSLE Model and GIS.	120
Adaptability of Sludge from Industrial Aggregate Processing as a Ceramic Raw Material: A Case Study of the Marrakech Region, Morocco	121
Lithological Mapping Using Multispectral Data and Machine Learning Algorithms: A Case Study from Tighardine Area (Western High Atlas, Morocco)	122
The Use of RUSLE Model and CHIRPS Satellite Precipitation Product for Estimating Soil Loss by Water in a Scarsly Gauged Semi-Arid Area: Case of Central Morocco	123
Sub-Daily Flood Dynamics in Semi-Arid and Arid Basins: A Case Study of Southern Morocco	124

Sediment Pollution by Heavy Metals from Mining Activities: Ecological Risks, Contributors, and Future Research Directions	125
Co-seismic Ground Deformation and Associated Hazards from the 2023 Mw 6.8 Al Haouz Earthquake, Morocco: Analysis of Seismological Data, DInSAR and Geomorphological Surveys	126
Spatiotemporal Characterization and Hydrological Impact of Drought Patterns in Northwestern Morocco	127
Advanced 3D Geo-Environmental Characterization and Modeling for Early Detection and Prevention of Acid Mine Drainage in Coal Mine Waste Rock	128
An Approach to Radar and Optical Imagery Super-Resolution.....	129
Earth Observation Data Warehouse for Land Degradation Mapping/Prediction	131
Environmental Sustainability and Supply Chain Management: Streamline KPI Monitoring Data Ecosystem.....	132
GIS Software, Different Software Solutions and Their Usage	132
Implementation of Land degradation prediction algorithm in ArcGIS environment.....	133

Invited lectures

From High Reliability to Resiliency Engineering – The Future of Patient Safety

Prof. Paul Barach

Thomas Jefferson University, USA
Imperial College London, School of Medicine, UK
Sigmund Frued University, Vienna, Austria

Health care institutions continue to face challenges in providing safe patient care in increasingly complex and demanding technical, organizational, and regulatory environments. The keynote will explore the applicability of engineering core concepts of high reliability and microsystems theories to the medical environment. Organizing health care around the pursuit of safety as an overarching priority and a professional obligation for all members of the health care teams. This goal can be accomplished by organizing around and shaping a safety culture focused on reliable performance but requires substantial investments in human capital. Healthcare should be centered around patient concerns and experience, integrated with science and engineering to improve patient diagnosis and outcomes, enhance operational efficiency, and foster sustainable primary healthcare practices/systems. Engineering systems incorporating and stimulating listening are central to any future change in patient outcomes. Both high reliability theory and clinical microsystems provide conceptual and practical frameworks for approaching the delivery of safe care. Although many ambiguities and conflicts arise from the implementation of these theoretic constructs, they should guide the development of work processes and stimulate innovation in fundamental engineering and designed ways to provide safe and effective care within health care systems. Readily accessible communication and information sharing are essential components for creating high reliability. Facilitating the design of systems to identify, prevent, absorb, and mitigate errors can provide remarkable opportunities for improving safety. Measuring reliability can improve the quality and value of our health care systems and quality improvement projects. A highly reliable system has a lower risk of errors and process failures that can cause patient's harm. Measuring reliability enables us to understand and learn from variability in our systems and discover whether our improvements result in higher reliability. The future of reliable outcomes requires to develop an integrated engineering approach and safety management system capable of navigating diverse engineering challenges to empower patients and healthcare providers with timely access and tailored delivery of critical health information wherever needed.

Reliability Importance Measures: from Local to Global

Prof. Emanuele Borgonovo

Bocconi University, Italy

In this seminar, we explore the definition and construction of reliability importance measures. We consider the analysis at the aleatory uncertainty level first and the move to importance measures that address parametric (epistemic) uncertainty. We review several importance measures, starting with the Birnbaum, Fussell-Vesely and closing with global sensitivity indices. We also study a connection between reliability theory and optimal transport. We show how the latter can be used to obtain importance measure that take the entire reliability curve into account.

Electromobility Transformation: Challenges for Reliability Engineering

Prof. Stefan Bracke

University of Wuppertal, Germany

Automotive power train engineering is in a state of upheaval. Within the European Union, the proportion of registered vehicles with electric drives is increasing exponentially, while the proportion of vehicles with conventional drives based on combustion engine technology is falling steadily. This transformation brings with it enormous challenges for the technical reliability of the electric drive with regard to the product life cycle against the backdrop of the circular economy. The focus here is particularly on the traction battery, as it is a function- and safety-critical system and at the same time has a high value-added share in the electric vehicle.

Therefore, on the one hand, the long-term reliability and maintainability of traction batteries must be ensured as part of the first life. On the other hand, strategies must be provided for 2nd life use in order to ensure a high degree of saving resources. In principle, there are two ways of saving resources: Reuse (or further use) of components and recycling of materials.

Here, reliability engineering plays a special role with regard to battery systems: aspects of degradation behavior, dismantlability, maintainability, testing of the condition of cells/submodules/modules, prognosis of the Remaining Useful Life (RUL) as well as safety tests are of essential importance.

The presentation focuses on the challenges of the technical reliability of traction batteries with regard to the product life cycle in multiple use against the background of the circular economy in the electromobility transformation phase.

Defending Complex Systems Against Intentional Attacks and Natural Impacts

Prof. Gregory Levitin

Southwest Jiaotong University, China

The presentation aims to explore various methods aimed at safeguarding systems from both intentional and natural impacts.

It discusses analysis of defense and attack strategies, examining how these strategies interact and influence each other. Central to the discussion is the methodology used to estimate and mitigate damage inflicted upon systems. This methodology draws upon a blend of risk analysis, game theory, and the theory of multi-state systems. By integrating these theoretical frameworks, the presentation proposes effective strategies for minimizing vulnerabilities and discusses their practical application in real-world scenarios.

Throughout the presentation, concrete examples are provided to illustrate key concepts and demonstrate how these theoretical frameworks can be translated into actionable strategies.

Some Dynamical Systems for Reliability Modelling and Estimation

Prof. Nikolaos Limnios

Université de Technologie de Compiègne, France

The aim of this talk is to present dynamical systems evolving in continuous-time and perturbed by Markov processes. We investigate both probabilistic modeling and statistical estimation of such systems. This work was initially developed in order to study cracking problems for the confinement device in nuclear power plants, where a jump Markov process was used as the perturbing process. The new key element here is the use of semi-Markov processes instead of Markov one for the randomization of the system. Numerical illustrations in reliability are investigated.

Workshop presentations

Advanced Learning from Information in the Chemical Industry

J.W. van Middelaar and Esta de Goede

TNO (Netherlands Organization for Applied Scientific Research), The Netherlands,
johan.van.middelaar@tno.nl , esta.goede-de@sitech.nl

Keywords: Safety; Learning; Big data; AI, Industry

Abstract. The chemical cluster industry 'Chemelot' in the Netherlands aims to be Europe's safest, most competitive and sustainable chemistry cluster by 2030. The project 'BLIC Vooruit' (Advanced Learning from information in the chemistry industry) is a Brightsite initiative that focuses on developing a predictive model for process safety. Within the project, a roadmap has been developed to identify weak signals and patterns in plant data using innovative techniques, including artificial intelligence (AI).

Background. Companies at a chemical industry cluster, like Chemelot, have a lot of (big) data at their disposal, however, only a small part of it is used for safety purposes. Incident prevention is now mainly focused on hindsight explaining why and how an incident has happened. With the emergence of AI, the idea arose whether it would be possible to extract information from big data with advanced data analyses techniques, and how to apply the information for the purpose of safety. In a previous project - with only one data source, one company and one AI technique - succeeded in identifying hidden patterns in safety datasets. Within this project we started to take this broader and develop it further.

Objective. The objective is to support plant owners to improve process safety by using advanced data analytics techniques. To this end, we have created a roadmap and an accompanying Handbook. The Handbook describes how the steps on the route look like, so that companies do not have to reinvent the wheel themselves. How to set up a Community of Practice (CoP) is included in the Handbook, as well as the initial experiences of participants at Chemelot. We hope that the industry will adopt the Handbook in order to further improve the safety of the industry.

Methods. A Community of Practice (CoP), has been established at the chemical industry cluster of Chemelot. The CoP consisted of ten parties: SABIC, Envalor, AnQore, USG, Sitech, TNO, Chemelot Site Permit, Maastricht University, TU Delft and Safety Delta Netherlands. Cooperation in a CoP can speed up the learning process, as companies learn directly from each other and do not have to go through each step and process separately. Together, we try to make the step from learning from the past to preventing incidents in the future. We do this by experimenting with different types of data (sources) and using different types of advanced data analysis techniques to find learning potentials and weak signals. In doing so, from the beginning, we take

into account the people who will eventually work with the systems, such as process operators in the factories. Therefore, the model is thought about from the shop floor so that it is useful and usable in practice.

Results. The outcome of this project is a Handbook with a roadmap. The roadmap is a process for identifying weak signals and learning potential in big data and analysing that with modern data analyses technology. The information thus obtained provides opportunities for earlier and more effective intervene in processes at risk of going wrong, thus preventing incidents.

Conclusion. Application of advanced data analytics can lead to mutual knowledge development, innovation and cooperation in the domain of safety. By sharing information, companies can learn from each other about best practices, risks, unusual occurrences, measures and areas for improvement relevant to their processes, products and services. This can help them raise their own safety levels, but also contribute to the safety of other participants in the CoP. By sharing information, companies also benefit from synergy, feedback, support and the expertise available in the CoP. This can help them respond faster and more effectively to changes, challenges or opportunities that arise in the environment.

Availability Models of a Recoverable Wireless Sensor Network for Forest Fire Monitoring System

Stanislav Skorobohatko, Herman Fesenko, Vyacheslav Kharchenko
and Bogdan Volochiy

s.skorobogatko@csn.khai.edu, h.fesenko@csn.khai.edu, v.kharchenko@csn.khai.edu,
bvolochiy@ukr.net

Keywords: wireless sensor networks, sensors, recovery, monitoring system, reliability

Abstract. The paper analyzes the types and architectures of wireless sensor networks (WSNs) used in environmental and critical facility monitoring (terrestrial, mobile, and hybrid networks). The reliability models of WSNs and their limitations due to the dimensionality of the tasks (monitoring area and the number and types of WSN sensors) are classified and analyzed. WSN reliability models built using analytical methods for single and multiple sensor failures for simple failure configurations in monitoring systems of simple geometric shapes (2D spaces) are discussed. In addition, simulation models of WSN reliability for 2D spaces of arbitrary shape are considered. The models of the availability of recoverable WSNs with different maintainability strategies are developed and explored. The study was performed using the apparatus of structural automata models and the ASNA tool. A methodology is proposed and the results of model validation are presented. Recommendations for the selection of WSN parameters are formulated.

An Asymmetrical Graph Siamese Network for One-Class Anomaly Detection of Engine Equipment with Multi-Source Fusion

Weicheng Wang

wzj21th@gmail.com

Keywords: Anomaly detection; Multi-source fusion; One-class model; Siamese network; Graph contrastive learning

Abstract. For the reliability and safety of engine equipment, real-time anomaly detection through monitoring signals from multi-source sensors is essential. However, signal coupling caused by complicated interactions between numerous components raises a challenge. Additionally, due to the extreme operating environment and severe malfunction result, the failure data is difficult to collect or simulate, leading to the lack of anomaly samples.

This paper proposed an asymmetrical graph Siamese network (AGSN) for one-class anomaly detection with multi-source fusion. The network consists of two weights-shared graph encoders and an extra remapping block which prevents the model from collapsing when one-class training. Firstly, AGSN adaptively constructs the graph structure based on sensor signals to model the components of systems and fuse multi-source signals into graph data. Secondly, graph data of normal samples are input into the AGSN for graph contrastive learning, enabling the graph encoders to completely cluster normal samples in the feature space. Thus, anomalous samples can be distinguished from normal samples when anomaly detection. The AGSN is evaluated on two datasets of liquid rocket engine (LRE) multi-sensor signals and compared with baseline approaches. The experimental results demonstrate that the proposed model is efficient, lightweight, and reliable, outperforming existing methods.

Contributions. 1) Adaptive graph construction and graph presentation learning are utilized to model the topological relation between various sensors and decouple the nonlinear multi-source signals. The local and global information of signals can be fully learned and represented by a graph structure. 2) The contrastive learning framework is built to simplify the model structure and reduce computational complexity. Thus the efficiency is enough for real-time monitoring data analysis. 3) A remapping block is proposed to form an asymmetrical Siamese network for one-class anomaly detection. The remapping block can adjust the outputs to guarantee model stability when training without anomaly samples. 4) The performance of the proposed method is evaluated on two datasets of liquid rocket engine (LRE) acquisition systems. Besides, comparative experiments with baseline models and ablation studies further demonstrate the effectiveness.

2050 Futures in AI: Two Horizons

D. Harkema¹ and C. van Gulijk^{1, 2, 3}

¹ Netherlands Organisation for Applied Scientific Research (TNO), BE Leiden, The Netherlands, denise.harkema@tno.nl

² School of Applied Sciences, University of Huddersfield, Huddersfield, UK

³ Faculty of Technology Policy and Management, Delft University of Technology, Delft, The Netherlands

Keywords: emerging technology; foresight; digitalisation; workforce; re-engineering safety management; futures

Abstract. This research identifies new technologies that can revolutionize business operations and integrate safety management, reliability engineering, and computational intelligence over the long term. Futures thinking methodology was applied to compile an overview of over 700 new technologies that have the potential to transform future business operations. In the long term, two main endpoints are indicated: (1) total immersion, which involves a shift towards virtual environments through immersive hybrid intelligence; and (2) total support, which involves digital applications to enhance physical business domains, improving the efficiency, speed, and cost-effectiveness of both employees and systems. The identified new technologies in each of these endpoints are expected to impact business operations, particularly through their potential to merge the domains of safety management, reliability engineering, and computational intelligence through extensive datafication. This research supports a better understanding of which new technologies are expected to change the way our businesses operate in the longterm future.

Background. The digital transition and AI in particular changes the way businesses operate in the future. The digital transition encompasses a wide variety of types of new technology which also creates a variety of possible impacts on businesses, operation and the human workforce. In order to understand how new technology can exactly change the landscape of business operation, in particular safety management, reliability engineering and computational intelligence, research is required to get a better understanding what these new technologies exactly are.

Objective. This research aims to identify new technologies that can change business operation and enhance the merge of safety management, reliability engineering and computational intelligence on the long term.

Methods. For this research, the internationally acknowledged methodology for futures thinking as described in The Futures Toolkit by UK Government Office for Science [1] is used.

This research gathers an overview of emerging technologies as identified in grey literature, like (trend) reports and forecasting studies from established organisations and institutes like Imperial TechForesight [2], World Economic Forum [3] and the European Commission [4].

This research led to an inventory of more than 700 technologies in several application areas, some of which could potentially influence the way businesses operate. The majority of the technologies are identified as emerging technology on the horizon 3 timeline, which shows the emergence of new patterns from being barely visible today to being important in the future.

Results. The inventory of new technologies shows a large diversity which can be clustered into two end points in business operation: *total immersion* and *total support*.

The introduction of digital applications into the physical domain: New technologies enter the physical domain of businesses and make more efficient, faster and cheaper production possible. The introduction of digital applications can be either focused on (full or partial) automation or on human monitoring and enhancement. Automation through the use of robotics, drones and/or AI can replace the need for human labour and/or replace humans in certain work processes. AI-enabled technology used to enhance and monitor humans can have the purpose monitor, evaluate and/or optimise the workforce both physically and mentally, thereby convergence human workforce and asset optimization through datafication. For lack of better definition, this we call total support.

Examples of new total support technologies are: autonomous transport of people (self-driving taxis and passenger drones), drone delivery and transport, smart dust, humanoids, cobots, insect-sized surveillance robots and swarm intelligence (drones), autonomous systems of unassisted AI robotics, business operation by AI-enabled robotics. Exoskeletons, smart tattoos, face and emotion recognition (CCTV), eye-tracking, automated motion analysis, intent decoding algorithms, sentiment analysis, sensor implants, human and AI hive intelligence, wearable anything, computerised clothing and shoes, thought controlled machine interfaces.

Business operation in a digital reality: business operation can also be transferred to a virtual world through immersive hybrid intelligence. This virtual world can be a simulation of a physical reality or it can be its own virtual environment where business processes and/or people meet and interact. The digital reality of business operation is also referred to as industrial metaverse. For lack of better definition, this we call total immersion.

Examples of new total immersion technologies are: full immersive Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), Extended Reality (XR), Digital Twins of persons, companies and/or environments, holograms, combined reality through AR glasses, full virtual work environment and/or virtual training environment.

The development towards these endpoints will be a long journey into the future, as research indicates the need to strengthen the foundation for new technologies through ever-increasing computing power and more powerful electronics. Examples include quantum computing and quantum-safe cryptography, graphene supercapacitors, deep mapping, fabric computing, blockchain technology, and edge analytics.

Conclusion. This research identified 700+ emerging technologies that can impact the operation of businesses, in particular those that can enhance the merge of safety management, reliability engineering and computational intelligence. The inventory of emerging technologies could be clustered in two end points: total immersion and total support.

The identified new technologies in each of these end points are expected to impact business operation, in particular through their potential to merge the domains safety management, reliability engineering and computational intelligence through far reaching datafication. Further research is needed in order to evaluate risks and opportunities of emerging technologies on business operation and evaluate this potential to merge the above mentioned domains.

References.

1. The Futures Toolkit, UK Government Office for Science, 2024.
2. Automated Futures, M. Jeansson, C. Sanna, Imperial TechForesight, 2020.
3. Future of Jobs Insight Report, World Economic Forum, 2023.
4. 100 Radical Innovation Breakthroughs for the future, Directorate-General for Research and Innovation, European Commission, 2019.

Application of a Bowtie Digital Twin: How a Mechanical Seal Looks Different from a Data Perspective

P. Singh¹, C.V. Gulijk¹ and N. Sunderland²

¹University of Huddersfield, Huddersfield, UK, paul.singh2@hud.ac.uk, c.vangulijk@hud.ac.uk

²Syngenta Huddersfield Manufacturing Centre, Huddersfield, UK, neil.sunderland@syngenta.com

Keywords: BowTie Digital Twin, Mechanical Seal, Big Data

Abstract. The BowTie diagram's purpose is to visualise the structure of a safety management system in place on a process. The BowTie diagram can also be applied to mechanical devices, such as mechanical seals, that can be treated to emulate a simplified process. The barriers for that mechanical seal can also be displayed as simple barriers but in actuality, they may also exist as complex systems. Time-series data from the processing environment in which the mechanical seal is employed, with the use of appropriate analytical tools, may be used to monitor and report the health of barriers and reflect upon the status of the mechanical system itself. Moving forward, the mechanical system can be re-engineered so that the BowTie of that system can be turned into a digital twin of the barrier system for the mechanical seal. Digital twin models of systems that mirror a real system and, in this case, it is the risk space associated with a mechanical seal. The BowTie model could turn out to be well suited to become the digital twin of a mechanical seal from a risk perspective as it maps out the risk-space together with controls and barriers around safe and effective operation of a mechanical seal. However, to develop a BowTie to become a true digital twin of the barriers and controls for a mechanical seal, rules and processes for designing the BowTie for that mechanical seal may change.

Two-Layer Model of Fake Information Classification Using Artificial Intelligence in Socially Oriented Systems

A. Khovrat¹, V. Kobziev¹, D. Uzlov² and S. Yakovlev^{2,3}

¹ Kharkiv National University of Radio Electronics, Kharkiv, Ukraine, artem.khovrat@nure.ua

² V.N. Karazin Kharkiv National University, Kharkiv, Ukraine

³ Lodz University of Technology, Lodz, Poland

Keywords: data analysis, naïve bayes classifier, neural networks, parallelisation, falsified news

Abstract. The problem of detecting fabricated information in systems characterized by high user interaction, such as social media platforms, is increasingly being examined in academic and legal contexts. This is mainly attributable to advancements in information generation technologies and the overall increase in informational load on individuals. In critical situations involving social upheaval, such misinformation can pose significant risks to individuals and society at large. This study focuses exclusively on textual news due to the current absence of reliable tools for generating credible visual forgeries from a human perceptual standpoint. In classifying textual data, three principal approaches are commonly employed: probabilistic models, neural networks, and naive polynomial models, including those utilizing linear additive convolutions with weighted coefficients and specific constraints.

Previous studies addressing the binary classification of data into credible and fabricated categories have examined probabilistic models and algorithms involving various neural networks. Results indicate that a hybrid network combining recurrent and convolutional capabilities – termed RCNN – emerges as one of the most effective in terms of both accuracy and computational efficiency. Some texts may adopt an overtly humorous tone that is readily perceived as non-threatening, resulting in negligible societal harm. Conversely, misinformation aimed at undermining significant legislative initiatives can pose risks to societal stability.

In the current study, a classification framework for types of fake information has been established, serving as a foundation for the classification of data filtered through the RCNN model. This framework includes the following categories: jokes with objectively identifiable manifestations; subtle jokes; malicious news targeting individuals or small groups; regionally harmful news; globally harmful news. This categorization enables a nuanced approach to the classification and analysis of fake information within the context of social media and other digital platforms.

Following the establishment of the foundational classes, three data grouping models were developed using neural network approaches, a naive Bayes classifier, and a polynomial algorithm. To assess the efficacy of these methodologies, an experiment was conducted to evaluate accuracy, time efficiency, and data volume reduction necessary to achieve an accuracy exceeding 80%.

The results indicated that each approach utilizing a two-layer model demonstrated, on average, a 15% increase in effectiveness compared to the

straightforward application of the RCNN method. Notably, the combination of the naive Bayes classifier and RCNN yielded the highest accuracy and operational speed. This finding underscores the potential for implementing this hybrid approach in high-load systems where rapid responses to fabricated information are essential.

Bayesian Networks as Surrogate Models: An Application to Energy Systems Analysis

Luca Podofillini¹, R. Kelk¹, V. N. Dang¹ and E. Panos^{1,2}

¹Centers for Nuclear Engineering and Science and for Energy and Environmental Sciences, Laboratory for Energy Systems Analysis, Paul Scherrer Institute, Villigen PSI, Switzerland, luca.podofillini@psi.ch

²Chair of Energy Systems Analysis, Institute of Energy and Process Engineering, ETH Zurich, Zurich 8092, Switzerland

Keywords: Bayesian networks; energy systems models; surrogate models; continuous variable discretization

Abstract. Energy systems models provide comprehensive and detail representation of the energy system sectors, from production to energy conversion and consumption, and are typically used to identify sustainable energy systems configurations under different policies and other technical and resource constraints, etc. Understanding and interpreting the results of energy system models is challenging because the obtained energy system pathways reflect the complexity of the emerging energy system and are derived from a large number of interdependent variables and involve multiple temporal and spatial scales. This study investigates the use of data-based discrete Bayesian Belief Networks (BBNs) as surrogate energy systems models, using a simplified version of Swiss TIMES (STEM), referred to as STEM-lite, as the application case.

A BBN optimization process is devised, based on BBN performance metrics related to the accuracy of the predictions against STEM-lite data records, avoiding BBN overparameterization with respect to the data available. Validation on a set of predetermined scenarios shows an average relative error below 2% in the BBN predictions: this ensures adequate performance as surrogate model. Two scenario cases are presented to demonstrate the BBN attractiveness concerning node and relationship visualization, fast and intuitive uncertainty propagation, and backward reasoning. For practical applications, future work shall overcome a number of simplifying assumptions: in the current development stage, the results shall not be taken as basis for energy systems and economics policy discussions.

Experimental Overview of Techniques Used for the Management of Intermediate Results in Calculations with Decision Diagrams

Michal Mrena and Miroslav Kvassay

Faculty of Management Science and Informatics, University of Zilina, Zilina, Slovakia,
michal.mrena@fri.uniza.sk

Keywords: cache, decision diagram, hash table, lookup table, memory complexity

Abstract. A decision diagram is an acyclic graph used to represent discrete functions. Different types of decision diagrams are widely used in various areas such as reliability analysis, logic circuit synthesis, or formal verification. Decision diagrams were first proposed to represent boolean functions and later generalized to represent multiple-valued logic functions. Moreover, researchers proposed several specialized decision diagram types designed to solve specific tasks. Nevertheless, all the types share the same essential property which is the sharing of diagram nodes. Moreover, most diagram implementations utilize the immutability of the graph structure. Most of the algorithms that operate on decision diagrams utilize recursion. The aforementioned properties imply that it is crucial to avoid expensive recomputation of the same value in a node that was already processed by the recursion. The paper focuses on existing techniques used to address this problem, mainly on two specific approaches. The first approach utilizes an external lookup table to store the results of computation in specific nodes. The second approach uses nodes themselves to store the results. The paper presents an experimental comparison of the two approaches that shows that the relative performance of the two approaches varies in different types of problems

Data Potential and Feasibility Study with Grid mean Algorithm

V.A. Holdovanskyi and V.I. Aliexsieiev

Lviv Polytechnic National University, Lviv, Ukraine, goldovanskijvladislav@gmail.com

Keywords: Correlation Analysis; Feasibility Study; Machine Learning

Abstract. The use of the determination-based correlation coefficient is explored as a tool for evaluating the potential of machine learning models for tabular data. This approach assesses the coefficient of determination and estimates other regression metrics, including MAE, RMSE, and MAPE. It enables businesses to preliminarily gauge the economic feasibility of developing models, facilitating more informed decisions about investing resources and time.

Background. Data-driven decision-making is crucial for success in today's business environment. One of the key tools for forecasting and optimizing processes is machine learning models. However, assessing the effectiveness and benefits of these models before investing resources is crucial. Using algorithms to calculate

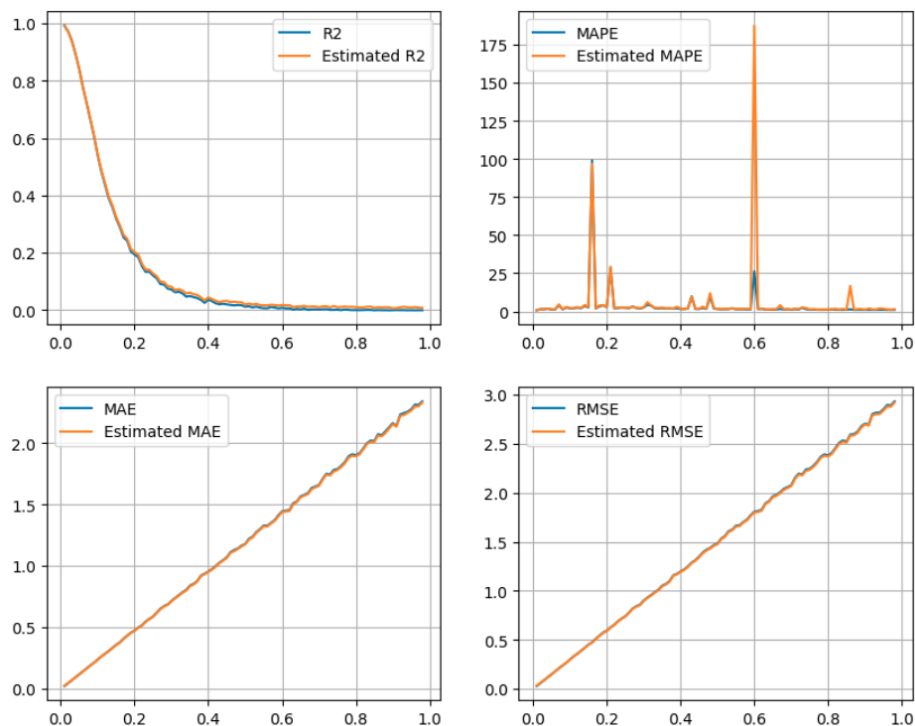
regression metrics on data before model development helps evaluate the model's potential value and make informed investment decisions.

Objective. The aim of the research is to demonstrate the effectiveness of using the Grid Mean Algorithm for the preliminary calculation of regression metrics on tabular data. This helps assess the economic feasibility of building a machine learning model and determines whether investing in model development is worthwhile or if it is better to allocate funds to other business initiatives.

Methods. The study utilizes concepts from our previous article, specifically the approximation of a random function using the Grid Mean Algorithm. As shown, this algorithm effectively approximates the function, with sufficiently accurate calculations of the coefficient of determination. We propose extending this algorithm to also calculate MAE, RMSE, MAPE, and other regression metrics. This approach allows for the analysis of the model and data potential for business, facilitating informed decisions about investing time and resources in model development.

Results. Experiments were conducted to compare the accuracy of the estimated metrics. Random x points were generated, and various functions (linear, quadratic, sinusoidal, step, etc.) were applied with added noise. The metrics were evaluated using our method and compared with exact functions.

The results demonstrated good practical accuracy. For the exponential function, where the algorithm has the lowest precision, the maximum metric errors are: $R^2 - 0.014$, $MAPE < 1\%$. Graphs illustrating results for the exponential function are provided.



Conclusion. The Grid Mean Algorithm allows for the calculation of regression metrics without training a machine learning model. Experiments demonstrate that this method provides sufficient accuracy for an initial assessment of data potential and model feasibility, aiding in the evaluation of the model's business relevance.

Evaluating Ground Impact Severity in Suborbital Vehicle Explosion Scenarios

Manuel Lombardi and Riccardo Patriarca

Department of Mechanical and Aerospace Engineering, Sapienza University of Rome, Rome, Italy
manuel.lombardi@uniroma1.it

Keywords: aerospace operations management; safety management; risk analysis; impact area; debris impact severity

Abstract. With the growing integration of space activities into traditional aviation, in recent times the role of the Civil Aviation Authorities (CAAs) in ensuring safety extends beyond atmospheric operations to include orbital and sub-orbital flights. In this regard, the continuous expansion of suborbital flight operations, fueled by growing private investments and the rise of space tourism, necessitates updates to licensing and operational oversight practices. The CAA's role in risk analysis becomes critical for maintaining the safety and integrity of both airspace and near-Earth space environments.

Accordingly, a proper pre-launch risk analysis is essential for managing for suborbital flight with the aim of identifying critical hazards for the operators, as well as for the public and the environment at large. This paper proposed a specialized methodology tailored for such purpose, specifically addressing the potential hazardous area of spacecraft debris resulting from an explosion during the suborbital cruise and determining the associated severity level, measured in terms of fatality/operation, with each debris. The methodology serves as a basis for analyzing flight trajectories by assessing debris generation and their corresponding trajectories, impacts on the ground, and severity level.

The study iterates the assessment for the analysis of a hypothetical trajectory in the context of 'A to A' suborbital flight operation, i.e., a flight whose starting and ending points coincide. The trajectory is divided into a number of equidistant control points, set to 70 in order to represent a credible yet computationally manageable scenario. The explosion is assumed to cause complete disintegration of the spacecraft, producing debris of different geometric shapes (i.e., spheres, cylinders and plates).

Debris trajectories are modelled using ballistic and planar fall equations, considering aerodynamic forces (i.e., drag and deviance) and wind effects. Through a series of Monte Carlo simulations involving 100 debris distributed across the three debris shapes in varying proportions, the study aims to identify which combination results in the largest ground impact area and calculate the associated severity levels. For higher representativeness, the simulation is stochastically defined by random variables associated to the heading angle, incidence angle and velocity impulse of the debris generated by the explosion. This approach estimates the overall risk area in a conservative manner. In turn, the procedure proposed provides a first step towards a systematic and conscious risk-based decision-making on the feasibility of potential suborbital flight operations.

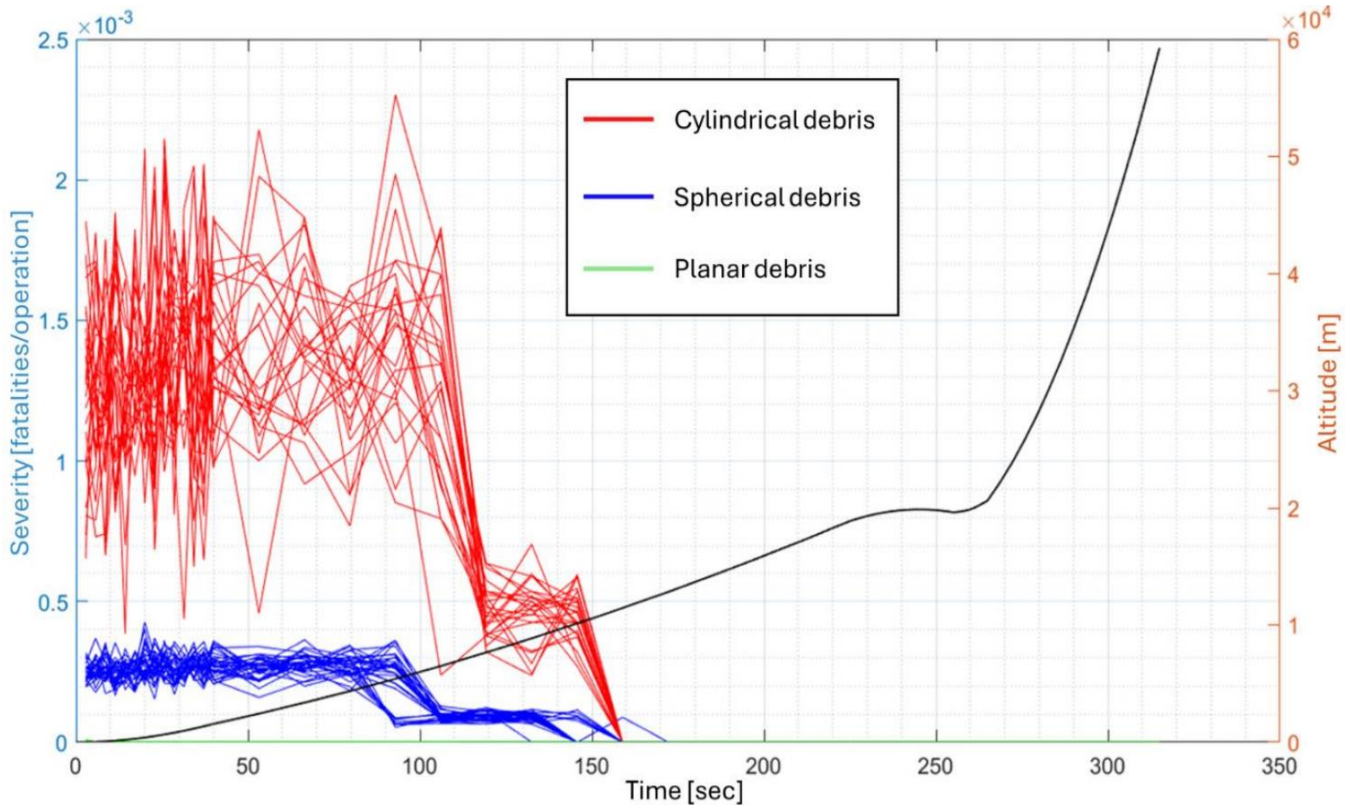


Figure 1: Severity values for each debris (each line corresponds to a debris, relative to the spacecraft trajectory (dark line)). After about 150 sec, the severity values remain 0 because debris are falling into the sea, which corresponds to a population density population of 0.

Code Performance Evaluation with Modern AI Models and Fine Tuning

A.V. Dovbysh and V.I. Aliksieiev

Lviv Polytechnic National University, Lviv, Ukraine, artur.v.dovbysh@lpnu.ua

Keywords: Code performance; Benchmarking; Fine Tuning; Machine Learning

Abstract. The paper investigates the use of large language models (LLMs), including Gemini, GPT models, for the task of code performance evaluation. The study details the preparation of domain-specific datasets, focusing on different implementations of well-known sorting algorithms like QuickSort, MergeSort, and HeapSort. These datasets are tailored to capture various performance metrics, such as runtime efficiency, memory utilization, and computational complexity. We explain the process of curating these datasets to ensure they accurately represent real-world code execution scenarios, making them ideal for fine-tuning LLMs to specialize in performance evaluation tasks.

Background. The fine-tuning process is central to this work, as it allows LLMs to be adapted for the specific domain of code performance analysis. We detail the methodology of fine-tuning models to capture intricate relationships between code structure and its performance characteristics. By leveraging transfer learning, we

ensure that these pre-trained models are adjusted to better evaluate specific metrics like algorithmic efficiency, memory overhead, and execution bottlenecks. This fine-tuning enables the models to offer more accurate and domain-specific recommendations for code optimization.

Objective. The article aims to explore how domain-specific datasets, built using sorting algorithms like QuickSort, MergeSort, and HeapSort, can be prepared to capture key performance metrics such as runtime and memory usage for code performance evaluation. It focuses on fine-tuning large language models (LLMs) like Gemini, GPT to improve their accuracy in assessing these metrics. Through comparative analysis, the article demonstrates that fine-tuned models provide significantly better insights into code performance, offering more precise recommendations for optimization.

Methods. The article employs several key methods to achieve its objectives. First, dataset preparation is conducted by selecting a range of sorting algorithms and generating performance metrics including runtime, memory usage, and computational complexity. These metrics serve as the foundation for fine-tuning the models. The fine-tuning process is central to the methodology. Pre-trained large language models (LLMs) like Gemini and GPT are adapted to the specific domain of code performance evaluation by adjusting their parameters using the prepared datasets. This transfer learning process enables the models to specialize in understanding the intricate relationships between code structure and performance metrics. Finally, a comparative analysis is performed to assess the models' performance before and after fine-tuning. This involves evaluating the accuracy of their predictions on code efficiency, optimization potential, and performance metrics, with the results showing significant improvement after fine-tuning. These methods collectively demonstrate how LLMs can be effectively adapted to specific domain tasks like code performance evaluation.

Result. Our experimental results highlight a significant improvement in performance evaluation after fine-tuning the models. We conduct a thorough comparison between the models' evaluations before and after fine-tuning, showing that the fine-tuned models consistently provide more accurate assessments of sorting algorithm performance based on F-score. The results demonstrate a deeper understanding of domain-specific tasks, leading to more precise insights and optimization strategies. In conclusion, the fine-tuning process substantially improves the models' capability in code performance evaluation, making them powerful tools for developers and engineers focused on code efficiency.

Conclusion. The fine-tuning process allows to significantly improve accuracy of existing LLMs within specific domain. Our experiments show that by applying this approach we can quickly and without extra efforts achieve better results in comparison to the raw model usage.

Estimating Electric Motor Temperatures with Machine Learning Models

Y.Pastukh¹, S.Liaskovska^{1,2} and A. Augousti²

¹ National University "Lviv Polytechnic", Institute of Computer Science and Information Technologies, Artificial Intelligence Systems Department, Lviv, Ukraine, solomiam@gmail.com

² Kingston University, Faculty of Engineering, Computing and the Environment, Department of Mechanical Engineering, Kingston Upon Thames, London, United Kingdom

Keywords: machine learning; permanent magnet synchronous motor; temperature; stator; deep learning

Abstract. Monitoring permanent magnet synchronous motor's (PMSM) temperatures is vital for maximizing its efficiency, safe utilization, and longevity [2]. While classical thermal modeling requires a lot of physical details and knowledge, a data-driven approach proves to be either more robust or easier to implement. In this work, supervised machine learning models are used to estimate motor's different components temperatures based on time-series data with multiple input features. Using open-source benchmark data [1], models are trained and optimized to predict temperatures of the following motor components: permanent magnet, stator windings, tooth, and yoke. Providing conclusive exploratory and explanatory analysis, input features are well-processed, derived, and filtered. Advanced hyper-parameters tuning techniques are used to automatically choose the most accurate and robust regressor model. The performance of the models is evaluated using various metrics and is compared to the existing solutions on the chosen benchmark dataset. Furthermore, multiple deep neural network architectures, such as recurrent neural network (RNN) and long-short-term memory (LSTM) [5], are proposed, which prove to be more efficient for temperature estimation over classic machine learning architectures when configured and optimized. Finally, the most accurate architectures are retrained on the complete dataset for inference and prepared for productization and real-time temperature estimations.

Background. Permanent Magnet Synchronous Motor (PMSM) is a type of brushless synchronous motor that is widely used in various industrial applications due to its high performance and reliability. PMSMs rely on permanent magnets that are the base of the rotor, which generate torque interacting with the electromagnetic field created by stator windings. Accurate temperature monitoring allows operators to optimize the motor's performance, ensure safe utilization, and prevent thermal damage. Traditional thermal monitoring methods usually require detailed physical models that depend on precise knowledge of the motor's structure and material properties, other exogenous factors [4]. As a result, such models are difficult to generalize across different motor types or operating conditions. Moreover, such approach becomes inaccurate over time with motor's exploitation.

Objective. The primary purpose of this paper is to develop an algorithm that would receive the input data (temperatures measured by sensors, torque, motor

speed, exogenous measurements) and predict permanent magnet, stator windings, tooth, and yoke temperatures in real-time, then passing this information and directives to the motor control allowing to prevent overheating.

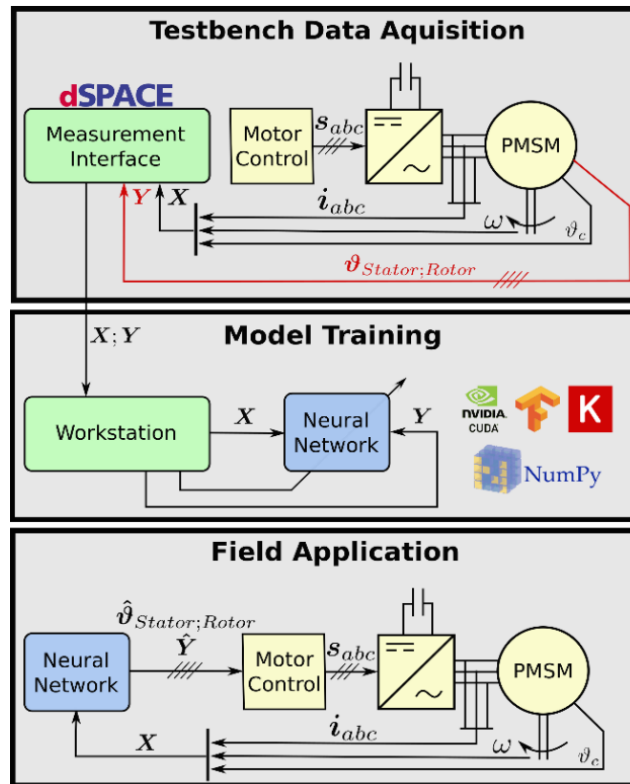


Figure 1. Simplified scheme of the whole process from data acquisition at the test bench over model training up to the applied temperature monitoring in the field [1].

Methods. The methodology presents comprehensive approach for a temperature estimation for PMSMs using both traditional machine learning and advanced deep learning algorithms (random forest, gradient boosting regression, RNN, LSTM, etc.). From data collection and pre-processing to model training and deployment, each step is designed to maximize accuracy and robustness. By leveraging time-series data and hyper-parameters tuning, the developed models provide reliable and real-time temperature predictions for key motor components, ensuring safe and efficient operation.

Results. When compared to existing benchmark methods for PMSM temperature estimation, the proposed machine learning and deep learning models, particularly LSTM, demonstrated Mean Squared Error (MSE) close to the most accurate existing solutions. However, it is difficult to compare our solution to existing ones as every author proposes a different way to deal with time-series data (different lag steps are chosen), which directly affects metrics values. We've confirmed that the data-driven approach is more viable compared to classical thermal modeling and is easier to implement. During the ongoing research, we are going to improve deep learning models' architectures and perform better hyper-parameters tuning and optimization while providing more computational capabilities to the research.

References.

1. W. Kirchgässner, O. Wallscheid and J. Böcker, "Estimating Electric Motor Temperatures With Deep Residual Machine Learning," in IEEE Transactions on Power Electronics, vol. 36, no. 7, pp. 7480-7488, July 2021, doi: 10.1109/TPEL.2020.3045596.
2. O. Wallscheid, W. Kirchgässner and J. Böcker, "Investigation of long short-term memory networks to temperature prediction for permanent magnet synchronous motors," 2017 International Joint Conference on Neural Networks (IJCNN), Anchorage, AK, USA, 2017, pp. 1940-1947, doi: 10.1109/IJCNN.2017.7966088.
3. D. Gaona, O. Wallscheid and J. Böcker, "Fusion of a lumped-parameter thermal network and speed-dependent flux observer for PM temperature estimation in synchronous machines," 2017 IEEE Southern Power Electronics Conference (SPEC), Puerto Varas, Chile, 2017, pp. 1-6, doi: 10.1109/SPEC.2017.8333640.
4. Zhang, X., Sun, L., Zhao, K., & Sun, L. (2012). Nonlinear speed control for PMSM system using sliding-mode control and disturbance compensation techniques. IEEE transactions on power electronics, 28(3), 1358-1365.
5. Hochreiter, Sepp & Schmidhuber, Jürgen. (1997). Long Short-term Memory. Neural computation. 9. 1735-80. 10.1162/neco.1997.9.8.1735.

Advanced Tools for Visualization and Animation in the Simulation and Computational Intelligence

Igor Melnyk¹, Andriy Luntovskyy², Alina Pochynok³,
Mykhailo Skrypka¹ and Mykola Surzikov¹

¹ Department of Electronic Devices and Systems National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" Kyiv, Ukraine: imelnik@phbme.kpi.ua

² BA Dresden Univ. of Coop. Education Saxon Study Academy, Dresden, Germany:
Andriy.Luntovskyy@ba-sachsen.de

³ Research Institute of Electronics and Microsystems Engineering National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine: alina_pochynok@yahoo.com

Keywords: scientific visualization, animation, CAD/ CAM, AVI format, parametric modelling, PHY, determinative physical process, stochastic physical process, GUI, computational intelligence

Abstract. Animation models forming for the simulation of different determinative and stochastic physical effects, processes, devices, and systems are complexly considered in the given work. All solutions are oriented towards using animation tools the MATLAB system for scientific and technical calculations. Diverse examples are discussed. Generally, the presented work examines the tools for creating animations in the internal MATLAB standard, without the possibility of viewing them in other software applications, and in AVI format. The advantages and disadvantages of both approaches are closely analyzed. The main workflow steps, that are necessary to create animations, are also described and illustrated for both approaches. The option of further combining internal MATLAB animations with the elements of a windowdriven GUI is carefully considered. This option can be deployed to provide advanced applications with deep parametric modelling of such complex physical effects, processes, and systems.

Using Intelligent Approaches in Algorithms of Interpolation and Extrapolation of Short-Focus Electron Beams Boundary Trajectories by Root-Polynomial Functions

Igor Melnyk¹, Andriy Luntovskyy², Alina Pochynok³, Mykhailo Skrypka¹,
Serhii Tuhai¹ and Oleksandr Kovalenko¹

¹ Department of Electronic Devices and Systems National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute” Kyiv, Ukraine: imelnik@phbme.kpi.ua

² BA Dresden Univ. of Coop. Education Saxon Study Academy, Dresden, Germany:
Andriy.Luntovskyy@ba-sachsen.de

³ Research Institute of Electronics and Microsystems Engineering National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”, Kyiv, Ukraine: alina_pochynok@yahoo.com

Keywords: Interpolation, Extrapolation, Root-Polynomial Function, Electron Beam Technologies, High Voltage Glow Discharge, Computational Intelligence, Machine Learning, Fuzzification

Abstract. The possibilities of interpolation and extrapolation of ravine numerical data sets, which correspond to boundary trajectories of electron beams propagated in soft vacuum in ionized gas by the root-polynomial functions of fifth and sixth order, are carefully considered in the paper. It is proven theoretically and by computer experiments that for asymmetric ravine data sets, the basic algorithm of interpolation, which has been considered early, gives a significant value of error relative to the etalon results of numerical simulation. It is proposed to use two different approaches for interpolation and extrapolation of asymmetric numerical data sets, which correspond to ravine functions.

The first approach is based on using a self-connected interpolation-extrapolation algorithm to solve the extrapolation task on the asymmetric branch of the ravine function data set. Using such an approach gives significant error in the region of extrapolation, but the focal parameters of the electron beam are estimated with very high precision. The second approach is based on interpolation by using a higher-order root polynomial function. Using such an approach gives the minimal average value of error for the whole region of interpolation, but estimating the focal parameters of the electron beam provided is not as accurate as in the case of using the interpolation-extrapolation algorithm. Choosing the best approach for the estimation of the boundary trajectory of an electron beam propagating in ionized gas depends on the requirements of customers for solving the specified technological problems.

A Reinforcement Learning Algorithm based on Markovian Model for Server Reliability Assessment in IIOT System

Maryna Kolisnyk¹, Axel Jantsch² and Iryna Piskachova³

¹Department of computer systems, networks and cybersecurity National Aerospace University "KhAI", Kharkiv, Ukraine, kolisnyk.maryna.al@gmail.com

² Institute of computer technology Vienna University of technology, Vienna, Austria

³Department of automation and computer-integrated technologies of State Biotechnological University, Kharkiv, Ukraine, ipiskacheva@gmail.com

Keywords: Reinforcement Learning, Server, Reliability, Availability, IIoT, Markov models.

Abstract. In Industrial Internet of Things (IIoT) systems, a large amount of information circulates: data from sensors, statistical data from network devices, documentation, instructions for technical staff, and personal data of company employees, etc. Most of this data is stored on a server, which is part of the IoT system. The server is a complex hardware (HW) multiprocessor and software (SW) system hardware-software multiprocessor system, the reliability of which depends on the reliability of both SW and HW. Recent studies of server development companies indicate that the requirements for server reliability have increased, in particular, now the requirements for fault tolerance SW server is 0.999999, HW server is 0.999999. Ensuring the required high server reliability is an important and necessary task of the problem, since server failure entails partial failure of the IoT system.

In the presented work, a system analysis of the server architecture was carried out. This allowed to identify the most important hardware and software subsystems of the server from the point of view of reliability of functioning. To assess the reliability of the server was used Reinforcement Learning (RL) algorithm based on the Markov model. The availability factor and availability function (since the server is a recoverable system) were chosen as the main indicator of server reliability.

The paper developed and investigated the RL algorithm based on the Markov model of server readiness under given initial conditions and initial data, which takes into account the technical states of the HW and SW subsystems of the server, as well as evaluated the main indicators of its reliability.

The result of the study showed that the obtained model allows to estimate the reliability of the server with high accuracy, verified using the Kolmogorov-Smirnov criterion. The conducted research has shown the expediency of using the developed model to assess the reliability of the server, and is valuable from a practical point of view for companies developers of servers and for specialists in their operation.

Use of ROS2 in Conjunction with YOLOv8 Image Recognition System for Mobile Robot Control System

Maksim Buren

Belarusian State University of Informatics and Radioelectronics, Minsk, Belarus

In modern robotic systems, the ability of robots to effectively perceive and analyze the environment plays a key role. One of the powerful tools for the integration of various sensors, control and data processing is ROS2 (Robot Operating System). In turn, YOLOv8 (You Only Look Once) is an advanced deep learning architecture specifically designed to recognize objects in images in real time.

The original version of YOLO (You Only Look Once) was created by Joseph Redmon in 2016. The original YOLO model was the first object detection network to combine the problem of bounding box formation and class identification in one end-to-end differentiable network. Some object detection models treat recognition as a two-part task. First, you determine the area of interest (bounding box) in which the object is located. Second, classify this particular area of interest. Treating the detection task as a one-time regression approach to determine bounding boxes, YOLO models often prove to be more performant than their counterparts, making them easier to use on devices with limited computing capabilities.

ROS is a pseudo-operating system based on the Unix family of operating systems (Linux, Mac OS). Thanks to this, it is possible to develop and test applications directly on personal computers and laptops. The architecture of an application based on ROS is based on the concept of Node. In ROS2, a Node is a fundamental unit of software architecture, which is a separate process that performs one or more tasks within a robotic system. Nodes in ROS2 are used to divide tasks into independent components that can communicate with each other through message passing, service calls, and data sharing.

The choice of these technologies is due to their performance and compatibility with each other. Both ROS 2 and YOLO 8 versions use the python3 programming interface, which makes them convenient to use within the same system.

The talk discusses the integration of ROS2 with the YOLOv8 image recognition system, which makes it possible to create solutions for automatic navigation, object detection, and decision-making in a dynamically changing environment. The study describes the main steps for connecting YOLOv8 to the ROS2 ecosystem, provides a rationale for choosing a specific mode of operation of the recognition system, and also considers an example of the architecture of an application for autonomous control of a mobile robot using computer vision.

Lightweight Convolutional Transformer for Fault Diagnosis on Vibration Signal in Time-Frequency Domain

A. Didenko, A.Oliinyk and S. Subbotin

National University "Zaporizhzhia Polytechnic", Zaporizhzhia, Ukraine, subbotin@zp.edu.ua

Keywords: fault diagnosis; vibration analysis; deep learning; transformer; convolution

Abstract. Vibration-based analysis is essential in diagnosing faults in rotating machinery. Traditional machine learning approaches and CNNs often struggle to capture long-term dependencies and complex patterns in data. Transformers have shown great potential in solving this task. However, their high computational complexity and large size make them challenging to use in practical applications. In this paper, lightweight convolutional transformer was proposed to detect faults based on time-frequency representation of the signal. The proposed model achieves 99.94% accuracy with 6 time less parameters than baseline Transformer. These results demonstrate the effectiveness of our lightweight architecture, making it an efficient solution for accurate fault diagnosis using vibration signals in the time-frequency domain.

Background. Vibration-based analysis is used in diagnosing faults in rotating machinery, such as motors, bearings and gears. When fault occurs, the vibration pattern of the mechanical component changes, revealing valuable information. By analysing the vibration signal, it can be possible to detect faults in the early stages.

Objective. The purpose of the paper is to develop an efficient and accurate method for diagnosing faults using STFT representation of the vibration signal.

Methods. The proposed method is the Transformer architecture with the following changes. First, a feature extractor was introduced to capture preliminary patterns in STFT spectrogram. Second, MHSA (Multi-head Self-attention) and Position-wise FFN (feed-forward network) were replaced with Channel Attention and Depth-wise FFN respectively to reduce number of parameters and enhance performance. Training data consists of samples from CWRU dataset and represents 10 classes (9 bearing fault types and 1 healthy condition). Each sample was created by splitting signal into chunks of 1024 datapoints and converted to spectrogram via STFT.

Results. The proposed method was trained for 50 epochs in each of the 10 independent runs. The only part that was replaced is the Transformer Encoder Block. According to the results, the proposed method achieves higher accuracy with less number of parameters. Depth-wise convolution enables model to reduce the number of training parameters while convolution allows model to learn local patterns. Channel Attention further enhances performance by emphasizing the most informative patches across the input.

Table 1. Quantitative comparison of the proposed method

Method	Accuracy(%)±Std	Total parameters (M)
Vanilla transformer	99.81 ± 0.22	0.123
Proposed method	99.94 ± 0.08	0.020

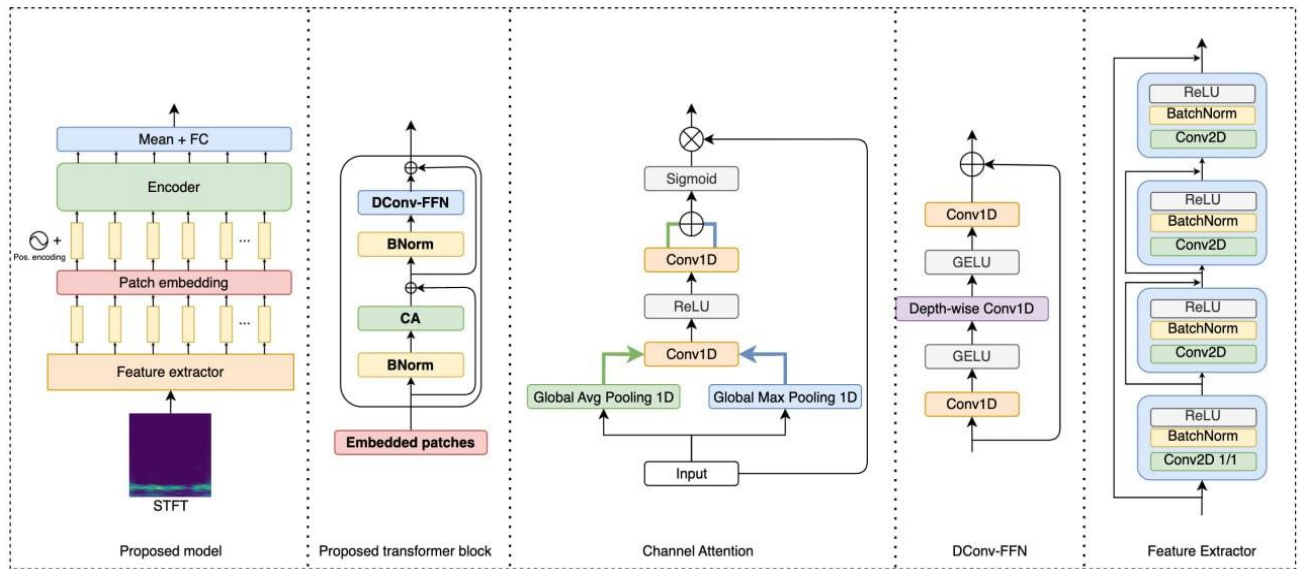


Fig 1. Architecture of the proposed method

Conclusion. In this paper, a lightweight convolutional Transformer was introduced. The experimental results show that the proposed model has higher accuracy with less number of parameters than vanilla Transformer architecture.

Overview of AI Applications in Electromechanical Systems

Tadeáš Kmecik and Peter Girovský

Department of Electrical Engineering and Mechatronics, Faculty of Electrical Engineering and Informatics Technical University of Košice Košice, Slovak Republic, tadeas.kmecik@tuke.sk, peter.girovsky@tuke.sk

Keywords: Artificial Intelligence (AI), Electromechanical Systems, Applications, Control Strategies, Optimization, Machine Learning

Abstract. This article analyses the use of artificial intelligence (AI) in the control, diagnostics, and maintenance of electromechanical systems, emphasizing its potential to improve the performance, accuracy, and reliability of these systems. In addition to highlighting the basic advantages AI offers, the article also examines its specific recent practical applications. Various AI approaches, including fuzzy logic, neural networks, and deep learning methods, are discussed in the context of electromechanical systems. The theoretical foundations of each AI method are briefly outlined. Special attention is given to the specific roles that AI methods play at different stages of the electromechanical systems' life cycles. The article concludes with a discussion of the advantages and disadvantages of AI in industrial applications, including computational demands, safety, and reliability. In this way, the article provides a comprehensive overview of current trends in the use of artificial intelligence in electromechanical systems, with a focus on its benefits in industrial practice.

Damage Detection in Road Images By YOLOv9 and Transfer Learning

Li Zhiyuan¹, Zhu Shuaiyu¹ and Sergey Ablameyko^{1,2}

¹ Belarusian State University, Minsk, Belarus, lil877422480@gmail.com

² United Institute of Informatics Problems, National Academy of Sciences of Belarus, Minsk, Belarus, ablameyko@bsu.by

Keywords: YOLOv8 neural network; object detection; remote sensing image; road damage detection

Abstract. This paper proposes the YOLOv9s model with the transfer learning, exploring optimization issues for image road damage detection. The proposed approach has been tested with two datasets: China Motorbike dataset and the Japan dataset from the RDD2022 dataset. The high-quality images from the China Motorbike dataset help the model extract fine road damage features, while the diversity of the Japan dataset enhances the model's generalization ability. By pre-training on the China Motorbike dataset and fine-tuning on the Japan dataset, the TL-YOLOv9s-ChinaMB-Japan model achieved improvements of 0.5% in mAP50 and 1.4% in F1-score, highlighting the effectiveness of transfer learning in improving detection performance across different environments.

Background. With the rapid advancement of urbanization, the construction and maintenance of roads have become increasingly important. Long-term use and external environmental factors, such as climate change and heavy traffic, often cause damage to road surfaces, including cracks and potholes, which threaten road safety and shorten the lifespan of the infrastructure. Therefore, timely detection and repair of road damage are crucial.

Traditional road inspection methods, conducted by personnel, are time-consuming and inefficient. Automated detection technologies based on image processing and deep learning are quickly emerging as effective solutions. By capturing road images through drones or vehicle-mounted cameras and integrating deep learning algorithms, road damage can be identified quickly and accurately, greatly improving detection efficiency. However, challenges in road damage detection include complex environments, diverse road materials, and varying data quality during image acquisition.

Objective. This paper proposes a YOLO-based road damage detection model using transfer learning. By leveraging transfer learning to combine the characteristics of different datasets, the proposed model performs well in various regions and complex environments. This enhances the model's ability to detect damage across different countries and geographical conditions, providing an effective solution for cross-regional road damage detection. Therefore, this research holds significant practical application value.

Comparison of Python and Octave as Tools for Developing Intelligent Systems

Liana Burko and Timur Zhuk

Belarusian State University of Informatics and Radioelectronics, Minsk, Belarus

As AI's popularity continues to rise, so does the number of available development tools. Within the realm of intelligent system development, various tools are meticulously crafted to address specific tasks. Some of these tools excel in machine learning model training, while others are tailored for data preprocessing or inference.

Python is a free and open-source (FOSS) programming language that is widely used for data science tasks. Python's extensive ecosystem of libraries and frameworks provides comprehensive support for various data science tasks. Both Python and MATLAB have large user bases, though the user base of the latter tool consists primarily of academics, engineers, and scientists.

GNU Octave, a MATLAB FOSS alternative, that mostly specializes in matrix operations and numerical computing. While Python, with such libraries as NumPy and SciPy, provides a more comprehensive ecosystem for scientific computing and machine learning, Octave excels in solving tasks common to academic, scientific and engineering. Python's versatility and widespread support make it a popular choice, whereas Octave offers a smooth transition for users with MATLAB background.

For research, two popular data sets were chosen. The first is "mall customers", which contains store visitors' data. The second "Hotel customer dataset" with 31 variables describes a total of 83,590 instances.

It has been demonstrated that Octave, despite its lower popularity, exhibits superior speed in rendering plots compared to Python. However, Python surpasses Octave in terms of efficiency when it comes to basic data processing tasks. These observations were made while conducting computations on a single machine.

Table 1. Time spent on an operation using different tools in seconds

Criteria	Pyt, set 1	Oct, set 1	Criteria	Pyt, set 2	Oct, set 2
Sort by age and income	0.000457	0.0024829	Sort by age and AverageLeadTime	0.017871	0.44558
Find median in inc. among fem.	0.000080	0.0021071	Find median in BC among DEU	0.006779	0.23357
Show plot of male score distr.	2.426822	0.5764	Plot of RoomNights distr. due to FRA	1.276732	0.90523

The Study of Hardware Resources Usage on Examples of Convolutional Neural Network Implementation

Dmitry Pertsau and Mikhail Tatur

Belarusian State University of Informatics and Radioelectronics, Minsk, Belarus, pertsev@bsuir.by

Keywords: CNN, LeNet-5, hardware implementation

Abstract. Deep learning convolutional neural networks marked another scientific breakthrough in the field of artificial intelligence. Following scientific achievements, technological solutions appeared both software and hardware, which were widely used in solving applied problems. Prominent representatives of software technologies are such projects as TensorFlow, PyTorch and Keras, among hardware projects - the development of GPU, the emergence of the Google Tensor Processing Unit and many other startups. On the whole, their use makes it possible to program quickly and parallelize the computational process on a modern hardware platform, and it is relatively easy to obtain satisfactory complete solutions. However, working at the “top level of technology”, the developer is deprived of the opportunity to fully manage key resources, such as performance, hardware costs, etc. Also, software developer often cannot develop original hardware implementations of neural network architectures using FPGA technologies. Software technologies such as NVIDIA CUDA allow you to manage and control the computing process. However, this approach requires a highly qualified developer to work with this technology. In the paper, we will try to demonstrate how it’s possible to manage the available resources by using various models of hardware design. In our conducting discussion, we were using the well-known convolutional network LeNet-5. In the paper, we also discuss the challenges and opportunities of introduced models.

Digitalization of Urban Systems: Kazakhstan's Experience in Creating Smart Cities

Elvira Rustenova, and Aizhan Ibyzhanova

Zhangir Khan West Kazakhstan Agrarian Technical University, Uralsk, Kazakhstan

Keywords: Smart City, information and communication technologies, digitalization, urban infrastructure, sustainable development

Abstract. The article deals with the concept of “smart city”, which attracts considerable attention among researchers and specialists in the field of sustainable development. The historical background of the emergence of this concept and its evolution since its appearance in the 1990s are described. The study analyzes the main elements and stages of building “smart cities” in Kazakhstan based on the Reference Standard Smart City Kazakhstan, approved by the Ministry of Digital Development, Innovation and Aerospace Industry of the Republic of Kazakhstan. A comparative analysis with international practices and standards is carried out, key

areas of digital initiatives are identified, and the advantages and challenges of implementing the concept in the conditions of modern urban development are assessed. The main attention is paid to the multi-level target architecture of the “smart city”, which includes the infrastructure layer, platforms, data, analytics, integration components and services. The authors conclude that the successful development of smart cities in Kazakhstan requires a systematic approach, coordination between government agencies and active participation of citizens. The article emphasizes the need for further development of pilot projects, investments and educational programs for professionals to ensure sustainable urban development and improve the quality of life of the population.

Acknowledgment. The presented research was a post-project activity of ERASMUS+ ACeSYRI: Advanced Center for PhD Students and Young Researchers in Informatics reg.no. 610166-EPP-1-2019-1-SK-EPPKA2-CBHE-JP.



Empirical Hardness of the AES Cipher

Martin Lukac and Kanat Alimanov

Hiroshima City University, Japan, malu@hiroshima-cu.ac.jp

Keywords: AES, Neural Networks, Machine Learning

Abstract. The AES symmetric cipher is a standard encryption method used in various currently used network protocols. Although it has proven resistant to most direct attacks, it hasn't been extensively studied from the perspective of modern neurocryptanalysis and big data. Therefore, this paper aims to experimentally analyze the components of the AES protocol, empirically determine their learnability, and provide empirical results that demonstrate the hardness of the cipher. For this purpose we build a full piece by piece neural equivalent of the AES cipher. We verify that if provided with correct parameters it implements a given AES encryption with up to 99.9% accuracy. We evaluate a neural model's ability to learn the different components of the AES cryptosystem as well as their combinations. Then we focus on learning the Add Round Key network representing the adding of the scheduled encryption key to the input message. Our target is to determine if and under what conditions it is possible to learn such network without extracting the encryption key directly. Through our research, we show that AES is indeed resistant to machine learning attacks. We also show that due to the diffusion operators a specific type of gradient concentration or vanishing appears while backpropagating through even a single of such diffusion neural models.

Finally, we also demonstrate that for specific configurations, reduced size AES can be learned but for standard size AES learning does not occur independently of the neural network or training data size.

Acknowledgment. The presented research was a post-project activity of ERASMUS+ ACeSYRI: Advanced Center for PhD Students and Young Researchers in Informatics reg.no. 610166-EPP-1-2019-1-SK-EPPKA2-CBHE-JP.



Testing Stability of Virtual Machines with Various Strategies of Resource Provisioning

Marek Durana and Miroslav Kvassay

Faculty of Management Science and Informatics, University of Zilina, Zilina, Slovakia,
marek.durana@fri.uniza.sk, miroslav.kvassay@fri.uniza.sk

Keywords: availability, benchmarking, virtual machine, virtualization

Abstract. Virtualization is an ever-present technology in modern IT infrastructures and poses a wide research area to the scientific community. In this work, we examine the history of virtualization and dive deeper into exploiting one of the most used implementations in Linux ecosystems – the Kernel-based Virtual Machine (KVM). KVM is a Type 1 hypervisor – running on a Linux operating system implemented directly in its kernel. This fact provides us with options to use Linux in its usual way, while allowing us to pass through hardware devices, like drives, directly to Virtual Machines (VMs), which can take advantage of this and provide higher input/output performance. With a benchmarking tool composing of various tests, we have been provided with detailed results of different system hardware configurations. These configurations varied in number of CPU cores, amount of system memory and number of VMs running in parallel. Tests were provided by Geekbench6 – a widely used Linux benchmarking tool. Run tests composed of various workloads, namely zipping and unzipping of files, generating directions between a sequence of locations, opening webpages, rendering complex PDF files, compiling Lua interpreter and others. Results were provided in score-like values, providing us a way to easily compare various specification scenarios. As was expected, more VMs used more resources until they were completely used up and started to crash. We also compared the results with running the tests directly on KVM host, which provided us with highest achievable benchmark scores of our system, and on VM running with hardware virtualization disabled in BIOS settings for reference. These results shall be used to help develop a dynamic scaling feature of virtual machines' specifications under Linux operating system.

Modelling Reliability of Multi-Purpose Synthesis System in Presence of Common-Cause Failures

V.I. Fettsov¹, N. Brînzei², and I.T. Utepbergenov¹

¹Almaty University of Power Engineering and Telecommunications, Automation and control department, 050013 Almaty, Kazakhstan, v.fettsov@inp.kz; i.utepbergenov@aes.kz

² Université de Lorraine, CNRS, CRAN, F-54000 Nancy, France, Nicolae.Brinzei@univ-lorraine.fr

Keywords: multi-purpose synthesis system; common-cause failure; Hasse diagram; system reliability

Abstract. This paper presents a study on modelling the reliability of a multi-purpose synthesis system made of Commercial off-the-shelf (COTS) parts operating under radioactive conditions, using a Hasse diagram-based approach. The system, exposed to radiation, requires high reliability to operate without failures. A classical and effective way to improve the system reliability to the high required level, is to use the redundancy of its components or subsystems. But the benefits of redundancy can be reduced when a common cause failure (CCF) occurs. The common cause failures are a class of dependent failures of several components at the same time resulting from a shared cause (e.g. radiation). To have an adequate system reliability model, in the presence of redundancies, CCFs should be considered.

Many models exist in the system reliability field to consider CCF. One of the best known and largely used models of CCF is the β -factor model. This model considers that the system components experiment two types of failures: independent failures specific to each component and common cause failures. In this study, a proposed approach incorporates β -factor model of CCF into Hasse diagrams to map the relationships between component failures and their impact on system reliability.

A new Boolean variable is added to the system state vector which represents now both the set of component's states and the CCF occurrence. Then a system reliability model taking into account CCF can be obtained as a form of graph model issued from Hasse diagram and so the reliability of multi-purpose synthesis system can be evaluated. The results highlight the critical role of accounting for CCFs, offering a structured approach to reliability modelling that is adaptable also to similar industrial applications.

Acknowledgment. The presented research was a post-project activity of ERASMUS+ ACeSYRI: Advanced Center for PhD Students and Young Researchers in Informatics reg.no. 610166-EPP-1-2019-1-SK-EPPKA2-CBHE-JP.



Improving the Reliability of Automatically Generated Test Suites

O. Kolchyn, S. Potiyenko and V. Volkov

V.M. Glushkov Institute of cybernetics NAS of Ukraine, Kyiv, Ukraine, kolchin@nas.gov.ua

Keywords: software testing, test suite generation; coverage criterion; software reliability

Testing is a crucial activity for software reliability. Due to its labour intensity, automated generation of test suites is often used. However, the pressing question is whether such a test suite can be trusted and relied upon.

Our experience with off-the-shelf model checkers and various structural coverage criteria leads us to the conclusion that such test suites are unreliable in many practical cases, even though they achieve high levels of coverage. A noticeable example of this problem is a case where a computed value never reached the output because it was reassigned or the test led to premature termination, rendering the entire test suite completely useless. The generated tests are often a confusing, chaotic, and intuitively unrelated sequence of actions. This is because they are artifacts of a search strategy, where the focus was solely on covering structural elements. Such test scenarios are usually unclear and meaningless to testers: they often tend to terminate early, failing to achieve the effect of the coverage, or the execution sequence can be unnecessarily long, and contain a high percentage of redundancy.

To improve the purposefulness of the tests and reasonability in their scenarios, we have developed more stringent coverage criteria that additionally rely on data flow to organize causal relationships in the test. We have also enhanced the all-uses criterion by requiring coverage of certain chains of conditions [1], where predicates refine variable values along the execution path. This strategy maintains cohesion in the sequence of test actions and adds reasonable variability to tests. Our experience shows that intensive use of data flow positively impacts achieving the desired test properties, contributes to data consistency, meaningfulness of the tested behaviour, and observability of the coverage effect. To address issues of complexity and excessive redundancy, the pure def-use criterion [2] was developed. This strategy tries to avoid redefinitions and focuses on producing simpler test cases that are considered more intuitive by practitioners.

To validate a test suite and ensure test cases are reliable, we developed an interactive post-processing method [3] that allows analysing the test case scenario and making safe modifications to it to eliminate shortcomings while preserving the test case's coverage targets.

As a result of applying these methods in legacy modernization projects [4], we achieve improving mutation-based assessment by about 20% and considerable enhancing of the reliability of model-based test generation strategy, thereby increasing confidence in the test suite.

References.

1. Kolchin A., Potiyenko S. Extending Data Flow Coverage to Test Constraint Refinements. In: iFM 2022. LNCS, vol. 13274. (2022).
2. Kolchin A., Potiyenko S., Weigert T. Extending data flow coverage with redefinition analysis. In: IEEE International Conference on Information and Digital Technologies. pp. 293–296 (2021).
3. Kolchyn O., Potiyenko S. Improving model-based testing through interactive validation, evaluation and reconstruction of test cases. In: QUATIC 2024, CCIS, vol. 2178, pp. 1–9. (2024).
4. Weigert T., et al. Generating test suites to validate legacy systems. In: SAM 2019. LNCS, vol. 11753, pp. 3–23. (2019).

Implementing 3MU Identification in Chaotic Environments

A. Nouri Qarahasanlou, A. Barabadi, and J. Barabady

Department of Technology and Safety, Faculty of Science and Technology, UiT The Arctic University of Norway - University of Tromsø, Tromsø, Norway, Ali.Nouri@uit.no, abbas.b.abadi@uit.no, javad.barabady@uit.no

Keywords: Lean, Muri-Mura-Muda (3MU), Rapid improvement, Muri-Mura-Muda identification process (3MU.IP)

Abstract. Waste identification is critical in the industry for reducing costs, improving efficiency, and sustaining competitive advantage. This project focused on the MURI, MURA, and MUDA (3MU) identification process (3MU.IP) to systematically eliminate waste. This approach begins with defining value, continues with waste identification, and then identifies the origins of waste to prioritize necessary measures. The methodology was implemented at the Jajarm Alumina Complex, specifically targeting leakage in the caustic soda transferring and receiving unit. Through the Extended Failure Mode, Effects, and Criticality Analysis (E-FMECA), 47 potential root causes were identified. The Rapid Improvement strategy prioritized these, highlighting key issues such as inadequate risk analysis (RPN = 175.50) and improper drainage (RPN = 408.89). Three strategies, risk-based, usual, and rapid improvement, were employed to address these causes. The findings emphasize the importance of precise risk assessment and quick action, with the rapid improvement strategy proving particularly effective in reducing waste.

This approach enabled the Jajarm Alumina Complex to achieve rapid improvement and mitigate waste in the caustic soda tank; the complex must develop accurate risk analysis capabilities.

Parallel Numerical Simulators for Surrogate Modeling of Random Fields

O. Dmytriyeva^{1,2}, V. Huskova² and A. Khalyhov³

¹ Institute for modelling hydraulic and environmental systems, University of Stuttgart, Stuttgart, Germany, olga.dmytriyeva@iws.uni-stuttgart.de

² National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”, Kyiv, Ukraine

³ Institute of Telecommunications and Global Information Space, Kyiv, Ukraine

Keywords: parallel numerical simulator; surrogate models; correlation matrix; eigenvalues

Abstract. Numerical simulators for surrogate modeling of random fields using correlation matrices of ultra-high dimensions are proposed in the paper. The developed software system is parallel-oriented for separating and refining the eigenvalues of symmetric filled Toeplitz matrices using priority search.

Background. Random fields are generated when modeling groundwater movement, including the transport of pollutants and geological processes of CO₂ storage in deep saline aquifers, which allows limiting greenhouse gas emissions into the atmosphere. In the numerical implementation of such types of stochastic processes, surrogate models have recently been actively used. These models, which are oriented toward reducing the ultra-high dimensionality in emulators of Gaussian processes, nevertheless ensure the preservation of the qualitative features of the original models.

Objective. When developing mathematical models of stochastic processes, there is a need to numerically determine the eigenvalues of the homogeneous integral Fredholm operator of the second kind, the kernel of which is the correlation function. The purpose of the work is to develop and efficiently implement in parallel the processes of calculating the eigenvalues of symmetric Toeplitz matrices of large dimension, which are formed when modeling stochastic fields.

Methods. The study's methods took into account the regular structure of the correlation matrices. An iterative procedure for calculating eigenvalues was employed, which, with minor modifications, allows for effective parallel implementation. The roots of the rational function were determined using the Trench method, incorporating recursive Levinson-Durbin transformations.

Results. The study explores modern approaches to mathematical modeling of random fields using ultra-high dimensional correlation matrices. It proposes constructing surrogate models to reduce the high dimensionality of stochastic input spaces. To determine the eigenvalue spectrum of symmetric Toeplitz matrices and localize the eigenvalues, the use of Gershgorin circles is suggested. A priority search procedure was developed for separating and specifying all eigenvalues of the matrix during the modeling of random fields. Comparative testing evaluated time consumption, solution accuracy, parallelism coefficients, and overall efficiency.

Conclusion. The research results presented in the work are oriented towards application in mathematical models aimed at processing random multidimensional spatial fields. This is connected with the implementation of numerical approaches that are highly resource-intensive both in terms of time and memory resources. The work examines modern approaches to mathematical modeling of random fields using correlation matrices of ultra-high dimensions. Techniques for building surrogate models focused on reducing the high dimensionality of stochastic input spaces are considered.

Reliability and Maintainability of Technical Systems: Modularisation Versus Overall System. Case Study Electric Vehicles

J. Pietruschka¹, M. Inoue², G. Ioannou¹ and S. Bracke¹

¹Chair of Reliability Engineering and Risk Analytics, Faculty of Mechanical and Safety Engineering, University of Wuppertal, Germany, {pietruschka, ioannou, bracke}@uni-wuppertal.de

² Department of Mechanical Engineering Informatics, Meiji University, Japan, m_inoue@meiji.ac.jp

Keywords: Electric Vehicles (EV); Electromobility; Traction battery system; Modularization; Circular Economy

Abstract. The general electrification of the mobility sector is leading to an exponential increase in the number of electrically powered vehicles. The core of the electrical energy supply is the battery pack, in which hundreds to thousands of battery cells are installed in a wide variety of cell shapes, sizes and arrangements. Various connection technologies are used to structure the batteries in parallel and series connections in order to guarantee the required energy and performance. The geometric, safety-related and customer-specific requirements for the various vehicle designs result in different integration concepts. Depending on the concept, battery packs can be used in modular form or in an overall system, resulting in different advantages and disadvantages in terms of scalability, adaptability, space requirements, costs, temperature and control management. While modular systems are fundamentally more maintenance-friendly due to distributed and partially independent integration, composite systems with cylindrical cell designs offer measures, in order to increase the service life of the battery, that are easier to implement in comparison. The heterogeneity of the battery concepts of the various manufacturers leads to the research question discussed in this article regarding the reliability and maintainability of these systems. Specifically, modular battery packs are compared with those in a composite system, as no design has yet established itself in the electric vehicle (EV) sector and all variants are represented. The focus of this comparison is the reliable reusability of the various package concepts in a circular economy, which is influenced by usage-related degradation processes.

Machine Learning Analysis of Potential Mobile APPS Threats on the Basis of Permissions

T. Hovorushchenko, O. Pavlova, V. Alekseiko and Andrii Kuzmin

Computer Engineering & Information Systems Department of Khmelnytskyi National University,
Khmelnyskyi, Ukraine, tat_yana@ukr.net

Keywords: mobile application; permission; threat; machine learning; cybersecurity

Abstract. Nowadays, the use of mobile applications is extremely common. The number of new applications is constantly increasing, and accordingly, because of this, it is becoming increasingly difficult to determine the level of danger of a particular application. The issue of privacy and data security is especially acute, particularly because of the permissions that apps request. Such permissions can give applications access to sensitive user information and system resources, which, if misused, can lead to security risks. This research focuses on mobile application threat analysis using machine learning (ML) with a focus on the Android permissions dataset. By examining how different apps use and potentially abuse permissions, this research aims to identify high-risk apps that pose a serious threat to user privacy and cybersecurity.

The importance of permissions as a vector for understanding mobile app security is undeniable, and a permission-based ML analysis approach can improve current app verification processes. This methodology can be further extended to include dynamic analysis where application behavior is monitored in real-time, providing an even more robust assessment of security risks in mobile environments.

Objective. On the basis of the dataset with detailed information on app permissions, it can be analyzed risk level of the app, using machine learning models to recognize dangerous request patterns. Permissions like access to location, contacts, and messaging are critical indicators of app behavior can lead to data leakage or unauthorized access to sensitive information. ML models can successfully differentiate between benign apps and those that exhibit suspicious behavior by analyzing permission patterns. The aim of the research to identify apps that request an unusually high number of dangerous permissions without clear justification, flagging them as high-risk.

Methods. During the research, the following general scientific research methods were applied: Empirical: descriptive, comparative, experimental. Theoretical: analysis, induction, modeling, abstraction, formalization.

Research of Automated Control System of Gravity Enrichment Method of Chrome ORE

Duzbay Nurdaulet

Kazakh National Research Technical University named after K. I. Satpayev, Kazakhstan, Almaty

Keywords: Productivity, processing of mined material, recycling, increasing efficiency.

Annotation. The study of the automated control system of the gravity beneficiation method of chrome ore is a key aspect in the field of mining industry. This study aims to evaluate the efficiency and potential of automation of the beneficiation process of chrome ore using gravity methods.

The aim of the study is to analyze the technical and technological parameters of the control system, develop and optimize automation algorithms, and assess the benefits of implementing an automated system in comparison with traditional enrichment methods.

It is necessary to improve the processing technologies of both mined and man-made raw materials, which are renewable resources and do not require additional costs for extraction and primary processing. Enrichment of existing man-made raw materials and high-quality processing of mined material can contribute to the ecological restoration of territories that have been negatively affected by the activities of the mining and mining processing industries. Moreover, in some cases, the content of valuable components in man-made waste exceeds their concentration in natural deposits, which makes their processing profitable from an economic point of view. The need for complete processing of ore and reduction of the volume of waste generated in the process of beneficiation production is becoming increasingly urgent.

The productivity of enrichment equipment is determined by enrichment indicators, such as the concentration of the valuable component in the final product (concentrate) and the content of the valuable component in production waste (tailings).

The results of the study will allow us to draw conclusions about the feasibility of introducing an automated control system for the method of gravity enrichment of chrome ore into industrial production. This can lead to improved product quality, increased production efficiency, and reduced personnel and equipment costs.

Sensitivity of Goal Function in R-Facility Interdiction Covering Problem and Systemic Risk

V.M. Gorbachuk, D.I. Nikolenko, V.V. Godliuk and D.O. Rybachok

V.M. Glushkov Institute of Cybernetics of the National Academy of Sciences of Ukraine, Kyiv, Ukraine, GorbachukVasyl@netscape.net

Keywords: target; demand point; coverage; location; Boolean

Background. Let the target be an object (facility, asset, tool). Suppose there is a set of objects that make up a system that can be attacked, and there are resources to attack some (r) of these objects. For example, communication facilities have a limit on how far each facility can communicate with a point of demand, providing the maximum standard of service. Each demand point will continue to receive broadcast communication as long as there is at least one means of communication after the attack that covers the demand range.

Objective. Here, the (attacker's) task is to find those objects that are worth attacking or damaging (destroying, blocking), and guarantee the absence of communication services for the highest volume of demand. In the mathematical model, decision variables maximize the objective function of the demand volume which will lose coverage after blocking.

Methods. The decision variables are: a Boolean variable with a value of 1, when the demand at the certain point is not covered; a Boolean variable with a value of 1 when the tool in the specific location is disabled (blocked). The problem includes a set of specific demand points, a set of specific locations of existing facilities to cover demand points, volume of demand at each location. This model has a limit on the number of blocked or destroyed objects. Therefore, only demand points that have lost all of their existing means of coverage can be considered to have lost full coverage. For different locations p of demand points, the problem of finding a subset of objects, whose blocking maximizes the resulting reduction in the coverage of these locations, is called the r -object coverage problem (r -facility interdiction covering problem).

Results. The problem can be solved using any integer linear programming software. If the number of tools is small enough, then the problem can be solved by enumeration. For example, if there are resources for blocking 3 tools among 10 existing ones, then there are only 120 different combinations of such blocking. The optimal value of the objective function of problem is dependent on r as well as other problem data.

Conclusion. Direct enumeration will require at least powerful computing resources (say, large-scale parallel computations over long periods of time) for large r and significant possible interdictions. The post-optimal sensitivity analysis of the problem above is a robust way to measure a systemic risk.

synTEXT4JSON: Framework for Generating Synthetic Data for Template-Filling Task

Miroslav Potočár and Michal Kvet

Faculty of Management Science and Informatics, University of Zilina, Zilina, Slovakia,
,miroslav.potocar@fri.uniza.sk, michal.kvet@fri.uniza.sk

Keywords: template-filling; data generation; large language model; JSON; synthetic data

Abstract. Template filling is a natural language processing task where unstructured text and a structured format template (such as JSON) are input into the process and the output is a target structure filled with data extracted from the unstructured text. This task has much in common with other natural language processing tasks such as reading comprehension, slot-filling and information extraction. The problem is that there is currently no suitable dataset that can be used to train and evaluate models solving this task yet. Manually creating a dataset for different domains would require a lot of human effort and time. Data augmentation can be used to address the problem of data scarcity, whereby a large amount of synthetic data can be generated from a small number of existing samples, which can then be used to train models. In a low-resource settings, such synthetic data was used to train the models, resulting in an improvement in performance on the test set. In this research, a novel framework, synTEXT4JSON, is proposed and described to synthetically generate texts for the task of template-filling. The framework consists of four basic components, a generator, an evaluator, an augments and a composer. The actual implementation of each component is not strictly defined, which makes it possible to use arbitrary implementations for each component. The functioning of the framework and its different components are presented on the real estate domain, where it is used to generate various synthetic data on apartments.

Background. The unstructured form of texts occurs very often in real-world scenarios. It can take the form of posts on social networks, product descriptions on e-shops or descriptions under advertisements. These texts often contain important information that needs to be further stored, analysed or evaluated, for which computers are used today. However, computers and machine learning algorithms require data in the required structured format as input. Extracting structured data from unstructured texts in an automated way poses a challenge. In most cases, the required format is known, and it is also known that the input unstructured text contains the required information. The challenge is how to extract the necessary information. This problem is represented by a template-filling task, where unstructured text is fed as input along with the required template containing the information to be extracted from the unstructured text, with the output being a structured format containing the required data. The task has much in common with various natural language processing tasks such as reading comprehension, information extraction, information retrieval, question answering or slot-filling.

However, it cannot be clearly classified into any of these categories. There are no suitable datasets (if any) available for this task that could be used to train and test models designed to solve this task. Therefore, the goal is to create appropriate datasets. Suitable texts need to be obtained and properly annotated. Such data gathering would require a lot of effort and time. Data augmentation can be used to generate initial datasets for this task, which allows the generation of synthetic training samples. For this reason, the synTEXT4JSON framework is proposed, which defines a procedure by which synthetic data can be generated for the task of template-filling.

Objective. The objective of the study is to propose and describe a method for generating synthetic data for the template-filling task. The whole synthetic data generation problem needs to be divided into several parts. The first is the creation of suitable structured templates to be populated based on unstructured texts. These unstructured texts need to be created first. Based on the required information in the structured templates, human sounding sentence templates are generated which will be appropriately populated with information. From these sentence templates, unstructured texts will be constructed, which will be populated with the information from the artificially filled templates. This will produce triples consisting of unstructured text, structured template and structured filled output. The triples created in this way represent a single data sample of the synthetic dataset.

Methods. As a demonstration example, data generation for a real estate domain was chosen. Through the synTEXT4JSON framework, a dataset is generated for the template-filling task. JSON was used as the template in which the attributes used represented information about the apartments such as area, price, number of bathrooms, etc. Based on these templates, unstructured texts are constructed using synTEXT4JSON framework.

The framework consists of 4 components. The first component is the generator. This is used to generate human sounding sentences for each attribute of the template. A pre-trained large language model is chosen as the generative model. Its task was to generate sentences, based on a given question related to an attribute (e.g. "What is the area of the apartment?"), which will contain the information needed to answer this question (e.g. "The area of the apartment is 50 square meters."). These sentences were then used to generate further questions. The task of the model was to generate a question that asks for the information given in the provided sentence. This creates a multi-turn generation, where the sentence generator generates sentences based on the questions and then these sentences are used by the question generator to generate questions. Not all generated questions and sentences are suitable. The generated outputs need to be evaluated by the classifier to see if they are appropriate to be used for further generation. The second component is used here, which is the evaluator. This can be represented by a human-in-the-loop approach or by training a classifier to evaluate whether the generated output is appropriate or inappropriate for further processing. However, since the goal is to generate a dataset in a low-resource setting, training a classifier is unlikely to be feasible. Therefore, a hybrid

approach can be used, where a human-in-the-loop technique will be used initially, where a human evaluates the generated outputs and based on these outputs a classifier will be trained to replace the human in the process over time. The third component is the augments. This component allows extracting even more additional input data from the generated questions and answers, which can be used in the next generation process by the generator or already in the actual construction of the unstructured texts. There are many possibilities of data augmentation. One of the augmentation methods is back-translation, which consists in translating the input text in the source language into another language and then translating this translation again into the source language. Although it is a simple and straightforward method, it achieves good results. The last component is the composer. Its task is to combine the generated sentence templates into a meaningful continuous text containing all the necessary information to fill the template. The composition process itself can take several forms. One possibility is to select sentences for each template attribute at random from the set of candidate sentences. Another option is to select sentences so that the resulting unstructured texts are as diversified as possible. This can be achieved by evaluating a metric expressing the diversity of the currently generated text from the previously generated texts when selecting sentences for the resulting unstructured text. Finally, data-filled target structured formats are generated for the unstructured texts and their templates, and the unstructured texts are filled with underlying data.

Results. The result of the work is materialized in the synTEXT4JSON framework, which provides a proposal on how to generate synthetic data for the template-filling task. The framework is modular and implementation-independent, making it suitable for generating datasets for different domains and different output structure formats. The framework was used to generate data from the real estate domain to generate a suitable dataset usable for training and evaluating models to solve the template-filling task. As this is the first version of this framework, not all the procedures are properly designed and fine-tuned, so there is room for further improvement. In future work, it would be useful to focus on the quality of the generated sentences. This can be improved by tuning the generative model or by designing better prompts. Attention should also be paid to the evaluator component. Here, emphasis should be placed on ensuring that the generated outputs are correctly classified with as little human effort as possible. This could be achieved by using a generic and domain-independent model that learns to correctly classify the generated sentences and questions based on a small number of training examples.

Conclusion. The need to convert unstructured text into the required structured format occurs very frequently in real-world scenarios. The task of template-filling tries to represent this problem as closely as possible. However, due to the lack of suitable datasets, it is not possible to develop new techniques and train models to address it. The synTEXT4JSON framework attempts to fill this gap and provides guidance on how to generate the necessary synthetic datasets so that this field of text mining and natural language processing can be further developed.

University Selection System, Problems and Solutions

T.V. Kisel¹ and B.V. Nikulshin²

¹Polesky State University, Pinsk, Belarus

²Belarusian State University of Informatics and Radioelectronics, Minsk, Belarus

Keywords: applicant; group of specialties; specialty priority; general competition

The aim of the study was to examine the current practice of admission to universities in the Republic of Belarus, in particular the organization of competitive selection by groups of specialties, identifying the strengths and weaknesses of this approach and developing recommendations for its improvement. In accordance with paragraph 30 of Chapter 5 of the Admission Rules, by decision of the admissions committee (when using an automated enrollment system), an applicant may be given the opportunity to participate in a competitive selection for any number of specialties within the selected group (enrollment is carried out for a specialty) in the order of priority determined by him in the application when submitting documents.

The organization of competitive selection by groups of specialties has a number of advantages for both applicants and universities. Many Belarusian universities use the selection system with a general competition by groups of specialties. This opportunity is widely used not only in our country, but also in the countries of the former Soviet Union. On the other hand, the possibility of organizing a competitive selection by groups of specialties provides greater variability in the formation of an application, which may be difficult for applicants and ultimately be the cause of dissatisfaction with the results of the competitive selection.

A possible solution to this problem may be the optimization of the set of specialties formed by the applicant and their ranking in the application. Initial data: a group of economic specialties of the educational institution "Polesie State University"; a set of specialties formed by the applicant; overall score of the applicant; passing scores for specialties (from 2020 to 2024). To determine the optimal set of specialties with their ranks, the Kemeny-Snell method was used to rank alternatives.

As a result, a recommendation was received for the current year of submission of documents, in the form of an ordered set of specialties, taking into account the statistics of previous years, which will improve the validity of decisions made by applicants when choosing specialties and, consequently, the level of their satisfaction with the results of the competitive selection

Synthetic Data Generation for Enhancing Specialized Object Detection Models

B. Sydor¹, S.Liaskovska^{1,2} and O. Duran²

¹ National University "Lviv Polytechnic", Institute of Computer Science and Information Technologies, Artificial Intelligence Systems Department, Lviv, Ukraine, solomiam@gmail.com

² Kingston University, Faculty of Engineering, Computing and the Environment, Department of Mechanical Engineering, Faculty of Engineering, Kingston Upon Thames, London, UK

Keywords: object detection; stable diffusion; gaussian splatting; synthetic data generation; 3D reconstruction; deep learning; computer vision

Abstract. Synthetic data generation for enhancing specialized object detection models The rapid development of artificial intelligence has propelled object recognition into a foundational role across diverse fields, such as autonomous driving, robotics, medical imaging, industrial inspection, and security systems. Object recognition models are integral to these technologies, allowing them to process and interpret complex visual information, which is essential for accurate and safe operations. The success of these models is highly dependent on access to extensive, high-quality datasets for training. However, gathering real-world data at the required scale, with controlled variations in lighting, perspective, and environmental context, is often prohibitively costly and logistically challenging. To address this, synthetic data generation has become an essential approach, providing a scalable, customizable alternative that supports the creation of large, diverse, and realistic datasets tailored for object recognition tasks. Despite progress with generative models, current methods often fall short of incorporating complex semantic information, leading to synthetic data that lacks realistic context and quality. This paper proposes a novel generative approach leveraging Stable Diffusion to produce synthetic datasets that are not only semantically consistent but also highly detailed, overcoming the resolution limitations of traditional models. Additionally, we integrate Gaussian Splatting, a recent advance in 3D reconstruction, to enhance object realism and provide diverse viewpoints. This framework achieves a higher level of detail and semantic alignment in synthetic data, boosting model generalization and robustness across a broad range of real-world applications. By offering an efficient and precise solution to data scarcity, this approach enables more effective deployment of object detection models for unique objects in critical environments.

Background. Object recognition is a foundational task in computer vision and machine learning, essential for applications like security systems and autonomous vehicles. This technology enables systems to identify and interpret objects within visual data, crucial for safety and efficiency in real-world environments. However, achieving high recognition accuracy requires models trained on large, diverse datasets, which are costly and challenging to create.

Although AI advances offer solutions, there is an ongoing need for new methods that efficiently generate high-quality training data and improve model robustness across varying conditions.

Objective. The primary purpose of this paper is to propose a novel approach for generating high quality synthetic datasets tailored for object recognition tasks. By leveraging Stable Diffusion and Gaussian Splatting, this method aims to address limitations in current data generation techniques by producing semantically rich and detailed synthetic data. This approach enhances model accuracy and robustness, supporting effective deployment of object recognition models across diverse, real-world applications.

Methods. This paper presents a comprehensive framework for synthetic data generation, combining Stable Diffusion for detailed and semantically consistent image creation with Gaussian Splatting for advanced 3D reconstruction. First, we reviewed existing synthetic data methods and identified key limitations in capturing complex semantic details. Using Stable Diffusion, we generated realistic images with controlled variations in lighting, angles, and environmental context, enhancing dataset diversity. Gaussian Splatting was applied to produce high-fidelity 3D object models from varied perspectives, further enriching the dataset. We trained object recognition models on these datasets and evaluated performance improvements compared to models trained on conventional data. Analytical metrics focused on model accuracy, robustness, and generalization across diverse scenarios. **RESULTS** The proposed synthetic data generation framework significantly improved object recognition model performance. Models trained on the datasets generated using Stable Diffusion and Gaussian Splatting achieved an accuracy increase of up to 95%, compared to 84% for models trained on synthetic datasets generated by previous SOTA methods. These results highlight the benefits of integrating semantically rich synthetic images with high fidelity 3D reconstructions, which provided the model with diverse and contextually accurate data. Furthermore, models demonstrated enhanced robustness and generalization, performing consistently well across varied lighting conditions, angles, and environments (Fig.1).

This approach confirms the effectiveness of our method in addressing limitations of traditional synthetic datasets, offering a viable solution for high-performance object recognition in real-world applications.

Conclusion. This study demonstrates that combining Stable Diffusion with Gaussian Splatting for synthetic data generation provides a robust solution for enhancing object recognition models. By generating semantically rich and contextually accurate synthetic datasets, this approach significantly improves model accuracy and adaptability across diverse conditions. The results indicate that synthetic data generated using this framework can effectively supplement or replace conventional datasets, reducing reliance on costly real-world data collection. This method has strong implications for advancing object recognition capabilities in critical fields such as autonomous systems, security, and industrial applications, promoting more efficient and reliable AI model deployment.

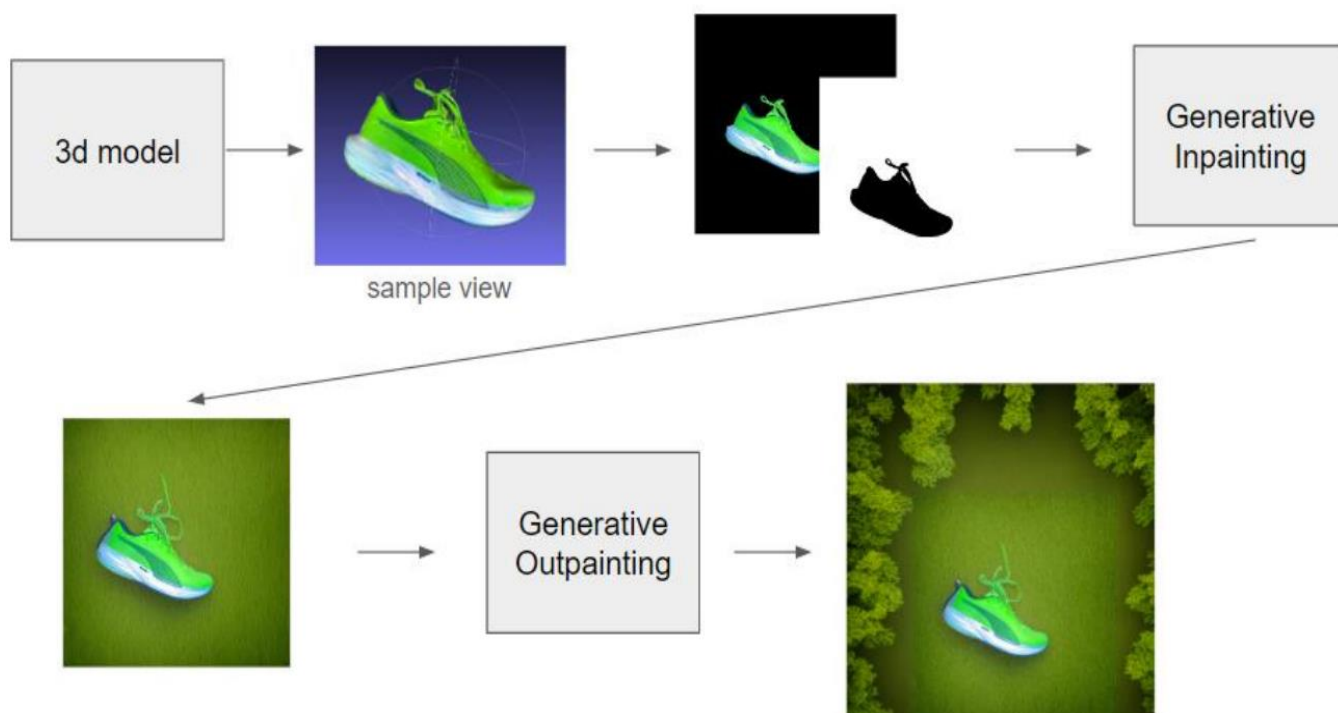


Figure 1. Synthetic data generation for enhancing specialized object detection models

References.

5. Maio R., Araújo T., Marques B. etc., Pervasive Augmented Reality to support real-time data monitoring in industrial scenarios. *Computers and Graphics (Pergamon)*. vol. 118, 2024. pp. 11–22. DOI:10.1016/j.cag.2023.10.025.
6. Velusamy S., Raguvaran S., Kumar S. V., etc. From Industry 4.0 to 5.0: Digital management model of personnel archives based on transition from digital manufacturing. *Emerging Technologies in Digital Manufacturing and Smart Factories*. 2023. pp. 1–25. DOI:10.4018/979-8-3693-0920-9.ch001.
7. Maio R., Araújo T., Marques B., etc. Pervasive Augmented Reality to support real-time data monitoring in industrial scenarios. *Computers and Graphics (Pergamon)*. vol. 118, 2024. pp. 11–22. DOI:10.1016/j.cag.2023.10.025.
8. S. Liaskovska, V. Mil, O. Duran, Y. Martyn, O. Pshenychny Efficient Collision Detection and Trajectory Validation Approach in Static Scenes Using Deep Neural Networks138-149 <https://ceur-ws.org/Vol-3699/paper10.pdf>
9. Penchel R. A., Aldaya I., Marim L., etc. Analysis of Cleaner Production Performance in Manufacturing Companies Employing Artificial Neural Networks. *Applied Sciences (Switzerland)*. Vol. 13, no 6. DOI:10.3390/app13064029.
10. J. A. J. Alsayaydeh, A. Aziz, A. I. A. Rahman, S. N. S. Salim, M. Zainon, Z. A. Baharudin, M. I. Abbasi, and A. W. Y. Khang, "Development of programmable home security using GSM system for early prevention," *ARPN Journal of Engineering and Applied Sciences*, vol. 16, no. 1, pp. 88-97, 2021.
11. Suhail, M., Esteves, C., Sigal, L., & Makadia, A. (2022). Generalizable Patch-Based Neural Rendering. *ArXiv*, abs/2207.10662.

Reducing the Impact of the Reproducibility Crisis on the Ranking of Binary Classifiers through the Examination of Performance Scores' Consistency

Attila Fazekas¹, Gyorgy Kovacs² and Mohammed Aad Khudhair¹

¹ Faculty of Informatics University of Debrecen Debrecen, Hungary, attila.fazekas@inf.unideb.hu, mohammeda.khudhair@inf.unideb.hu

² Analytical Minds Ltd. Beregsurany, Hungary, gyuriofkovacs@gmail.com

Abstract. Binary classification tasks are prevalent in various fields of computer science, leading to the development of numerous classifiers for their efficient solution. This has implied a demand for ranking the binary classifiers, typically based on performance scores. Considering that, due to the reproducibility crisis, often only published performance scores are available, verifying their reliability is crucial. In recent years, the system of expectations related to research has undergone significant transformation. This is primarily because individual countries have developed methods to measure the effectiveness of research projects in order to create an efficient financing system. While using these developed methods has beneficial effects, it also comes with several disadvantages. One of these negative effects is that researchers face expectations that make it important to maximize the value of indicators that assess research performance. A very simple example of this is that when research performance was measured by the number of publications, it became advisable to publish several short papers instead of one long.

Today, one such expectation for researchers is to publish their results in the shortest possible time in the most prestigious journals (D1, Q1, Q2) or to present them at high-quality conferences (A*, A, B). This publication pressure also imposes high expectations on journals (similarly to conferences), as they must select the best publications from numerous submitted manuscripts in the shortest possible time to ensure rapid publication. To achieve this goal, journals expect reviewers to make quick decisions about whether a manuscript is suitable for publication in its current or future form.

This is also necessary to maintain the ranking of journals or conferences. This has also contributed to the importance of using so-called performance scores to characterize new methods and algorithms in many areas of computer science. The widespread use of these performance scores has almost naturally resulted in the usefulness and often the publishability of a new method or algorithm is determined by whether it has better performance scores compared to previously published methods or algorithms.

A decision based on such a simple principle (better performance score – better algorithm) might be justified if these performance scores were reproduced by reviewers. In research, it is crucial that published results are well-founded and reliable [1]. Therefore, the reproducibility of results should be considered one of the

cornerstones of science, as the inability to reproduce results calls into question their validity. Despite this, a 2016 survey [2] revealed that more than 70% of researchers failed to reproduce a research experiment. This so-called reproducibility crisis prevents new results from being integrated into the existing body of knowledge.

The above trends have undoubtedly been reinforced by the start of so-called challenges, which are essentially research competitions where an algorithm suitable for solving a well-defined problem must be developed, with the necessary data for testing publicly available. Furthermore, the performance scores for measuring the quality of the developed algorithm are also known in advance. The winning algorithm is the one that has better performance scores compared to all other submitted algorithms. Among the many such websites, we mention <https://grand-challenge.org/challenges/> as an example.

A very interesting phenomenon can be observed regarding challenges. Even though most challenges aim to ensure a fair ranking of algorithms with precise task descriptions and well-structured tests (benchmarks), the issue of reproducibility remains secondary. Thus, in many areas, the scientific community has prioritized algorithms with better performance scores over reproducible but less impressive ones. Consequently, many well performing, reproducible algorithms have not been published due to their lower performance scores, while in some fields, numerous publications have appeared with demonstrably flawed performance scores [1].

Based on the above, it is evident that it is important to develop a method, preferably based on scientific principles, to at least assess the reliability of performance scores published as algorithm characteristics, even if reproducibility is not ensured. Recently, we have conducted intensive research in this area and developed a method to determine whether the system of performance scores defined during algorithm testing is consistent (consistency test) [3]–[5]. This article aims to highlight the relevance of the topic, briefly summarize our results so far, and draw the reader's attention to a software package we have developed that facilitates the consistency test of performance scores. We hope its use will help correct numerous flawed results.

References

1. D. Nunzio, G. Maria, and R. Minzoni, "A thorough reproducibility study on sentiment classification: Methodology, experimental setting, results," *Information*, vol. 14, no. 2, p. 76, 2023.
2. M. Baker, "Reproducibility crisis," *Nature*, vol. 533, p. 353–366, 2016.
3. G. Kovacs and A. Fazekas, "A new baseline for retinal vessel segmentation: Numerical identification and correction of methodological inconsistencies affecting 100+ papers," *Medical Image Analysis*, vol. 75, p. 102300, 2022.
4. A. Fazekas and G. Kovacs, "Testing the consistency of performance scores reported for binary classification problems," *Applied Soft Computing*, vol. 164, p. 111993, 2024.
5. G. Kovacs and A. Fazekas, "mlscorecheck: Testing the consistency of reported performance scores and experiments in machine learning," *Neurocomputing*, vol. 583, pp. 1–4, 2024.

Comparison of Open APIs for the Data Collection on environment Indicator: A Case Study on Air Quality in Almaty, Kazakhstan

Armanzhan Kuanaev and Alexey Belousov

¹ Institute of Automation and Information Technology, Satbayev University (KazNRTU), Almaty, Kazakhstan, armanzhankuanaev@gmail.com, a.belousov87@gmail.com

Keywords. open API, weather, air quality, data management

Information and computer technology advancement has greatly accelerated the ability to collect and store vast amounts of digital data. The relatively recent data mining technique presents a promising approach for uncovering knowledge and patterns within large, multidimensional, and complex data sets. This paper offers an overview of available Open APIs and related tools while demonstrating the potential of data mining in air quality research through example applications. Although traditional data mining techniques exist, they operate in isolation, remaining largely standalone and specialized in scope.

Due to industrial development, rapid growth of automobile transport, cities, and insufficient environmental control, the situation in Kazakhstan is one of the most tense, especially the concentration of major pollutants (PM10, NO₂, and SO₂). In this regard, we considered 5 Open APIs for collecting and analyzing the main environmental indicators of the Almaty city. A comparative analysis of these sources and their advantages and disadvantages for scientific research and use in the following machine learning analysis is provided. In addition, a scheme for storing and visualizing environmental data is proposed.

This research paper focuses on motivating research scientists with limited programming and data mining expertise to leverage available Open API resources and data mining tools. By adopting traditional data mining techniques and methods, they can gain deeper insights and identify patterns within highly complex data sets.

Modeling and Control of a Mobile Robot with Differential Drive Based on a Digital Twin Complete

T. Yu. Kim

Robotic systems laboratory, United Institute of Informatics Problems of NAS, Minsk, Belarus,
tatyna_kim92@mail.ru

Keywords: digital twin (DT); mobile robot; control system; MATLAB/Simulink

Abstract. Digital twins (DT) have become essential tools in industry and logistics, especially for managing warehouse robots. Transitioning from physical robots to their DT is a logical step as DT combines the advantages of working with real objects and the flexibility of simulation models (SM) [1].

A DT is fundamentally based on SM and the developed control system (CS), which operates in parallel with the real object, constantly receiving input and output data from the object. A key aspect of a DT's operation is the transmission of data from the real object using various sensors, allowing for a self-adjusting DT that stays relevant through continuous updating [2].

The developed DT comprises two interconnected modules:

- 1) A comprehensive SM of the mechanical parts and sensors of the mobile robot RoboCake [3];
- 2) A control system developed in the MATLAB/Simulink simulation environment.

The robot moves along a color-contrast line at a speed of 1 m/s, ensuring the line remains between two front sensors, with an optimal line width of 2.4 cm.

A PID controller from the Control System Toolbox was used to control movement. The CS was designed based on a classical PID controller with a dual-loop feedback system: feedback on the position of the sensor center above the line and on the wheel rotation speed [4]. The PID controller coefficients for the wheel rotation speed were calculated separately [5].

The optical line sensor was created based on three QRE1113 light sensors installed on the RoboCake MR. The sensor encodes the main signal, which describes the location of the center above the line and corrects the MR depending on the conditions (Fig. 1).

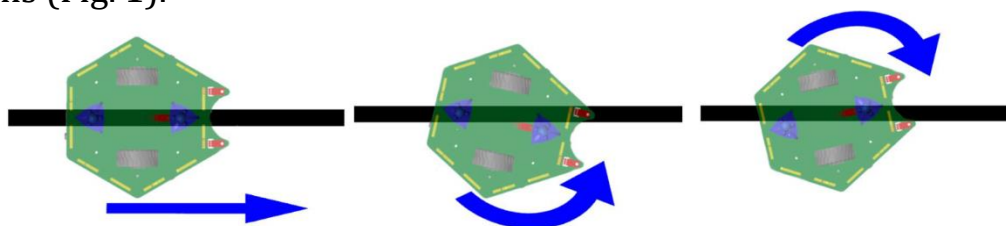


Fig. 1. The process of correcting the position of the MR relative to the center of the line during forward movement: a) without changes; b) with a shift to the left; c) with a shift to the right

The main attention was paid to the stages of developing the IM and the control system of the mobile robot using the model-oriented design technology. The

hardware part of the control system is implemented on the basis of the Arduino Mega 2560 microcontroller board, the software part is implemented using the MATLAB/Simulink libraries [6-7]. These software packages allow you to work with a real Arduino family board, receive a signal from analog and digital sensors, run the developed algorithm in real time, without compilation and monitor the results, as well as generate code. The robot can operate autonomously without exchanging information via USB, changing parameters in real time.

Objective. The aim of the study is to model and develop a control system for a mobile robot with a differential drive moving along a color-contrast line based on DT technology.

Methods. Control System Design: A CS based on a classical PID controller with dual-loop feedback was developed for the RoboCake mobile robot. Feedback was implemented for the sensor center's position above the line and the wheel rotation speed. Optical Line Sensor: An optical sensor based on three QRE1113 light sensors was created and installed on the mobile robot. The sensor encodes a signal describing the position of the center above the line. Model-Based Design: The MATLAB/Simulink libraries were used to develop the CS software. The hardware part was implemented on the Arduino Mega 2560 microcontroller.

Results. The developed CS allowed the robot to move along a color-contrast line at a speed of 1 m/s, maintaining the line between two front sensors. The optimal line width was determined to be 2.4 cm (fig 2).

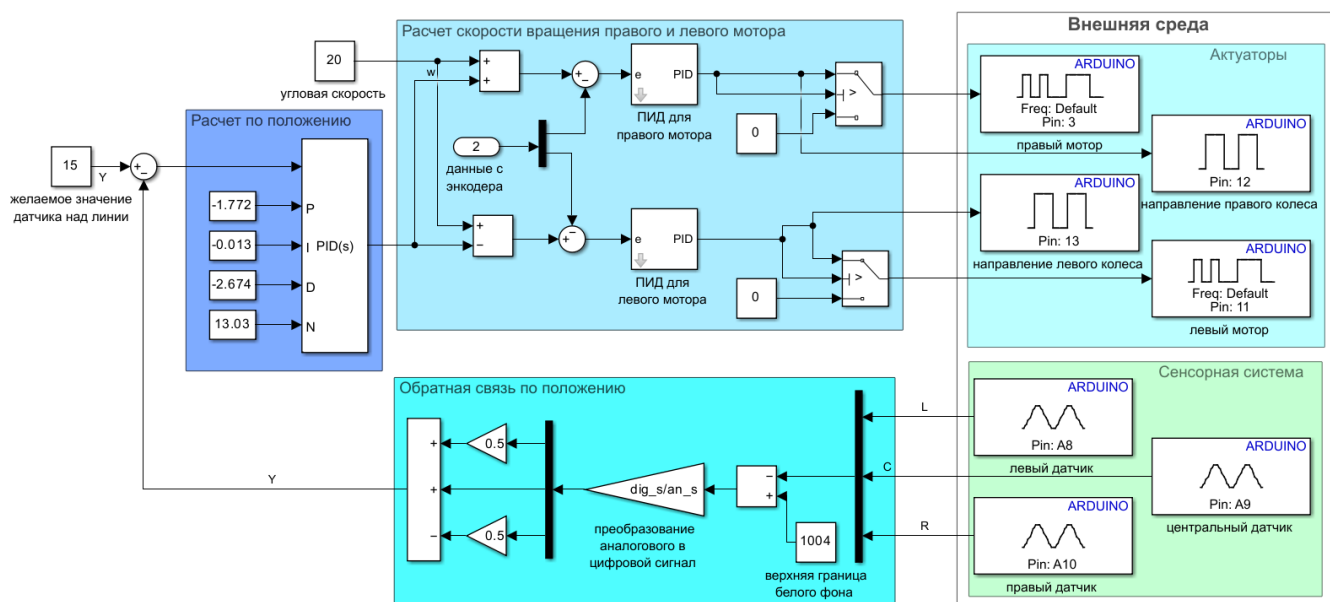


Fig. 2. Feedback control system

The developed IM moves along the color-contrast line, showing the synchronous operation of the engines and three sensors (Fig. 3). After the electronic model of the microprocessor control system was implemented in Simulink, we can state the fact of the appearance of a real digital twin of the designed mobile robot.

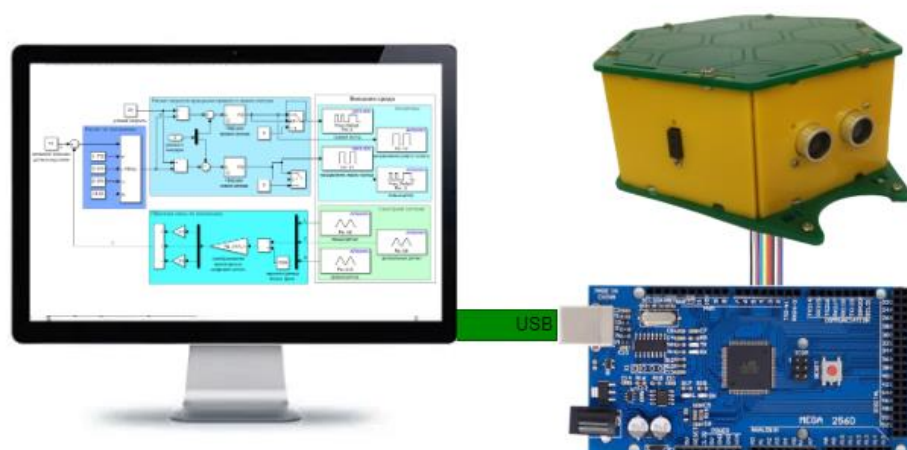


Fig. 3. Scheme of the experiment with a real control object

The simulation and control system demonstrated synchronous operation of the motors and sensors, and the digital twin provided real-time feedback and adjustments based on sensor inputs.

Conclusion. This research has demonstrated that digital twins enable efficient modeling and control of robotic systems. The developed control systems for mobile robots showed high precision and reliability. The use of digitalization technologies and model-based design has enhanced production processes and improved logistics efficiency.

References.

1. Kim T. Yu., Prapakovich R. A., Application of digital twin technologies in the educational process for students of technical specialization. In: X All-Russian scientific and practical conference on simulation modeling and its application in science and industry "Simulation modeling. Theory and practice" (IMMOD-2021) - 2021.
2. Kim T. Yu., Developing a digital twin for automatic motion trajectory generation using deep learning, Conference "Lomonosov 2020".
3. Kim T. Yu., Development of a digital twin of a mobile robot for research and educational purposes based on MATLAB/Simulink. In: XVIII International Conference of Young Scientists "Youth in Science - 2.0'21", pp. 580-584. Belarus, Minsk (2021).
4. Levine, W. S.: "PID Control," in The Control Handbook. NJ: IEEE Press, pp. 198–209. Ed. Piscataway (1996)
5. Kim T. Yu., Prapakovich R. A. Optimization of the PID coefficients for the line-follower mobile robot controller employing genetic algorithms. Informatika [Informatics], vol. 18, no. 4, pp. 54–69, 2021. <https://doi.org/10.37661/1816-0301-2021-18-4-54-69>
6. MATLAB Support Package for Arduino Hardware (Release 2020b) [Electronic resource] // Mathworks.com. - 2021. Mode of access: https://www.mathworks.com/add-ons/ML_ARDUINO/?s_tid=srchtitle. - Date of access: 05.07.2021.
7. Simulink Support Package for Arduino Hardware (Release 2020b) [Electronic resource] // Mathworks.com. - 2021. - Mode of access: https://www.mathworks.com/add-ons/ARDUINO/?s_tid=srchtitle. - Date of access: 05.07.2021.

Identification of Thematic Groups of Publication Corpora using Top2Vec

Vladimir Albrecht and Ravil Mukhamediyev

Institute of Automation and Information Technology, Satbayev University (KazNRTU), Almaty,
Kazakhstan, sluminat2@gmail.com, ravil.muhamedyev@gmail.com

Keywords: Scientometrics, UAVs, top2vec, environmental monitoring, trend analysis

Abstract. Identification of thematic groups of scientific publications and analysis of their behavior plays an important role in scientometric analysis. Thematic modeling methods are traditionally used for such purposes. In this study, the Top2Vec algorithm was used to identify thematic groups of scientific publications. For this purpose, a corpus of more than 500 thousand abstracts of scientific articles posted on the arXiv platform over a 14-year period was used. Thematic modeling was carried out in the rapidly developing field of UAV application in environmental monitoring. Initially, the authors identified five key domains in their opinion: monitoring of air, water, surface pollution, causes of pollution and problems in the use of UAVs. Then, by extracting keywords and using ChatGPT, sets of keywords for each domain were formed.

In the next stage, clustering of publications was carried out using Top2Vec and determining the degree of belonging of semantic clusters to the identified domains. As a result, subdomains were formed and publication activity curves were constructed for each subdomain. For example, the fastest growth is demonstrated by the data processing and interpretation subdomain, and the slowest growth is demonstrated by the subdomain dedicated to nitric oxide.

The obtained result allows us to judge the increase or decrease in the interest of the research community in the identified thematic groups.

Acknowledgment. The presented research was a post-project activity of ERASMUS+ ACeSYRI: Advanced Center for PhD Students and Young Researchers in Informatics reg.no. 610166-EPP-1-2019-1-SK-EPPKA2-CBHE-JP.



UAV Flight Planning for Solving Monitoring Problems

Kirill Yakunin and Dias Kussain

Institute of Automation and Information Technology, Satbayev University (KazNRTU), Almaty,
Kazakhstan, Yakunin.k@mail.ru

Keywords: path planning, computational intelligence, flight controller, precision agriculture, monitoring, ecology, urban agglomeration

Abstract. The scope of application of unmanned aerial vehicles is constantly expanding. One of the most important tasks of UAVs is monitoring. In particular, such a task arises in the process of monitoring the environmental situation in urban agglomerations and in solving precision farming problems. In many cases, a UAV considered as an aerial platform carries one or another set of equipment and solves the problem of coverage, so that cameras or sensors receive comprehensive information about the underlying surface or the air environment being studied. In this case, the optimal route of one or more UAVs and flight support equipment must be planned and transmitted to the UAV controllers to complete the mission. This paper focuses on the integration of the flight planning system and the UAV flight controller.

Acknowledgment. The presented research was a post-project activity of ERASMUS+ ACeSYRI: Advanced Center for PhD Students and Young Researchers in Informatics reg.no. 610166-EPP-1-2019-1-SK-EPPKA2-CBHE-JP.



Using UAVs and Deep Neural Networks to Count the Number of Cars on City Roads

Valentin Smurygin and Adilkhan Symagulov

Institute of Automation and Information Technology, Satbayev University (KazNRTU), Almaty,
Kazakhstan, valentinsmurygin@gmail.com

Keywords: traffic, machine learning, YOLO, SORT, Ultralytics, air pollution

Abstract. The use of UAVs to control traffic is a well-known problem. One of its indirect applications is monitoring air quality in an urban environment. UAVs, due to their mobility and the ability to move by air, can complement traffic monitoring carried out by ground vehicles. One of the important tasks for both traffic flow management and pollution assessment is counting cars and estimating the average speed of the traffic flow. This paper describes a method for counting the number of cars based on the capabilities of the well-known YOLO algorithm and the Ultralytics package. The basic principle is to count vehicles crossing a virtual boundary line. As a result of solving the problem, a software package was developed that solves the problem of counting vehicles in a video stream.

Acknowledgment. The presented research was a post-project activity of ERASMUS+ ACeSYRI: Advanced Center for PhD Students and Young Researchers in Informatics reg.no. 610166-EPP-1-2019-1-SK-EPPKA2-CBHE-JP.



Testing Software for Error-Correcting Data Coding at the Processor Level

S.D. Kolbin¹, V.D. Liauchuk¹ and A.A. Liauchuk²

¹ Belarusian State University of Informatics and Radioelectronics, Minsk, Belarus, stepankolbindmitreevich@gmail.com, liauchuk@gmail.com

² Belarusian State University, Minsk, Belarus, ealevchuk@gmail.com

Keywords: low-level error-correcting data coding; testing; Rust

Abstract. Any device with a processor is vulnerable to malicious interference or to physical factors such as natural radiation. The consequence of vulnerability is data integrity. The first author developed tools for low-level error-correcting data coding. This software allows programmers to create data containers regardless of hardware support for the error correcting method. The algorithms use Hamming correction codes. Similar codes are also used to protect data on disks and ECC memory. The project was developed with the help of the cross-platform compiled programming language Rust. To test the performance of the implemented coding algorithms, an external memory interference simulator and a library for working with memory were developed. The interference simulator is a Python script that, using the provided address, changes the data in memory. The following test cases were implemented: data integrity check, error registration with options for recovery or container termination, integrated test. In the data integrity check, the simulator calls the container and passes a reference to the data to the constructor. Then the method responsible for decoding the data is called, and the result is compared with the data passed to the constructor. The test was passed successfully. In the error registration test, the constructor successfully created a protected container that detected a bit change in the address space and restored the data. These two tests were conducted on a desktop computer. STM32 microcontroller was used for the integrated test. Using a Rust application, a container was created for the microcontroller, which encoded the data. The container was flashed into the microcontroller. After introducing an error into the address space, the container was stopped, and the microcontroller's LED stopped blinking. The test results allow us to conclude that the tools for error-correcting data coding at the processor level are working correctly.

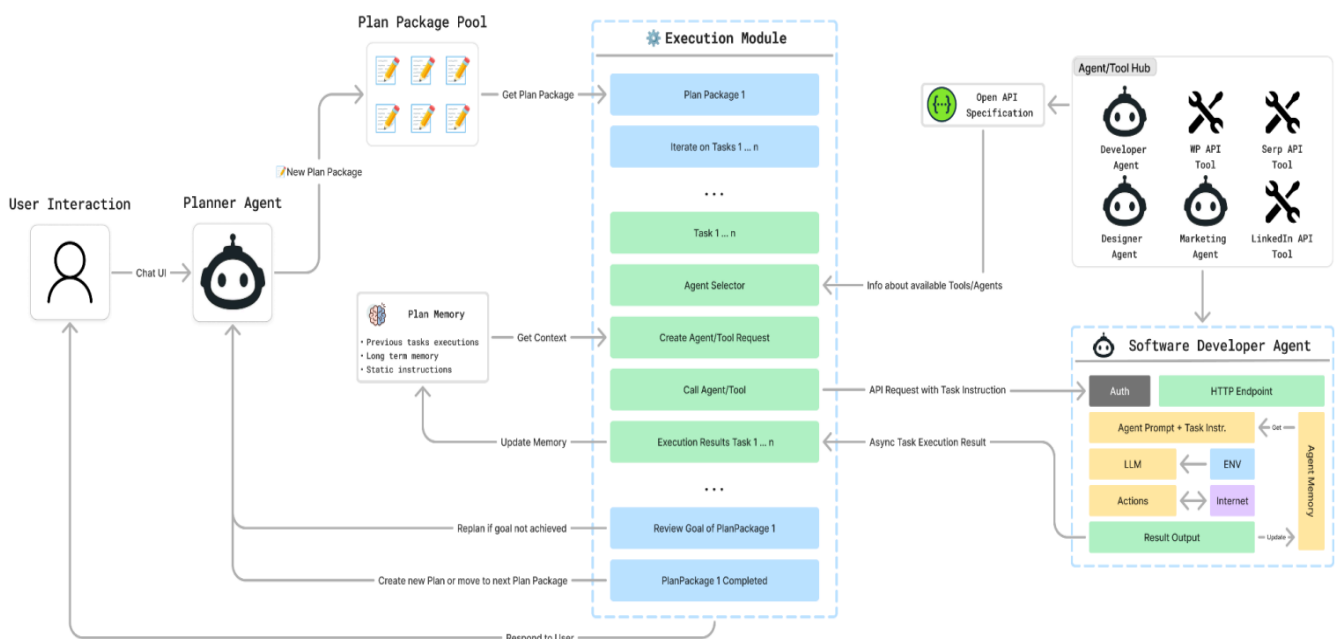
LLMAgentNet: A Collaborative Network of Autonomous AI Agents for Complex Task Execution

Andrii Bidochko

Department of Artificial Intelligence Systems, Institute of Computer Science and Information Technologies (ICSI), Lviv Polytechnic National University, Ukraine. andrii.bidochko@gmail.com

Keywords: Large Language Models (LLMs); AI Agents; Multi-Agent Systems; AI Collaboration; Autonomous Task Execution; RESTful APIs

Abstract. Recent advancements in Large Language Models (LLMs) have opened new possibilities for building autonomous AI agents capable of executing complex tasks. However, existing multi-agent frameworks often face limitations in integrating diverse agents and tools due to rigid communication protocols and ecosystem dependencies. To address these challenges, we introduce LLMAgentNet, a collaborative framework designed for autonomous AI agents to work together efficiently using LLMs for task planning and execution. Leveraging RESTful APIs as the communication backbone, LLMAgentNet enables seamless interactions between AI agents, allowing them to decompose high-level user requests into manageable sub-tasks and execute them autonomously. The framework utilizes the OpenAPI Specification to ensure the smooth integration of new agents and tools, as well as real-time reconfiguration of existing agents. This design allows the system to incorporate external AI agents developed with other frameworks, offering high flexibility and scalability. LLMAgentNet adopts a Humans-on-the-Loop approach, maintaining human oversight while allowing agents to autonomously handle multi-step tasks. Through experimentation, LLMAgentNet demonstrates strong performance in complex task execution, paving the way toward more advanced AI systems and contributing to the journey toward AGI.



Background. Recent advancements in Large Language Models (LLMs) like GPT-4 have greatly enhanced the capabilities of autonomous AI agents, enabling them to manage complex tasks with minimal human intervention. However, many existing multi-agent systems struggle to integrate diverse agents and tools due to rigid communication protocols and limited ecosystem compatibility. LLMAgentNet addresses these challenges by leveraging LLMs for task planning and RESTful APIs for seamless communication, allowing for dynamic reconfiguration and integration of new agents and tools.

Objective. The main objective of this paper is to introduce LLMAgentNet, a framework designed to allow autonomous AI agents to collaborate and execute complex tasks using LLMs. The framework focuses on overcoming the limitations of current multi-agent systems by enabling seamless integration of new agents, dynamic reconfiguration, and effective communication through RESTful APIs.

Methods. The framework design involves the use of LLMs (GPT-4 and Claude 3.5 Sonnet) for task planning and decomposition, with RESTful APIs facilitating communication between agents. The OpenAPI Specification is utilized to integrate new agents in real-time and reconfigure existing ones. Data collection involved testing the system across a range of real-world task scenarios, with performance evaluated using benchmarks such as HotPotQA, TaskBench, and GAIA.

Results. LLMAgentNet demonstrated its ability to execute complex tasks across multiple scenarios efficiently. The system was able to dynamically integrate new agents and reconfigure existing ones in real time, enhancing flexibility and scalability. The use of LLMs for task decomposition proved effective, and the Humans-on-the-Loop approach allowed for minimal human supervision during multi-step task execution. In practical applications, LLMAgentNet was deployed to fully automate marketing departments, particularly focusing on SEO and SMM (LinkedIn, Twitter), as well as in software development tasks like creating web pages and landing pages. Implemented on the UBOS.tech low-code platform, NodeRED facilitated task orchestration, ChromaDB handled memory management, and the OpenAI API powered LLM-driven task execution. The OpenAPI Specification enabled seamless real-time integration of new tools and agents, while Telegram ensured effective user-agent communication. Overall, LLMAgentNet proved highly flexible and scalable, demonstrating robust performance across diverse, real-world applications with minimal human intervention.

Conclusion. LLMAgentNet is a flexible and scalable framework that enables seamless collaboration between autonomous AI agents using LLMs. The framework overcomes the limitations of current multi-agent systems by enabling dynamic agent integration and reconfiguration via RESTful APIs. LLMAgentNet represents a significant step forward in multi-agent collaboration, contributing to the broader goal of achieving Artificial General Intelligence (AGI).

Fine-Tuning LLM for Code Style Analysis: An Approach Augmented with DFA

A.I. Holovko and V.I. Aliksieiev

Department of Applied Mathematics, Lviv Polytechnic National University, Lviv, Ukraine,
andrii.i.holovko@lpnu.ua

Keywords: code-style analysis; large language models; Llama models; fine-tuning; definite finite automata

Background. The organization and consistency of programming code have a significant impact on its reliability and maintainability, particularly in large codebases managed by multiple teams. One way to achieve consistency and effectively manage complexity is to follow style guides, and Large Language Models (LLMs) can greatly assist in checking code compliance. However, this often requires fine-tuning of the base model to recognize company-specific style standards. Our preliminary research revealed that both the Llama 2 7B and Llama 3 8B models require at least 240 training samples per custom style rule to be 99% accurate at classifying Python code snippets. Preparing such a large amount of training data can be challenging, making it necessary to look for a more practical solution.

Objective. This study aims to develop a solution that allows to fine-tune LLMs, such as Llama 2 and Llama 3, to accurately classify code snippets as compliant or non-compliant with coding style rules without requiring manually prepared training samples. We explore the use of definite finite automata (DFA) to generate synthetic training data based on a set of declarative style rules.

Methods. We defined the style rule by providing both the correct and incorrect code variants. To expand these samples, definite finite automata were used to generate a larger training dataset. The Llama 2 7B and Llama 3 8B models were fine-tuned on these synthetic data using the quantized Low-Rank Adaptation (QLoRA) method. We then evaluated the fine-tuned model on data it had not encountered during the training process.

Results. The integration of DFA-based synthetic training data into the fine-tuning process resulted in models demonstrating performance comparable to that of the traditional manual data preparation approach. Both Llama models achieved the target accuracy of 99% in classifying code snippets for PEP-8 indentation compliance, showcasing a significant reduction in human involvement during dataset creation.

Conclusion. Definite Finite Automata can be effectively integrated into the fine-tuning process to minimize the need for manual dataset preparation. The results of our work can be used to develop a highly customized personal coding assistance tool, improving both the reliability and consistency of software development.

Flight Safety Calculations in a Computer Aided Flight Planning System

V.I. Alieksieiev¹ and O.V. Sydorenko²

¹ Department of Applied Mathematics, Lviv Polytechnic National University, Lviv, Ukraine, vladyslav.i.aliexsieiev@lpnu.ua, oleg.v.sydorenko@lpnu.ua

² Department of Automated Control Systems, Lviv Polytechnic National University, Lviv, Ukraine,

Keywords: flight plan safety; fuel consumption; terrain clearance; route safety; computer flight plan service provider (CFSP)

Abstract. Supporting flight safety is of primary importance and the main goal for any computer flight plan service provider (CFSP). The major steps in building the reliable and safe flight plan for any CFSP customer should include: 1) path search (finding the correct and safe route from departure to destination airport considering weather forecast and avoiding dangerous or forbidden/closed areas); 2) fuel and weight & balance calculations (making precise assessment of aircraft fuel consumption in the flight with respect to all the weights carried, including crew, passengers, cargo etc.); 3) vertical profile calculations (means providing the flight plan safety regarding terrain clearance and picking flight level adequate to aircraft performance, type of flight, and other flight options by customer's choice); 4) air traffic rules and regulation restrictions compatibility (to meet air traffic regulation requirements and provide all related authorities with the flight plan information accordingly); 5) advanced safety calculations (including flight planning with alternate landing aerodromes and calculations for drift down flight). The problem generally known as 5D flight planning requires much computation efforts due to many interlinked dependencies.

Despite the most obvious way of solving a problem by splitting it into minor sub-tasks or steps, like we've described previously, the complexity of 5D flight planning typically require multiple repetitive consequent calculations to build some reliable flight plan with respect to possible impact of further steps on calculations that have been recently made on previous steps. This brings the necessity to implement a recursive algorithm or a convolutional approach. However, convergence of such calculation process is not guaranteed. And this states another important issue for any computer aided flight planning system – the problem of time consumption for the single flight planning calculation. The core of the problem is the quick changing circumstances for the flight. This includes both updates of weather/wind forecast (which can be updated each 6 hours or, sometimes, even more often), and air traffic management (which means some restrictions can appear within few hours and overlapping the time of flight can make the flight impossible). Also, the CFSP customer typically wants to see a new flight plan within a several seconds (and not even a few minutes). These aspects bring also another side of complexity related to application/software architecture.

Our current research work is focused on meeting all the requirements of safe and reliable flight planning within one solution with respect to software architecture and design for expected calculations speed.

On the Use of Offline Reinforcement Learning Methods in Condition-based Maintenance

Q.K. Tran, K.T. Huynh, A. Grall and Y. Langeron

LIST3N, University of Technology of Troyes, Troyes, France, quang_khai.tran@utt.fr

Keywords: condition-based maintenance; offline reinforcement learning; Markov decision process; degradation process;

Abstract. Reinforcement learning is a class of machine learning methods that focuses on deriving effective policies for an acting agent in a potentially stochastic environment. Reinforcement learning has been widely applied in various fields of study, including maintenance. A key aspect of reinforcement learning is that the agent needs to iteratively interact with the environment (through exploration and exploitation actions) to gather interaction data for the learning algorithm. However, in some scenarios, exploring the environment to discover potential high-reward state-action pairs can be difficult, costly, or even dangerous. Additionally, in some cases, especially in the maintenance field, collecting interaction data is challenging, as the time between two interactions can be very long. If a fixed dataset containing interaction data is available, offline reinforcement learning can be utilized to learn the policy. Offline reinforcement learning is a branch of reinforcement learning that focuses on learning policies from a single fixed dataset without further interactions with the environment. The maintenance sector can leverage offline reinforcement learning, as exploration in industrial systems can be hazardous (such as avoiding maintenance in crucial states), but historical maintenance data (such as the system state and the corresponding maintenance action) can provide significant value. In this work, we examine the potential of offline reinforcement learning in condition-based maintenance. We assume that there exists some static maintenance data (possibly with non-optimal maintenance actions) from identical machines/systems. We then analyze the size of the dataset needed for the learning algorithms to learn effective policies. Since no extra maintenance actions can be taken in offline settings, we mainly focus on off policy methods to learn the policies. Furthermore, we try to determine how the policies derived from an offline dataset compare to those obtained through model-based reinforcement learning.

The expected results show that, although offline policies cannot outperform perfect model based methods, they have immense potential in practice.

Exploring Social Dynamics and Stability Using Cellular Automata

D.I. Symonov, B.Y. Zaika and Y.D. Symonov

V.M. Glushkov Institute of Cybernetics of the National Academy of Sciences, Kyiv, Ukraine,
denys.symonov@gmail.com

Keywords: cellular automata; modeling of social systems; behavioral patterns; predicting the stability of social norms; transformation of a dynamic system

Abstract. In the context of globalization, rapid development of technologies and information networks, social processes are becoming increasingly complex and interconnected. A mathematical model of a social system based on cellular automata is an effective tool for studying complex phenomena that occur in dynamic systems with local interactions. Cellular automata as a modeling tool allows us to reproduce and analyze these complex dynamics, which is critical for predicting social change, developing effective management strategies, and making decisions in the field of social policy.

Using a discrete two-dimensional lattice, each cell of which represents an individual or group of individuals, various social phenomena can be modeled, including the spread of opinions, innovations, and social norms. Such models allow us to analyze the impact of local interactions on the formation of global patterns, which makes them ideal for studying complex social systems.

The analysis of system dynamics based on cellular automata modeling demonstrates interesting possibilities for identifying patterns of collective behavior. One of them is phase transitions, when the system abruptly changes its state when a certain critical threshold of the dynamic system parameters is reached. This is analogous to phenomena in physical systems and allows us to better understand how innovations, social norms, or propaganda spread in society. Using models based on cellular automata allows us to study how random events or individual differences can affect the dynamics of the whole society and predict the future state and rate of transformation of a dynamic system.

The results of numerical experiments with different model parameters confirm the possibility of complex collective behavior and patterns at the macro level even with simple rules at the micro level. For example, when modeling the spread of disinformation, we observed the emergence of clusters of individuals who accepted inaccurate information, as well as their subsequent influence on neighboring groups. Such clusters may be analogous to social groups or subcultures in real society. The proposed model of cellular automata also allows us to analyze the stability of social norms. Studies show that certain social norms can be resistant to external influences under certain conditions. However, when critical thresholds are exceeded, norms can change rapidly, making this model useful for predicting social change.

Cellular automata have limitations, such as lacking individual diversity. These can be addressed by adding parameters or using agent-based models. Despite this, they effectively model social systems and can be extended to analyze social data for predictions

Modeling and Optimization of Software Reliability using Fuzzy-Algorithmic Approach

H.B. Rakytyanska and B.V. Prus

Vinnitsia National Technical University, Ukraine, rakit@vntu.edu.ua, bohdan.prus.vntu@gmail.com

Keywords: software reliability optimization; logical-algorithmic model of the development process; multi-criteria variant analysis; fuzzy model of software reliability

Abstract. An approach to software reliability modeling and optimization based on the algebra of processes and fuzzy logic is proposed. The software development process is described using V.M. Hlushkov's algebra of algorithms. The sequence of events related to the introduction, detection and removal of errors is modeled using logical-algorithmic structures "work - control - correction", which correspond to the processes of development, testing and debugging. The logical-algorithmic model corresponds to the fuzzy knowledge base, which connects correctness levels of the working, testing and debugging stages with the decision classes interpreted as correct or incorrect execution of the task. To provide the best quality product within a limited time (cost), improving substitutions are embedded into the logical-algorithmic model. Improving substitutions aimed at selecting patterns of the development stages determine the structure and parameters of the software reliability model. Controllable variables associated with improving substitutions are interpreted as identifiers of implementation options of the development stages. Each variant is a logical algorithmic structure with controllable variables related to the quality of execution of the working, control and correction operations. Then the optimization problem arises, which is formulated in a direct and dual statement. It is necessary to find the implementation options, as well as controllable variables related to the quality of execution of logic-algorithmic structures, which ensure the constrained or extreme levels of software reliability and development time. A method of software reliability optimization based on multi-criteria analysis of variants is proposed. Software faultlessness criteria are considered as fuzzy sets defined on a universal set of variants using membership functions. For each stage, membership functions of fuzzy reliability estimates are constructed by means of a pairwise comparison of variants using the Saaty scale. Ranking of implementation options is carried out by intersecting fuzzy sets of criteria corresponding to the Bellman-Zadeh scheme. The ranks of the criteria which define the parameters of concentration of fuzzy sets correspond to the quality indicators of working, checking and correction operations. The synthesis of the logical-algorithmic model that ensures acceptable levels of software reliability and development time is carried out by selecting controllable variables associated with improving substitutions. The genetic algorithm is used to determine the structure of the reliability model by selecting the implementation options of the development stages. To ensure compliance with the requirements, the gradient method is used to adjust the parameters of the reliability model by selecting the ratios of repeated inspections and corrections.

Robust Bayesian Method for Step-Stress Accelerated Life Testing Data

Sultan Albalwy^{1,2}, Frank Coolen¹ and Jonathan Cumming¹

¹Dept. of Mathematical Sciences, Durham University, Durham, UK, sultan.e.albalwy@durham.ac.uk

²Dept. of Statistics, Tabuk University, Tabuk, Saudi Arabia

Keywords: imprecise statistical inference; step stress accelerated life testing; robust Bayesian analysis

Abstract. A robust Bayesian method is developed for the analysis of step-stress accelerated life testing (SSALT) data, utilizing imprecise probabilities to account for uncertainty in prior knowledge. This method incorporates imprecision by modelling vague prior knowledge on the model parameters, allowing for the derivation of both lower and upper bounds for the posterior distribution. The imprecise prior knowledge is represented by a class of prior distributions, with the extremes of this class reflecting complete lack of knowledge about the parameters. Using these extreme bounds, the lower and upper posterior predictive distributions are derived, enabling predictions of future failure times at the normal stress level. This approach also facilitates the construction of lower and upper predictive survival functions for normal stress conditions. Finally, the performance of the proposed method is evaluated through simulation studies.

A Development of Fuzzy Inference System for Modeling the Degradation of Light Emitting Diode

Q.T. La¹, Z. VINTR¹, D. Vališ¹, Z. Kohl¹, and L. Žák²

¹ University of Defence, Brno, Czech Republic, quoctiep.la@unob.cz, zdenek.vintr@unob.cz, david.valis@unob.cz, zdenek.kohl@unob.cz

² Brno University of Technology, zak.l@fme.vutbr.cz

Keywords: Light Emitting Diode; Accelerated Degradation Tests; Fuzzy Inference System; modified FIS; LED; ADT

Abstract. In light of technological advancements, Light Emitting Diodes (LEDs) have exhibited extensive applicability across a wide range of fields, spanning from basic to intricate applications. Consequently, it is imperative to ensure their reliability and gain insight into their technical degradation, particularly in applications that necessitate high precision and replaceability. The Fuzzy Inference System (FIS) has established itself as a robust and effective method for addressing estimation and prediction challenges, rendering it an invaluable tool in reliability studies. In this article, we introduce a modified FIS designed to model the degradation of LEDs using data acquired from Accelerated Degradation Tests (ADTs), with specific structural adjustments made to traditional FIS components. The dense data obtained from ADTs undergo monitoring and recording and are utilized for modelling purposes. The performance of the proposed model is assessed by comparing it with several existing methods using the same dataset. The findings suggest that the proposed approach holds promise for effectively modelling the degradation of LEDs.

Synchronization of the Time Zones in the Temporal Database Environment Making Transparent Reliable Solution

Michal Kvet

Faculty of Management Science and Informatics, University of Zilina, Zilina, Slovakia,
michal.kvet@fri.uniza.sk

Keywords: temporal databases, synchronization, time zone mapping

Abstract. Currently, the number of complex systems and applications is rapidly rising. By making the system accessible across the world, it is necessary to synchronize time zones in a transparent manner. This paper investigates existing solutions, primarily pointing to the SQL translation profile offering dynamic switches between server and session date and time values. The main contribution of the paper is represented by own solution mapping. It incorporates time zone differences to the result set just after the execution of the query. By using the proposed approach, SQL statement is not changed at all in the initialization phases, making it reliable. Furthermore, proposed solution does not influence existing execution plans and SQL profiles. And finally, performance benefits from using already existing indexes.

Verification of Markov Model-Based Availability Assessment of Intelligent Diagnostic Systems Using Two Methodologies and Tools

Vladyslav Shcheglov¹, Vyacheslav Kharchenko¹, Olga Morozova¹ and Bogdan Volochiy²

¹Dept. of Computer Systems, Networks and Cybersecurity of National Aerospace University "KhAI", Kharkiv, Ukraine, v.shcheglov@csn.khai.edu, v.kharchenko@csn.khai.edu

²Dept. of Theoretical Radio Engineering and Radio Measurement of Institute of Telecommunications, Radioelectronics and Electronic Engineering of Lviv Polytechnic National University, Lviv, Ukraine, bvolochiy@ukr.net

This paper investigates two methodologies and toolsets for developing, analyzing, and assessing multi-fragmental Markov models considering change of diagnostics trustworthiness measures caused by relearning during operation. The first methodology utilizes vertex graphs to develop Markov models and employs the R language with the Markov chain package to calculate availability indicators. The second methodology leverages structural automata models and the ASNA tool. Each approach was applied to the same intelligent diagnostic system. Markov chain models were developed, and a series of validation and verification tests were conducted for each methodology. Finally, the availability indicator results from both methodologies and toolsets were compared to perform cross-verification. The challenges posed by Markov modeling tools, particularly those that require strict accuracy, are discussed in the context of the proposed approaches.

Concept and Analysis of Segmentation Algorithms in Modern Intelligent Computer Vision Systems

V. Korshenko, D. Uzlov and V. Strukov

V.N. Karazin Kharkiv National University, Kharkiv, 61022, Ukraine, v.korshenko@karazin.ua

Keywords: computer vision, image segmentation, optical flow, deep learning, intelligent systems, real-time processing

Abstract. In modern intelligent systems, computer vision has become a key component for solving the problems of recognizing and classifying objects in a video stream, in particular in the areas of security, transportation, and automated monitoring. This paper presents the concept of an integrated intelligent system developed by the author for analyzing video streams.

The first module of the system is designed to perform object segmentation and recognition, which is the basis for further data interpretation and decision-making. To solve this task, background subtraction, optical flow, and deep neural network-based methods are used, which allows to distinguish moving and static objects with different accuracy and speed. A comparative analysis of these algorithms was carried out according to such criteria as accuracy, performance, and adaptability to environmental changes, such as lighting and camera position.

An important issue also covered by this research is malicious machine learning, in particular attacks on computer vision algorithms that can disrupt their correct operation, reduce the number of correct detections, and cause other system failures. Understanding the impact of such attacks is important to ensure the reliability and resilience of the developed intelligent system, which is taken into account when evaluating the effectiveness of the algorithms under consideration.

The results of the study demonstrate that deep learning-based methods, such as Mask R-CNN and YOLACT++, provide the high accuracy and performance required for real-time tasks, although they require more computing resources. At the same time, background subtraction and optical flow methods are effective for tasks with static cameras, where it is important to quickly detect objects against a stationary background.

Thus, the work makes it possible to determine the optimal algorithms for different operating conditions of intelligent computer vision systems, taking into account both performance and resistance to possible attacks, which is important for improving the reliability and accuracy of real-time video data processing.

Quantifying System Reliability based on Accelerated Life Test Data for Components

Y.C. Yin^{1,2} and F.P.A. Coolen²

¹ School of Mechanical and Intelligent Manufacturing, Chongqing University of Science and Technology, China, yinyichao@cqust.edu.cn

² Department of Mathematical Sciences, Durham University, Durham, UK

Keywords: The survival signature; Accelerated life testing; Nonparametric predictive inference; Imprecise probability; Lower and upper survival functions

Abstract. This study explores the integration of component-level Accelerated Life Testing (ALT) with the survival signature for uncertainty quantification of system reliability. ALT implies that components are tested at higher than normal stress levels. ALT is effective in reducing the time and costs needed to test components, but ALT data tend to be less informative than life testing data at the normal stress level. The survival signature is a powerful concept for describing the links between component functioning and system functioning, enabling quantification of reliability of large-scale systems and networks. This research presents a Nonparametric Predictive Approach (NPI) for component reliability based on ALT data, linked with the use of the survival signature to quantify system reliability. In NPI, uncertainty is quantified by lower and upper probabilities, with the difference between them reflecting the amount of information available. The use of ALT data leads to more imprecision in predicted system reliability than would occur if all components were tested at the normal stress level. The presented method is illustrated via examples and simulations studies, and further research opportunities are briefly discussed.

Solid Waste Detection During Monitoring of Urban Agglomerations using UAVs

Luidmila Gorodeckaya and Ravil I. Mukhamediev

Institute of Automation and Information Technology, Satbayev University (KazNRTU), Almaty, Kazakhstan, ludmila260601@gmail.com

Keywords: monitoring, UAVs, solid waste, YOLO

This project focuses on the development of an automatic detection system for solid waste (SW) in images obtained using unmanned aerial vehicles (UAVs) with the application of deep learning techniques. Solid waste includes various types of debris such as plastic, paper, metal, and organic materials that require disposal or recycling.

The relevance of this research is driven by the need to create effective and automated methods for monitoring the environmental state of urban areas. Traditional landfill detection methods are resource-intensive, whereas automation

using UAVs and neural networks significantly enhances the accuracy and speed of waste detection, especially in hard-to-reach or hazardous areas.

The aim of this study is to develop a solid waste detection system based on UAV imagery to track the emergence of illegal dumps in the Almaty region and assess pollution levels in specific areas. The main research tasks include data collection and annotation, model training, tuning its parameters to improve detection accuracy, and analyzing the results obtained.

The study utilized a dataset of 760 images extracted from drone video footage recorded in the Almaty region. The waste sites were manually labeled, and various augmentation techniques were applied. The YOLOv8x model was trained over 60 epochs.

The project achieved a precision (P) of 0.801, recall (R) of 0.789, and mean average precision (mAP50) of 0.846. Future research will focus on expanding the dataset, optimizing augmentation techniques, and improving model parameters to enhance system performance.

Acknowledgment. The presented research was a post-project activity of ERASMUS+ ACeSYRI: Advanced Center for PhD Students and Young Researchers in Informatics reg.no. 610166-EPP-1-2019-1-SK-EPPKA2-CBHE-JP.



Stages of Planning and Modeling the Bread Baking Process in the Context of Creating a Digital Twin

Kaldybek Makhambetov^{1,2}, Viktor Pokusov¹ and Baurzhan Belgibaev²

¹Kazakhstan Information Security Association, Almaty, Kazakhstan, 1998kaldybek@gmail.com

²Al-Farabi Kazakh National University, Almaty, Kazakhstan

Keywords: digital twin, CAD/CAE, computer simulation, Matlab, process optimization, thermal process simulation, production automation.

Abstract. The development of digital twin technologies opens up new opportunities for increasing the efficiency and flexibility of production processes in the food industry. This article discusses the stages of planning and modeling the bread-baking process aimed at creating a digital twin. The main focus is on the development of a step-by-step approach, starting with the analysis of process parameters and product quality requirements to the creation of a model capable of simulating the physicochemical changes in the dough during baking. The stages of implementing a digital twin are described, including setting up control algorithms, integrating sensor data, validating the model, and optimizing parameters for precise process control. The presented modeling approach allows for predicting and

adjusting key process parameters, which ensures improved product quality, reduced energy costs, and adaptation to changing production conditions.

Acknowledgment. The presented research was a post-project activity of ERASMUS+ ACeSYRI: Advanced Center for PhD Students and Young Researchers in Informatics reg.no. 610166-EPP-1-2019-1-SK-EPPKA2-CBHE-JP.



Stream on *Reliability Engineering and Computational Intelligence in Healthcare*

The aim of the stream is discussion on relevant topics and trends in reliability engineering, data mining, and machine learning in healthcare, medicine, and biotechnologies. The possible areas include but are not limited to

- Biomedical Engineering,
- Biomedical Informatics,
- Computer-Aided Diagnosis,
- Education in eHealth and Telemedicine,
- Electronic Health Records and Medical Databases,
- Innovative eHealth,
- Precision Medicine,
- Applications and Products,
- Legal, Social, Ethical and Financial Aspects,
- Medical Image Analysis and Biomedical Visualization,
- Telemedicine,
- Telehealth and Remote Monitoring, etc.

The stream is organized in accordance with activities of the project “*University-Industry Educational Centre in Advanced Biomedical and Medical Informatics*” (reg.no. 612462-EPP-1-2019-1-SK-EPPKA2-KA supported by the European Union’s Erasmus+ programme).

The stream is also a post-project activity of “*Development of Methods of Healthcare System Risk and Reliability Evaluation under Coronavirus Outbreak*” (reg.no. APVV PP-COVID-20-0013), which was supported by the Slovak Research and Development Agency in years 2020 and 2021.



New Biotechnological Directions in Diagnostics and Treatment of Ischemic Cardiomyopathy

Moglan Iulia and Capcelea Svetlana

“Nicolae Testemitanu” State University of Medicine and Pharmacy, Chisinau, Republic of Moldova,
moglaniulia9@gmail.com

Cardiovascular disease is the leading cause of death in both developed and developing countries. According to the World Health Organization, 17.9 million people across the globe (31%) die due to cardiovascular disease, of which 85% die from myocardial infarction. One of the most frequent nosology is ischemic cardiomyopathy which constitutes the leading global cause of mortality and morbidity. Ischemic cardiomyopathy represents a major provocation for the global medical system. Due to effective interdisciplinary research between healthcare and bioengineering, new technologies are complementary supporting decision-makers in cardiology by promising technologies in diagnostics and treatment of ischemic cardiomyopathy.

The actual diagnosis of ischemic cardiomyopathy relies on coronary angiography – to perform the anatomical and functional permeability of the coronary artery. Despite this, there are still cases of misdiagnosis due to technical factors, the complexity of coronary anatomy and plaque configuration. Also, non-imaging biomarkers used for diagnosis are cardiac troponin I and T forms and high-sensitivity C-reactive protein. Biotechnological advances offered a new complementary technique to adjust decision-makers - the novel micro-RNA. It offers high prospects for the possibility of detecting ischemic cardiomyopathy in its early stages. Mainly, extracellular vesicle-carried micro-RNAs have been reported as significantly expressed in ischemic heart disease patients and have excellent diagnostic efficacy. Some studies confirmed that circulating micro RNAs have been considered promising biomarkers for rapid diagnosis and disease management of ischemic heart disease. Hence, cell-derived protein factors, exosomes, and miRNAs have been isolated and delivered through engineered particles to overcome many innate limitations of live cell therapy. Additionally, new directions in the treatment of ischemic heart disease is cardiac reprogramming. This reprogramming includes biotechnologies and techniques for cardiac repair. Some of them are: cell reprogramming - by converting somatic cell lineage into pluripotent stem cells, gene editing, and 3D cardiac patches. All of them are promising methods. In conclusion, biotechnological advances make new diagnostic and treatment technologies for ischemic cardiomyopathy possible. They include the micro-RNA technique and treatment technologies like direct modulation of cardiac reprogramming, using nanoparticle-mediated drugs and transplantation of pluripotent stem cells which generate competent myocardial tissue that is electrically and mechanically integrated into the surrounding native heart tissue.

CRISPR: A New, Versatile Biotechnology

M. O. Senceacovici and L. Rotaru

“Nicolae Testemitanu” State University of Medicine and Pharmacy, Chisinau, Republic of Moldova,
mihasenceacovici@gmail.com, 2 ludmila.rotaru@usmf.md

Keywords: CRISPR, DNA, gene, PAM, Cas

Introduction. The CRISPR-Cas system is a new discovery, with its true role only being discovered in 2007. CRISPR-Cas (Clustered Regularly Interspaced Short Palindromic Repeats - CRISPR-associated protein) is a revolutionary gene editing technology that allows researchers to modify DNA in a precise and efficient way. The function of CRISPR is to cut DNA sequences at specific locations and allow specific genes to be added, deleted or modified. This technology is based on a natural system that prokaryotic organisms use to defend themselves against viruses. It has ongoing research and new findings every year relating to its potential clinical significance.

Objective. This paper intends to gather the most significant CRISPR-related research on its practical applications and appreciate its significance as a scientific finding and potential use cases.

Methods. In this paper the available primary research articles on CRISPR and its applications were analysed. The articles used were obtained from databases such as PubMed, ScienceDirect, Scopus, and JSTOR among others.

Results. Due to its direct role in prokaryotic immune system and unique ability to knock out specific genes, the scientific community has been exploring potential therapeutic applications for the CRISPR-Cas system. Thus far, beyond using CRISPR in human cells directly for its original role – fighting infectious diseases, research indicates a potential use for it in gene editing in genetic disorders, cancer therapy, epigenetic editing, organ transplantation, agriculture, and production of recombinant substances, as well as a potential diagnostic role. Some applications of CRISPR: Gene editing treatment for glaucoma, sickle cell anaemia, Beta-thalassemia, Duchenne muscular dystrophy, Cystic fibrosis. Applications in cancer therapy - targeting the EGFR gene in lung cancer, the FASN gene in breast cancer, ER-beta gene in prostate cancer and cancer prevention. Infectious diseases such as HIV-1, Hepatitis B, Hepatitis C may be a potential target for the CRISPR-Cas system. The delivery of the CRISPR-Cas system into target cells are currently limited and can only be achieved via viral vectors or lipid nanoparticles. The speculated limitations for CRISPR when used in vitro include impermanence of the results, off-target effects, immune response to the Cas proteins, immune reaction to the cells with the edited genome, among others.

Conclusion. CRISPR is one of the most promising and transformative scientific discoveries of recent decades, with the potential to revolutionize medicine, agriculture, and various other fields. However, its implementation must be managed with caution to ensure a balance between extraordinary benefits and potential ethical and safety risks.

From Genome to Treatment: The ENCODE Project's Impact on Precision Medicine and Technological Innovations

Kuzhipurayidathil Vijayakumar Anaswara and Ludmila Sidorenko

“Nicolae Testemitanu” State University of Medicine and Pharmacy, Chisinau, Republic of Moldova,
anurvijayakumar@gmail.com, ludmila.sidorenco@usmf.md

Keywords: ENCODE, CRISPR gene editing, single-cell sequencing, gene

Background. The ENCODE (Encyclopedia of DNA Elements) project has emerged as a critical resource in the field of precision medicine, mapping functional elements across the human genome. ENCODE, when coupled with cutting-edge technologies like CRISPR gene editing, single-cell sequencing, and advanced analytics, makes it easier to integrate multi-omics data, allowing for a more thorough understanding of disease causes.

Objective. To investigate the ENCODE project's contributions to precision medicine by focusing on its role in mapping functional genomic elements and allowing the integration of modern technologies, with the ultimate goal of improving individualized treatment options and patient outcomes.

Methods. Bibliographic sources for the study were analyzed using PubMed, Google Scholar, Nature and Medline and were released between 2014 to 2024.

Results. The ENCODE project has significantly advanced precision medicine by offering extensive functional annotations of the human genome. It has found several regulatory elements, including enhancers and promoters, across various cell types, enhancing the comprehension of gene expression control. This comprehensive mapping has provided insights into the relationships between non-coding genetic variations and several illnesses, improving the identification of possible genetic risk factors. Accurate disease modeling also depends on a knowledge of the intricate relationships that control biological processes, which has been made possible by the integration of multi-omics data, including transcriptomics, epigenomics, and proteomics. By encouraging creativity in the identification of new biomarkers and therapeutic targets, ENCODE's tools have also aided in the creation of tailored treatment plans and targeted treatments. Furthermore, by empowering researchers worldwide and encouraging teamwork, its dedication to open-access data has accelerated precision medicine developments.

Conclusion. ENCODE has improved our knowledge of gene regulation and the complex connections between genetic variants and illness by offering a comprehensive inventory of functional components found in the human genome. Combining innovative technology with ENCODE's extensive datasets has made it easier to find new biomarkers and therapeutic targets as well as to develop more individualized treatment plans based on the unique characteristics of each patient, revolutionizing how we approach individualized diagnosis and therapy.

Genetic Aspects of Hereditary Thrombophilia in Pregnancy

Mihaela Ababii¹, Svetlana Hadjiu^{2,3,4}, Ludmila Sidorenko¹, Elena Halabudenco², Stela Racoviță¹, and Mariana Sprincean^{1,3,4}

¹ Department of Molecular Biology and Human Genetics, State University of Medicine and Pharmacy "Nicolae Testemitanu", Chisinau, Republic of Moldova

² IMSP Institute of Mother and Child, Chisinau, Republic of Moldova

³ Department of Molecular Biology and Human Genetics, State University of Medicine and Pharmacy "Nicolae Testemitanu", Chisinau, Republic of Moldova

⁴ Laboratory of Neurobiology and Medical Genetics of the Brain Health Center, State University of Medicine and Pharmacy "Nicolae Testemitanu", Chisinau, Republic of Moldova

⁵ Genetics Laboratory of the Center for Personalized Medicine, State University of Medicine and Pharmacy "Nicolae Testemitanu", Chisinau, Republic of Moldova, mariana.sprincean@usmf.md

Keywords: Hereditary thrombophilia, testing, genes, pregnancy

Background: Hereditary thrombophilia represents a heterogeneous etiological entity, determined by mutations in most coagulation and fibrinolysis factors. These pathological mutations complicates diagnosis and management during pregnancy, being a challenge for clinicians in all medical fields.

Objective: Evaluation of the genetic aspects of hereditary thrombophilia in pregnancy to improve the diagnostic management of this disease.

Methods: The study was carried out based on the review of literature data (30 articles published from 2019-2024 on the platforms PubMed, Medscape, NEJM, GeneCards, Lecturio, AMBOSS) about the characteristic genetic aspects of hereditary thrombophilia in pregnancy.

Results: During pregnancy, the risk for thrombosis is five to ten times higher, a phenomenon due to the physiological increase in coagulation factors and the decrease in fibrinolytic activity, in order to prepare the future mother for childbirth and the postpartum period. In the context of pregnancy, variations in the genes encoding coagulation factors – F2, F5, FXIII, deficiency of anticoagulant factors such as antithrombin III, protein C, protein S, or fibrinolysis factors – PAI-1, PAI-2, MTHFR are associated with thrombophilia and obstetric complications. Complications that can occur in a pregnancy with hereditary thrombophilia can be recurrent miscarriage, severe preeclampsia, fetal growth restriction, premature detachment of the normally inserted placenta, venous or arterial thromboembolism.

Conclusion: Hereditary thrombophilia is a public health problem through its major impact on pregnancy and birth in the general population. Testing patients for factors that may further increase thrombotic risk, respectively identification the mutations of genes involved in development of hereditary thrombophilia, can contribute to correct diagnosis and management of the disease.

Technologies for Breast Cancer Diagnosis

Dana Bivol, Ludmila Rotaru and Elena Babara

“Nicolae Testemitanu” State University of Medicine and Pharmacy, Chisinau, Republic of Moldova,
bivol.dana13@gmail.com, ludmila.rotaru@usmf.md, elena.babara@usmf.md

Keywords: breast cancer, diagnostic technologies, early diagnosis, genetic mutations

Background. Breast cancer is the most common cancer among women, it's incidence increasing with age. Risk factors include genetic mutations, family history, age, hormonal factors (early period onset, late menopause), late or no childbirth, obesity, benign tumours, radiation exposure, diet, pollution, alcohol, oral contraceptives, etc. Early diagnosis can lower mortality, though benefits vary by age. Assessing individual risk helps guide screening decisions. Diagnosis typically involves clinical breast exams and imaging tests.

Objective. To analyse traditional and emerging diagnostic methods, including imaging techniques and genetic screenings, and to discuss recent advancements in automated image and signal processing technologies.

Results. The most important diagnostic methods are the following: *Mammography* - The best method for detecting cancer in it's early stages, recommended for women over 40. *Breast Ultrasound* - Uses sound waves to distinguish a solid mass and a cyst; suitable for all ages. *Galactography* - Investigates milk ducts using contrast material, useful for detecting small cysts, especially once that involve the ducts. *Biopsy* - Fine Needle Aspiration (FNA) or Core Needle Biopsy (CNB) samples tissue to determine the histological type and stage of cancer. *Computed Tomography (CT)* - Uses X-rays to create detailed images of breast tissue, detecting even thin sections (1-2 mm) and possible metastasis.

Magnetic Resonance Imaging (MRI) - Highly sensitive, recommended for those with dense breast tissue, implants, or microcalcifications. *Other Imaging Systems* - Includes scintimammography and positron emission tomography (PET), which use radioactive compounds, and methods analysing temperature, optical, or electrical properties. Many aim to supplement traditional mammography, though their effectiveness varies.

Genetic advances have shown that mutations, such as in BRCA1/BRCA2, increase breast cancer risk. While only 10% of cases are inherited, most result from lifetime mutations. Gene screenings and biomarkers in liquid biopsies offer diagnostic potential, but more research is needed. Technologies like CRISPR are also being explored to modify cancer-related genes, opening paths to new therapies and insights into tumour biology.

Conclusion. Various breast cancer diagnostic techniques have been studied and developed over the years, with new features and improved performance. Recent studies relevant to breast cancer detection use image and signal processing through predictive models that utilize automated methods and classification algorithms to determine the type of breast cancer. Therefore, image and signal processing play a critical role in maximizing breast cancer detection.

Biotechnological Progress in Determining Genotypic Diversity and Mutation Profiles of Multidrug-Resistant Mycobacterium Tuberculosis

Elena Chesov^{1,2}, Stela Racoviță^{1,2} and Valeriu Crudu³

¹ Department of Molecular Biology and Human Genetics, Nicolae Testemițanu State University of Medicine and Pharmacy (USMF), Chișinău, Republic of Moldova, elena.chesov@usmf.md

² Genetics Laboratory, Center for Personalized Medicine, Nicolae Testemițanu State University of Medicine and Pharmacy (USMF), Chișinău, Republic of Moldova, stela.racovita@usmf.md

³ Microbiology and Morphology of Tuberculosis Laboratory, Chiril Draganiuc Institute of Phthisiopneumology (IMSP), Chișinău, Republic of Moldova, valeriu.crudu@gmail.com

Keywords: Biotechnological progress; Genotypic diversity; Whole-genome sequencing; Isoniazid resistance.

Background: Multidrug-resistant Mycobacterium tuberculosis (MDR-MTB) remains a major public health threat, obstructing global tuberculosis (TB) control efforts. Resistance to isoniazid (INH), a key feature of MDR-MTB, is often linked to mutations in genes involved in drug metabolism, such as *katG* and the promoter region of *fabG1*. Biotechnological advances like whole-genome sequencing (WGS) provide valuable tools to detect genotypic diversity and resistance mechanisms, supporting the development of improved diagnostic and therapeutic strategies.

Objective: To investigate the genotypic diversity and INH-resistance mutations in MDR-MTB isolates through advanced biotechnological tools and to analyze their impact on pulmonary cavity development.

Methods: This study analyzed 132 MDR-MTB isolates obtained from the biobank of the National Reference Laboratory in Tuberculosis Microbiology, collected between 2016 and 2018. WGS was employed to identify resistance-related mutations, with a focus on mutations in the *katG* gene and the *fabG1* promoter region.

Results: Of the 132 MDR-MTB isolates, 80 (60.6%) exhibited mutations in both *katG* and the *fabG1* promoter region, with most strains belonging to Lineage 4, predominantly the Ural subtype. The remaining 52 isolates (39.4%) harbored only a *katG* mutation, with 45 of these strains identified as part of Lineage 2 (Beijing). Pulmonary cavity lesions were more frequent among strains carrying only the *katG* mutation. Specifically, 25 out of 44 patients (56.8%) with single *katG* mutations developed cavitory lesions, compared to 29 out of 70 (41.4%) in patients with dual mutations (*katG* and *fabG1*). These results suggest that other genetic factors may contribute to severe lung pathology in Lineage 2 (Beijing) strains, highlighting the complexity of host-pathogen interactions in MDR-MTB.

Conclusion: Biotechnological tools such as WGS provide valuable insights into the genotypic diversity and mutation profiles of MDR-MTB isolates resistant to INH. Our findings emphasize the need for further research to identify additional genetic factors influencing TB severity.

AI, Algorithmic Management and Teachers' Occupational Safety and Health

M.Bowdler¹ and C.van Gulijk^{1,2,3}

¹ Netherlands Organisation for Applied Scientific Research (TNO), Leiden, The Netherlands

² School of Applied Sciences, University of Huddersfield, Huddersfield, UK

³ Faculty of Technology Policy and Management, Delft University of Technology, Delft, The Netherlands

Keywords: Teachers; Education; Occupational Safety and Health; Digital; Technology; Artificial Intelligence; Algorithmic Management

Abstract. This research investigates the rapid integration of digital technologies, such as AI and algorithmic management, within the education sector, classified as 'high risk' under the EU AI Act. The research highlights the lack of literature on the occupational health and safety (OSH) impacts of these technologies on teachers, despite their widespread adoption since COVID-19. A thorough review was conducted, identifying and analysing relevant literature to synthesize current research on AI and algorithmic technologies and their OSH impacts within the education sector. Findings indicate that, unlike other sectors where such technologies often negatively impact workers' OSH, for teachers, enhanced productivity, efficiency, and reduced stress levels, was reported, contributing positively to teachers mental and psychosocial health. However, the positive effects depend on adequate training and skill development, highlighting the need for continued research using diverse methods, such as observations, interviews, and surveys, to further assess the use and impact of digital technologies on teachers. This research will also support the creation of comprehensive frameworks to guide the necessary AI and algorithmic competencies for safe and effective implementation in educational settings.

Background. In 2021, the ETUCE Statement introduced an EU OSH Strategic Framework addressing several key issues concerning the occupational health and safety (OSH) of teachers, academics and other education personnel across Europe (ETUCE., 2021). Among these, it emphasized the growing use of digital technologies in the education sector, with ETUCE urging the EU and its member states to conduct research on the effects of expanding digital education on the psychosocial risks and well-being of education professionals.

Following this statement, digitalization and technology such as AI tools including algorithmic management have undeniably made their way into the education sector, and being accelerated by the COVID pandemic, their usage is now rather widespread (EU-OSHA., 2022; Fernández-Macías et al., 2023). This shift raises potential new concerns regarding their impact on teachers' OSH. So far, the effects of the integration of digital technologies in education has primarily focused on the students, but along with this growing implementation of technology, increasing attention is now being directed towards teachers as well (Bollmann, 2024).

In education, it seems that the AI technologies including algorithmic management are being used for various reasons, such as, identifying optimal teaching strategies, streamlining administrative tasks, creating assessments, and automating grading and feedback (Chaudhry & Kazim., 2022).

In other sectors, such as the use of such technologies have been found to have negative effects on OSH of workers. These sectors include; platform workers (Urzi et al., 2020; Jarrahi et al., 2019), healthcare (Rani et al., 2024), logistics (Delfanti., 2019; Rani et al., 2024), retail (Mateescu and Nguyen., 2019), transportation (Cox & Anttila., 2024), white-collar workers (Eloundou et al., 2024). The associated negative effects include issues effecting autonomy, workload, variety, emotional strain and support (Parent-Rocheleau & Parker., 2022).

Parker & Grote (2022) contend that these new technologies, can have both positive and negative impacts on job resources and demands. Similarly, the use of digital technologies in education could pose both OSH risks and benefits to employees involved. Certain risks include reduced autonomy (Selwyn., 2022) and cognitive overloads (Giannini., 2023), both detrimental to OSH. Having said this, certain opportunities have also been outlined. One of them was productivity gains (Keppler et al., 2024), which is interesting considering that AI and algorithms are usually reported to lead to decreased productivity in the workplace (e.g. Cox & Anttila., 2024). Additionally, AI technologies can lighten teachers' workload, streamline resource planning, and enhance grading accuracy, and with certain implementation, teacher well-being can be supported (Bollmann, 2024).

Despite numerous interventions for students, there is a notable lack of digital interventions specifically designed to support teachers' mental health, highlighting a significant gap in research and development (Costardi et al., 2023). This further stresses the need for a shift in focus from students to teachers, particularly regarding the impact of digital technologies such as AI and algorithmic management on teachers OSH.

Objective. The primary objective of this research is to explore the growing emergence of digitalization and technologies such as AI and algorithmic management within the educational sector, a sector that is classified as 'high risk' (EU AI Act., (European Union., 2024)). This study aims to assess the impact of these technologies on the OSH of education professionals, considering both their positive and negative effects. By doing so, the research seeks to initiate a continuum of inquiry in this field, encouraging further international studies on how teachers are utilizing AI and algorithmic technologies, the OSH implications of these tools, and strategies for their safe implementation.

Methods. A comprehensive literature review was conducted to synthesize existing research on digital technologies such as AI and algorithmic management and occupational safety and health within education. Relevant peer-reviewed articles, books, and conference papers were identified through electronic databases such as Google Scholar, and Scopus using keywords such as, 'data-driven innovation', 'artificial intelligence' 'algorithmic management', 'education', 'teachers',

‘occupational safety and health’, ‘risks’, ‘benefits’. Data was extracted and analysed to identify key themes, trends, and gaps in the current literature.

Results. The results of this research indicate a rapid emergence of digital technologies, such as AI and algorithmic management, within the education sector. Despite the widespread adoption of these technologies following the COVID-19 pandemic, there has been a notable lack of research focusing on their effects related to OSH on teachers.

Interestingly, the findings reveal that, unlike other sectors where the introduction of such technologies has often led to negative impacts on workers’ OSH, the educational sector shows more potential for positive effects. Teachers report that these tools enhance their productivity and efficiency, reduce stress levels, and generally support their mental and psychosocial health.

However, for these positive effects to be realized, it is crucial that teachers are adequately trained and possess the necessary skills to use these tools effectively. This underscores the need for educational stakeholders to develop comprehensive strategies to ensure the successful adoption and beneficial impact of these technologies.

Conclusion. In conclusion, this research highlights the rapid integration of digital technologies, such as AI and algorithmic management within the education sector. While these tools have shown potential for positive impacts on teachers’ productivity, efficiency, and overall well-being, there remains a significant gap in research focusing on their effects on teachers’ OSH.

To address this gap, it is essential to continue focusing on this area. More international data must be collected through various methods, such as observations, interviews, and surveys, to further assess how teachers are using these digital technologies and what the effects are. From this, more comprehensive frameworks can be developed to inform teachers of the necessary AI competencies, ensuring the safe and effective use of these tools in their professional environment.

References

- Bollmann, U. (2024). Artificial intelligence and education: A teacher-centred approach to safety and health.
- Chaudhry, M. A., & Kazim, E. (2022). Artificial Intelligence in Education (AIEd): A high-level academic and industry note 2021. *AI and Ethics*, 2(1), 157–165
- Costardi, CG; D’agostini, ACC; Pan, PM & Bressan, RA (2023). Digital mental health interventions for school teachers – A narrative review. *Early intervention in Psychiatry* 17(8), 749-758.
- Cox, T., & Anttila, J. (2024). Algorithmic management and workplace knowledge, skills, and safety: Insights from the transport and logistics and retail sectors. Sorsa Foundation. Retrieved from <https://sorsafoundation.fi/wp-content/uploads/algorithmic-management-and-workplace-kss-.pdf>
- Delfanti A (2019) Machinic dispossession and augmented despotism: Digital work in an Amazon warehouse. *New Media & Society* 23(1): 39-55
- Eloundou, T., Manning, S., Mishkin, P., & Rock, D. (2024). GPTs are GPTs: Labor market impact potential of LLMs. *Science*, 384(6702), 1306-1308
- EU-OSHA. (2022). Education – evidence from the European Survey of Enterprises on New and Emerging Risks (ESENER). Retrieved from <https://osha.europa.eu/en/publications/education-evidence-european-survey-enterprises-new-and-emerging-risks-esener>. [Accessed on 10/10/2024]
- European Union. (2024). Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 on harmonised rules on artificial intelligence. Retrieved from <https://eurlex.europa.eu/eli/reg/2024/1689/oj> [Accessed on 10/10/2024]

- European Trade Union Committee for Education (ETUCE). (2021). ETUCE Statement on the EU Strategic Framework on Health and Safety at Work for 2021-2027. Retrieved from <https://www.csee-etu.org/en/resources/statements/4634-etuce-statement-on-the-eu-strategic-framework-on-health-and-safety-at-work-for-2021-2027-november-2021>. [Accessed on 10/10/2024]
- Fernández-Macías, E., Urzì Brancati, C., Wright, S., & Pesole, A. (2023). The platformisation of work. Joint Research Centre (Seville Site): Sevilla, Spain.
- Giannini, S (2023). Reflections on generative AI and the future of education. Paris: United Nations Educational, Scientific & Cultural Organization (UNESCO). <https://unesdoc.unesco.org/ark:/48223/pf0000385877>
- Jarrahi, M. H., & Sutherland, W. (2019). Algorithmic management and algorithmic competencies: Understanding and appropriating algorithms in gig work. In *Information in Contemporary Society: 14th International Conference, iConference 2019, Washington, DC, USA, March 31–April 3, 2019, Proceedings 14* (pp. 578-589). Springer International Publishing.
- Keppler, S., Sinchaisri, W. P., & Snyder, C. (2024). Backwards Planning with Generative AI: Case Study Evidence from US K12 Teachers. Available at SSRN.
- Mateescu, A., Nguyen, A. (2019). Algorithmic management in the workplace. *Data & Society*. Available at: https://datasociety.net/wpcontent/uploads/2019/02/DS_Algorithmic_Management_Explainer.pdf
- Parent-Rocheleau, X., & Parker, S. K. (2022). Algorithms as work designers: How algorithmic management influences the design of jobs. *Human resource management review*, 32(3), 100838.
- Parker, S. K., & Grote, G. (2022). Automation, algorithms, and beyond: Why work design matters more than ever in a digital world. *Applied psychology*, 71(4), 1171-1204.
- Rani, U., Pesole, A., & González Vázquez, I. (2024). Algorithmic Management practices in regular workplaces: case studies in logistics and healthcare (No. JRC136063). Joint Research Centre.
- Selwyn, N (2022). *Education and technology: Key issues and debates*. 3rd edition. London and New York: Bloomsbury Academic. ISBN 9781350145566
- Urzì Brancati, M. C., Pesole, A., & Fernández-Macías, E. (2020). New evidence on platform workers in Europe: Results from the second COLLEEM survey (No. JRC118570). Joint Research Centre (Seville site).

Application of Artificial Intelligence to Enhance the Reliability of Lightweight Cryptographic Systems in Precision Medicine

S.V. Naumenko¹, I.O. Rozlomii² and A.V. Yarmilko²

¹ Bohdan Khmelnytsky National University of Cherkasy, Ukraine

² Cherkasy State Technological University, Ukraine

Keywords: lightweight cryptography; medical cyber-physical systems; artificial intelligence; dependability; hardware security modules; risk prediction; adaptive cryptographic protection

Abstract. The article discusses the implementation of lightweight cryptographic systems as a factor in enhancing the reliability of medical cyber-physical systems. Special attention is given to algorithms developed for devices with limited computational resources, such as PRESENT, GIFT, SKINNY, and LEA. Key indicators of the reliability of cryptographic systems are analyzed. The potential of applying artificial intelligence to enhance system reliability is examined, particularly through risk prediction and providing adaptive cryptographic protection based on the analysis of current threats. The role of innovative technologies, including the implementation of hardware security modules and quantum-resistant algorithms, in ensuring data protection in medical systems is explored. The article also presents methods for integrating lightweight cryptographic solutions into modern medical devices while considering the requirements for patient data privacy.

Biotechnological Transplantation of Hematopoietic Stem Cells with Mutation of the CCR5 Gene as a Way of Treating HIV Infection

Iulia Zama¹, Mariana Sprincean^{1,2} and Ludmila Sidorenko¹

¹“Nicolae Testemitanu” State University of Medicine and Pharmacy, Chisinau, Republic of Moldova, zama032002@gmail.com, ludmila.sidorenko@usmf.md

²MPHI Institute of Mother and Child, mariana.sprincean@usmf.md

Keywords: HIV, hematopoietic stem cell transplantation, CCR5 gene mutation.

Background. HIV infection is a disease caused by the human immunodeficiency virus (HIV). It is one of the most widespread and pressing problems for humanity. This is primarily due to the fact that no cure for the virus currently exists, and the mortality rate among infected individuals continues to rise. Traditional treatment methods, such as antiretroviral therapy (ART), are effective at suppressing viral replication but require lifelong medication and do not lead to a complete cure.

Objective of the study. To evaluate the possibility and effectiveness of hematopoietic stem cell transplantation with CCR5 gene mutation.

Material and Methods. 1. National Center for Biotechnology Information. 2. PubMed. 3. National Institutes of Health. 4. National Institutes of Health. 5. Google Scholar

Results. The CCR5 protein (C-C chemokine receptor type 5) is a receptor found on the surface of immune cells, such as T-lymphocytes, and plays a key role in the pathogenesis of HIV-1. HIV uses this receptor to enter host cells, and its presence is necessary for the infection of the majority of virus strains. However, people who have a homozygous mutation in the CCR5-Δ32 gene (a 32 base pair deletion) exhibit a partial or complete absence of this receptor on the cell surface, leading to resistance to HIV infection. Studies have shown that the CCR5-Δ32 mutation occurs in about 1% of the European population, and these individuals have a natural resistance to HIV-1. Specifically, the absence of a functional CCR5 receptor prevents viral entry into cells, thus preventing infection. This phenomenon has become the foundation for the development of innovative therapies aimed at modifying or blocking CCR5 in patients with HIV infection. The idea of using this mutation for HIV treatment arose after successful cases of bone marrow transplantation from donors with the CCR5-Δ32 mutation. The first confirmed case of a complete HIV cure was recorded in 2007 following a hematopoietic stem cell transplant from a donor with the CCR5-Δ32 mutation (known as the “Berlin patient”). This case demonstrated that the complete absence of a functional CCR5 receptor on immune cells can prevent viral replication in the body. Similar results were later observed in other patients, including the “London patient,” further confirming the potential of the CCR5 mutation for HIV treatment.

Conclusion. Gene therapy targeting the editing of the CCR5 gene represents one of the most promising strategies for treating HIV infection. With successful development, this therapy could provide a long-term, and possibly definitive, solution for millions of people living with HIV.

Recent Progress for Determination of Association of Some Periodontal Microorganisms with PD-L1 and PD-1 Protein Expression

Cristina Popa^{1,2}, Valentina Stratan¹, Valeri Țuțuianu¹, Mihail Novac¹, Victor Sîtnic¹,
Veronica Balan¹, Mariana Sprincean^{2,3} and Andrian Clipca¹

¹Scientific Laboratory of Cancer Biology, Institute of Oncology, Chisinau, Republic of Moldova,
cristina.popa18@yahoo.com

²"Nicolae Testemitanu" State University of Medicine and Pharmacy, Chisinau, Republic of
Moldova, mariana.sprincean@usmf.md

³ MPHI Institute of Mother and Child, Republic of Moldova

Key words: Periodontal microorganisms, PD-L1, PD-1

Introduction: Periodontal microorganisms may play an important role in head and neck squamous cell carcinoma (HNSCC), contributing to chronic inflammation and changes in the tumor microenvironment. These microorganisms can influence cancer progression through mechanisms that include modifying the immune response, promoting local inflammation, and increasing the expression of immunosuppressive molecules, such as PD-L1 and PD-1, which can help cancer cells escape immune system attack.

Methods: In the study was included a cohort of 47 patients primarily diagnosed with head and neck squamous cell carcinoma (HNSCC). The expression of PD-1 and PD-L1 proteins (tumor cells and inflammatory cells) was determined by the immunohistochemical method and the amount (copies/mL) of the microorganisms *Aggregatibacter actinomycetemcomitans* (Aa), *Porphyromonas gingivalis* (Pg), *Porphyromonas endodontalis* (Pe), *Treponema denticola* (Td), *Tannerella forsythia* (Tf), *Prevotella intermedia* (Pi) and *Fusobacterium nucleatum* (Fn) was identified by the RT-PCR method.

Results: We found strong positive correlations between PD-L1 protein expression on the surface of inflammatory cells and the amount of the following species of microorganisms: Pe ($r = 0.81$), Fn ($r = 0.88$), Tf ($r = 0.90$), Td ($r = 0.91$) and Pi ($r = 0.92$). Also, a strong positive correlation is observed between the concentrations of all these species of microorganisms ($r = 0.93 - 0.96$). At the same time, the correlation coefficient between the amount of microorganisms and the expression of PD-L1 protein on tumor cells and PD-1 protein is statistically insignificant (PD-L1, $r = -0.26 - 0.49$; PD-1, $r = -0.20 - 0.14$).

Conclusions: The concentrations of tested periodontal microorganisms show that periodontal microorganisms influence PD-L1 expression on inflammatory but not tumor cells.

Medical Image Segmentation with Graph Reasoning

Di Zhao, Yi Tang, Dmitry Pertsau, Dziana Kupryianava and Alevtina Gourinovitch

Belarusian State University of Informatics and Radioelectronics, Minsk, Belarus,
3189124246@qq.com

Keywords: medical image segmentation, graph reasoning, graph convolutional network

This paper introduces a novel Synergistic Edge-Guided Graph Reasoning Network (SEGRNet) designed to address the limitations of traditional Convolutional Neural Networks (CNNs) in medical image segmentation, particularly in capturing global information and modeling complex topological relationships. Existing CNN-based methods, such as U-Net and its variants, suffer from limited receptive fields, hindering their ability to capture comprehensive global context, especially in structurally complex biological tissues. To overcome these challenges, SEGRNet incorporates Graph Convolutional Networks (GCNs) to leverage the feature extraction strengths of CNNs with GCNs' capability to model graph structures. Specifically, SEGRNet utilizes Res2Net50 as the backbone and integrates an edge-guided module and a region-guided module to process low-level edge features and high-level semantic features.

The core of the SEGRNet architecture is its Synergistic Edge-Guided Graph Reasoning (SEGR) module, which enhances the model's ability to perform cohesive and adaptive reasoning across edge and region features. This is achieved through a three-step graph reasoning process: projection, interaction, and reverse projection, allowing the model to capture both local and global dependencies, significantly improving segmentation accuracy.

Experiments were conducted on the Low-Grade Glioma (LGG) dataset, sourced from the National Cancer Institute's Cancer Imaging Archive. The results demonstrate that SEGRNet consistently outperforms state-of-the-art methods across multiple evaluation metrics. Specifically, SEGRNet achieves a mean Dice coefficient (mDice) of 0.849, mean Intersection over Union (mIoU) of 0.760, S-Measure of 0.904, F-Measure of 0.856, and E-Measure of 0.962. These results surpass competing models such as ResUnet++ and PraNet, with significant improvements in mIoU, which is essential for evaluating the overlap between predicted and ground truth segmentations. Future work will focus on optimizing the model's computational efficiency and expanding its applicability to other datasets to further enhance its generalization and robustness.

Acknowledgment: The research was supported by the China Scholarship Council (CSC).

Investigating the Relationship between Lighting, Human Circadian Rhythms and Physiological Parameters

Yehor Zheliazkov^{1,2}, Iuliia Yamnenko^{1,2}, and Larysa Globa^{1,2}

¹ National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute»,
yzheliazkov2@gmail.com yys315171-eds@iit.kpi.ua, lgloba@its.kpi.ua

² Technical university of Dresden, Dezernat Personal, Dresden, yehor.zheliazkov@tu-dresden.de

Keywords: adaptive lighting, circadian rhythms, indoor comfort level, psychological data

Abstract. Parameters of natural and artificial light affect human circadian rhythms, and consequently health and well-being. Thus, changing the light parameters indoor (e.g. at a workplace) could be a tool to influence not only human state, but also the comfort level and productivity. Many publications investigate the impact of lighting parameters on human circadian rhythms.

Nowadays, there are many clinics, institutes, research centers, sleep laboratories and other institutions all over the world that study circadian rhythms. Existing technical solutions of adaptive lighting systems can adjust parameters during the day and detect whether a person is present in the room. However, not all these systems are adjustable to the physiological parameters of a person with the considering of a particular day period. The concept of smart adaptive lighting integrates all mentioned parameters. As a result, a synchronization of lighting with human circadian rhythms could be achieved, offering personalized and health-conscious lighting solutions. These should tackle the challenges of complexity, accurate capturing and interpreting physiological data, potential privacy concerns, and the technical feasibility of real time realization.

The paper presents a mathematical model of external environment, which differs from the known ones by representing the dependencies between microclimate parameters and human physiological data in the form of fuzzy knowledge base. Such approach offers personalized lighting scenarios that align with individual circadian rhythms. This can not only to enhance a comfort, but also to minimize the adverse effects associated with inappropriate lighting, such as sleep disturbances or reduced alertness. Theoretical findings are presented in the form suitable for integrating of light technical solutions into an IoT system of indoor microclimate control.

Integration of eHealth Competences into Health Students' Curriculum

Raquel Faubel¹ and Aarón Sújar²

¹ PTinMOTION-Physiotherapy in Motion Multispeciality Research Group, Department of Physiotherapy, Universitat de València, Valencia, Spain, raquel.faubel@uv.es

² Department of Informatics and Statistics, Universidad Rey Juan Carlos, Móstoles, Spain

Keywords: ehealth; telephysiotherapy; ICT; physical therapy

Background. Future health sciences professionals will be encouraged to apply ehealth in their professional practices. Disciplines as ehealth and telehealth will be relevant specifically for physical therapists as a leading largely nonpharmacological health profession. Explicit mention to ehealth related terms in their curricula will be a strategy to guarantee the acquisition of ehealth competences.

Objective. The aim of this study is to assess the integration of eHealth competences into undergraduate Physical Therapy Degree curricula.

Methods. A systematic search was executed -using a structured process- in the teaching guides of all the subjects constituting the Physical Therapy Degree (PT) at two different Spanish universities: Universitat de València and Universidad Rey Juan Carlos. Keywords related to ehealth selected were tele*, virtual, eHealth, tecnol*, technol*, simula*, electronic*, robot*, mhealth, digital, ingen*, engine*, bioinf*, biotec*, Tic*, ICT* and intel* both in Spanish and English language.

Results. A total of 62 teaching guides constituting PT degree on UV (39 subjects) and on URJC (23 subjects) were assessed in order to analyse the integration of the ehealth discipline into the content of the curricula. Only 3 subjects at the UV (Physiotherapy in clinical specialties IV, Use of Information communication technology, and Physiotherapy of the nervous system) and 1 subject at the URJC (Specific methods for intervention in PT) explicitly mentioned terms related to ehealth on its contents. On the other hand, there were many citations to simulation techniques as innovative resources applied on the teaching-learning process, but not referring to specific contents of a subject.

UV curriculum includes 8 references to “new technologies for neurological conditions” “virtual reality and robotics for neurorehabilitation”, “ehealth, telehealth, digital practice and telephysiotherapy”, “ICT for research methodology”, “ICT for physiotherapy”, “introduction to informatics and ICT”, “AI and social media”, “AI applications in physiotherapy”. Regarding URJC, a reference to “ICT applications” is included.

Institution	Subjects assessed	Subjects with explicit mention	Terms mentioned	ICT	tele*	virtual	Intel*	technol*	robot*	eHealth
UV	39	3	8	x	x	x	x	x	x	x
URJC	23	1	1	x						

Conclusion. A comprehensive and appropriate training during the undergraduate degree is relevant in order to encourage the proper ehealth competences of future health sciences professionals. Explicit references to keywords related to the ehealth discipline -included within the contents of the subjects- could contribute to the visibility and recognition of ehealth as a relevant strategy for their professional practice.

These results may be indicative of the fact that university curricula still need to be improved. A possible future work could be to analyse other health related degrees (nursing, or medicine). This would help public institutions to take more specific actions.

Wearable Devices in Cardiovascular Medicine

Vladimir Redzhepov and Dmitry Pertsau

Belarusian State University of Informatics and Radioelectronics, Minsk, Belarus,
vladimir.redzhepov@gmail.com

Keywords: wearables; cardiovascular; physiological signals; sensors; personal health

Abstract. Wearable technology, often known as "wearables," encompasses a variety of electronic devices designed for hands-free use. These devices play a significant role in measuring physiological signals, diagnosing medical conditions, and even treating diseases. Recent advancements in miniaturization, sensor technology, battery life, and production costs have led to the development of highly sophisticated wearables equipped with numerous sensors. Modern smartwatches, for instance, feature capabilities such as pulse and oxygen saturation monitoring, movement and activity tracking, distance and location tracking, sound recording and electrocardiogram recording. These multifunctional devices not only enhance personal health monitoring but also contribute to a broader understanding of individual health patterns, paving the way for proactive healthcare management. The purpose of the article is a review of existing wearable devices and their features in cardiovascular medicine.

Advances in Gene Therapy for Duchenne Muscular Dystrophy: Promising Strategies and Future Directions

Alexei Dragos, Ludmila Rotaru and Ludmila Sidorenko

“Nicolae Testemitanu” State University of Medicine and Pharmacy, Chisinau, Republic of Moldova,
alexei.dragos@gmail.com, ludmila.rotaru@usmf.md

Keywords: Duchenne muscular dystrophy, gene therapy, Adeno-associated viral vectors.

Background: Duchenne muscular dystrophy (DMD) is one of the most severe genetically transmitted muscular dystrophies and is caused by a mutation of the dystrophin gene, located on chromosome Xp21, that affects mostly men, with an estimated occurrence of about 1 in 3600 male live-born infants. Dystrophin is a structural protein that maintains the integrity of muscle fibers and prevents contraction induced damage. The absence of dystrophin leads to muscle degradation and weakness that initially presents difficulties in movement and progressively advances leading to cardiomyopathy and weakness of respiratory muscles, causing death

Objective: To evaluate new biotechnological therapies based on adeno-associated viral (AAV) vectors as a way of treating DMD.

Methods: Several bibliographic sources for the study were analyzed using PubMed, Google Scholar, Nature communications, and BioSpace and were released between 2021 and 2024.

Results: Current gene transfer using AAV follows two directions, due to the large size of the dystrophin gene and the small capacity of the AAV virus (around 4.7 kb) some scientists are currently experimenting with micro-dystrophin genes, that still retains the protein's function. At the moment, micro-dystrophin gene therapy studies are led by Sarepta therapeutics, that are using delandistrogene moxeparvovec, delivered by intravenous infusion, and has been approved for medical use in the United States of America as of June 2023. Fordadistrogene movaparvovec is another alternative offered by Pfizer that has yet to obtain approval for medical use. It is important to note that these gene therapy treatments are targeted for patients 4-5 years of age. Another path to treatment of DMD using gene therapy is the delivery of full-length dystrophin, with the help of a triple vector system, each of the vectors carrying a part of the dystrophin gene. This method is thought of being superior to the previous one due to the better functionality of large dystrophin as opposed to micro-dystrophins. Yet, this study is at an initial stage being only applied on mice.

Conclusion: Gene therapy presents a promising approach to treating Duchenne muscular dystrophy. The use of adeno-associated viral vectors conveys cutting-edge developments in the field, allowing for delivery of micro-dystrophin and full-length dystrophin. While full-length dystrophin presents a more promising treatment it is still at an initial stage, compared to micro-dystrophin that has been granted permission for medical use in the US. However, these advancements have a long way ahead, especially full-length dystrophin gene therapy, before becoming an efficient treatment for DMD.

New Bioengineering Technologies in the Diagnosis and Treatment of Multiple Sclerosis

Zalesskaya Daria¹, Svetlana Sidorenko² and Ludmila Sidorenko¹

¹“Nicolae Testemitanu” State University of Medicine and Pharmacy, Chisinau, Republic of Moldova, zalesskaya.dasha01@gmail.com, ludmila.sidorenko@usmf.md

²Rehabilitation Clinic Valens, Bad Ragaz, Switzerland, svetlana.sidorenko@yahoo.com

Keywords: multiple sclerosis; bioengineering; stem cell therapy; gene therapy; biomarkers.

Background. Multiple sclerosis (MS) is an autoimmune progressive inflammatory-degenerative disease of the central nervous system, clinically manifested by scattered organic neurological symptoms, the appearance of inflammation and demyelination foci, followed by the formation of sclerotic plaques in the white matter of the brain and/or spinal cord.

Objective. It is necessary to establish how bioengineering contributes to the development of new methods of treatment and diagnosis of multiple sclerosis.

Methods. The research is based on bibliographic sources that were analyzed using PubMed, Google Scholar, Oxford Academic and Medline, published within the period of 2021-2024.

Results. One of the bioengineering approaches being researched for the treatment of multiple sclerosis is stem cell therapy. Since 1995, active research on stem cell transplantation for multiple sclerosis has been underway in the United States and Europe. The essence of the stem cell transplantation method is that it allows for the elimination of the root cause of the disease—destroying the autoimmune T-lymphocytes that mistakenly attack the patient’s myelin sheath, mistaking it for a foreign protein. Therefore, after high-dose immunosuppressive therapy, the patient is given hematopoietic stem cells, which restore the normal functioning of the hematopoietic and immune systems. As a result, after transplantation, pathological immune cells either do not reappear at all, or their activity is completely suppressed. Another bioengineering approach in the treatment of multiple sclerosis is gene therapy, aimed at introducing genes that encode proteins capable of suppressing autoimmune reactions or restoring the function of genes associated with nerve myelination. Equally important is CRISPR/Cas9 genome editing technology, which can precisely cut out and modify genetic genes that cause pathological autoimmune reactions, or correct genetic mutations that predispose to multiple sclerosis. For example, genes involved in inflammation or the destruction of the myelin response in the central nervous system can be edited. Bioengineering also aims to create new biomarkers for diagnosing and monitoring multiple sclerosis. In this context, the development of sensitive, reliable biomarkers to measure neurodegeneration is a primary necessity to facilitate successful informative clinical research.

Conclusion. Bioengineering research continues to open up new opportunities to create more effective and targeted treatments for MS to not only slow the progression of the disease but even potentially repair damaged areas of the nervous system.

Recent Biotechnologies to Assess Genetic Factors in Atherosclerosis

Abdul Raheem Fauzi, Ludmila Rotaru and Ludmila Sidorenko

“Nicolae Testemitanu” State University of Medicine and Pharmacy, Chisinau, Republic of Moldova,
a4abdulraheemfauzi@gmail.com, ludmila.rotaru@usmf.md, ludmila.sidorenko@usmf.md

Keywords: atherosclerosis, coronary artery disease (CAD)

Background: Atherosclerosis results from complex interactions between genetic and environmental factors. Though traditional risk factors are important, genetic variants also play a vital role in susceptibility and disease progression.

Objective: To explore the genetic factors influencing atherosclerosis, and to determine the genes and their loci associated with atherosclerosis.

Methods: The 18 bibliographic sources for the study were analyzed using PubMed, Google Scholar, Oxford Academic, and Medline and were released between 2014 to 2024.

Results: Atherosclerotic (ischemic, coronary artery disease (CAD)) Nearly all patients with a genetic susceptibility to developing CAD have traditional CV risk factors and an appreciable heritable component. Although familial hypercholesterolemia (FH) illustrates Mendelian inheritance, there is considerable variability in atherosclerosis even among patients with FH. Linkage studies have identified over 40 loci that are associated in some way with CAD but few true candidate genes – LRP6, ALOX5AP, and MEF2A being amongst those with the strongest evidence - mouse model has convincingly validated none of these three. Subsequent genome-wide association studies (GWAS) have deepened the understanding of the genetic architecture of CAD and helped identify 34 independent, significant loci associated with myocardial infarction and/or CAD as a phenotype including novel genes at chromosome locus 9p21. 3. The noncoding RNA and neighboring genes CDKN2A and CDKN23B are likely involved in atherogenesis but no defined mechanism for these associations has been described. Several candidate genes such as ADAMTS7 have been identified, with variants shown to correlate both genetically and functionally with vascular smooth muscle cell phenotypes important in atherogenesis. Another also able professional inflammatory chemokine, CXCL12 associated with inflammation and angiogenesis is a future prospect in CAD pathology. Further, genome-wide significant locus (ABO) was also associated with cholesterol levels and susceptibility to MI underscoring the complex nature of genetic interactions affecting cardiovascular risk.

Conclusion: In conclusion, new molecular-genetic biotechnologies make the assessment of the genetic influences on coronary artery disease possible, identifying significant loci and candidate genes such as ADAMTS7 and CXCL12, emphasizing the complexity of genetic interactions affecting cardiovascular risk.

New Biotechnological Directions in Treatment of Cystic Fibrosis

Nicoleta Pojoga, Ludmila Sidorenko and Ludmila Rotaru

“Nicolae Testemitanu” State University of Medicine and Pharmacy, Chisinau, Republic of Moldova,
nicoleta.pojoga3@gmail.com, ludmila.rotaru@usmf.md

Background: Cystic fibrosis (CF) is a genetic disease caused by insufficient levels or defective functioning of the CFTR (cystic fibrosis transmembrane regulator) protein due to mutations in the CFTR gene on chromosome 7.

Objective: To evaluate new biotechnological directions in the treatment of cystic fibrosis.

Methods: The 11 bibliographic sources for the study were analyzed using PubMed, Google Scholar, Oxford Academic, and Medline and were released between 2012 to 2023.

Results: Within the past few years, new technologies, such as CRISPR/Cas gene editing, have emerged as an appealing platform to revise the genome. The CRISPR gene editing system operates through a precise mechanism involving several key components: a guide RNA (gRNA), a DNA repair template, and the Cas9 endonuclease. Researchers are exploring the use of CRISPR technology to treat cystic fibrosis. The disorder is caused by a genetic mutation in the CFTR (cystic fibrosis transmembrane conductance regulator) gene, which compromises both the structure and function of the protein it encodes, leading to the disease. While there is currently no cure, some modulating drugs are available to manage symptoms and reduce complications. Notably, in 2013, scientists successfully corrected the CFTR mutation in intestinal stem cells from cystic fibrosis patients, leading to normal protein expression. Since then, CRISPR-Cas has been studied for its potential as a gene therapy for cystic fibrosis. The guide RNA directs the Cas9 protein to a specific location on the CFTR gene where a pathogenic mutation resides by recognizing the complementary DNA sequence. Once bound, the Cas9 endonuclease functions as molecular "scissors," inducing a double-strand break at the target site. This DNA break activates the cell's endogenous DNA repair pathways, primarily homology-directed repair (HDR) if a DNA template is provided. The repair template contains the correct, wild-type sequence, allowing the cell's repair machinery to use it as a blueprint to replace the defective sequence. The corrected sequence is then integrated into the genome, resulting in a permanent repair of the mutation within that cell. However, there are around 1,700 different mutations in CFTR that can cause cystic fibrosis, and they are distributed throughout the entire gene. This alone presents a major challenge when developing CRISPR-based therapies for the disease.

Conclusion: While current therapies help manage the disease, CRISPR/Cas gene editing offers the potential for a permanent cure by repairing mutations. However, challenges like the large size of the CFTR gene and difficulties in delivering gene-editing components must be addressed to develop a comprehensive treatment.

Biotechnologies Improving the Diagnostic Establishment of Molecular Mechanisms Involved into Synaptic Dysfunction of Dopaminergic Neurons in Parkinson's Disease

Alexandra Sochirca¹, Svetlana Sidorenko², Liliana Badan¹ and Ludmila Sidorenko¹

¹“Nicolae Testemitanu” State University of Medicine and Pharmacy, Chisinau, Republic of Moldova, sochirca.alecsandra@gmail.com, liliana.badan@usmf.md, ludmila.sidorenko@usmf.com

²Rehabilitation Clinic Valens, Bad Ragaz, Switzerland, svetlana.sidorenko@yahoo.com

Keywords: Parkinson's disease, alpha-synuclein, protein degradation, mitochondrial dysfunction.

Background: By virtue of newly developed approaches of bioengineering it was possible to illuminate the earlier approximately elusive pathomechanism of Parkinson's disease (PD), which is known as a chronically progressive neurodegenerative disorder. Its clinical manifestation is associated with bradykinesia, tremor, and rigidity, being the second most common central nervous system degenerative disorder after Alzheimer's disease.

Objective: The evaluation of the molecular background of PD's pathogenesis.

Methods: A bibliographic study of scientific literature specialized in molecular mechanisms of pathogenesis of Parkinson's disease. The number of researched scientific articles has counted 15 essays on the subject, analyzed using PubMed, Google Scholar, Oxford Academic, and Medline, published from 2014 to 2024, filtered by the keywords.

Results: Scientific data analysis has shown that the pathogenesis lies in three molecular interdependent mechanisms, localized in dopaminergic neurons of substantia nigra pars compacta, the simultaneous activity of which causes synaptic dysfunction and, as a consequence, leads to neurodegeneration. One of them is mitochondrial dysfunction, caused by a wide range of genetic mutations, which increases reactive oxidative species and affects fusion, mitophagy, and the mitochondrial respiratory chain, which leads to mitochondrial fragmentation. The following one is alpha-synuclein pathobiology, which is characterized by pathologic aggregates of alpha-synuclein, that can adopt similar conformations, self-propagating and causing amyloidosis. The final mechanism is failed protein degradation, released by defective Ubiquitin-proteasome pathway and autophagy-lysosomal system, which leads to the accumulation of defective mitophagy and Lewy bodies, causing cell's dysfunction.

Conclusion: Thus, due to the progress of biotechnologies and their implementation of PD emergence is dependent on several complex molecular mechanisms caused by the interplay between genetic and environmental factors, which lead to synaptic dysfunction and neurodegenerative processes.

Simulation-based Approaches to Managing Infectious Disease Risks in Conflict Zones: Opportunities and Limitations

Dmytro Chumachenko^{1,2}

National Aerospace University, Kharkiv, Ukraine, d.chumachenko@khai.edu

² Balsillie School of International Affairs, Waterloo, ON, Canada

Keywords: epidemic model; SWOT; PESTLE; infectious disease simulation; emergency

Abstract. Infectious disease outbreaks pose serious public health challenges in conflict zones, where war-related disruptions to infrastructure, healthcare, and population stability amplify risks and hinder control efforts. This paper explores the application of simulation-based approaches to managing infectious disease threats in conflict zones, specifically examining the ongoing Russian invasion of Ukraine. Using SWOT (Strengths, Weaknesses, Opportunities, and Threats) and PESTLE (Political, Economic, Social, Technological, Legal, Environmental) analyses, the potential of simulation models to forecast, monitor, and mitigate the spread of infectious diseases under the unique constraints of wartime conditions has been evaluated.

Simulation-based models offer significant predictive power, enabling health authorities to anticipate disease outbreaks, allocate resources, and test intervention strategies. Strengths of these approaches include the adaptability of simulations to war-specific conditions, such as disrupted infrastructure and mass displacement, and their utility in real-time scenario testing without risking human lives. However, challenges are notable: the accuracy of simulations often suffers due to limited and outdated data on population movements, resource access, and healthcare facility functionality. Additionally, the complexity of accurately modelling disease spread in highly dynamic, conflict-impacted environments can demand advanced computational resources and expertise that may be scarce in emergencies.

The paper also highlights significant opportunities for integrating simulation tools with emerging technologies, such as satellite data and real-time geographic information systems, to enhance disease tracking and forecasting accuracy in war zones. These technologies could support partnerships with international health organizations, fostering collaboration and improving intervention outcomes. Nonetheless, threats to effective implementation persist, including potential data access restrictions, ethical and privacy concerns, and the unpredictable nature of conflict, which can abruptly alter transmission dynamics and reduce model accuracy.

From a PESTLE perspective, political instability and military control can impede data access and hinder stakeholder cooperation. Economically, strained resources in war-torn regions may limit the feasibility of extensive simulation deployment, while social factors, such as displaced populations with varying health literacy, affect intervention adherence. Technologically, while advanced simulation tools offer precision, their deployment may be hampered by degraded local infrastructure. Collecting and using health data in conflict settings raises privacy concerns, and environmental, conflict-driven sanitation issues and extreme conditions compound infection risks.

By assessing the strengths, weaknesses, opportunities, and limitations, this paper provides a framework for understanding the potential and challenges of simulation-based infectious disease modelling in emergency contexts, offering insights for future applications in similarly affected regions.

Biotechnological Development of Targeted Treatments based on a Tumor's Specific Genetic Mutations in PARP Inhibitors

Anand Muraleedharan, Ludmila Rotaru and Ludmila Sidorenko

“Nicolae Testemitanu” State University of Medicine and Pharmacy, Chisinau, Republic of Moldova,
anandmuralips88@gmail.com, ludmila.rotaru@usmf.md, ludmila.sidorenko@usmf.md

Keywords: DNA repair; PARP inhibitors; DNA damage sensor.

Background: Polyadenosine diphosphate-ribose polymerase inhibitors, or PARP inhibitors, are an intriguing family of targeted cancer therapies. Many cases (80% high-grade serious and 21,750 new cases) were epithelial in origin in 2020. 13,940 fatalities were predicted from ovarian cancer in the United States.

Objective: To evaluate new biotechnological therapies based on PARP inhibitors that target tumor-specific genetic abnormalities, notably in malignancies with Breast Cancer gene1/Breast Cancer gene2 (BRCA1/BRCA2) mutations and other homologous recombination deficits (HRD).

Methods: The 18 bibliographic sources for the study were analyzed using PubMed, Google Scholar, Oxford Academic, and Medline and were released between 2014 to 2024.

Results: The next-generation PARP inhibitors are being developed for higher specificity and patient outcomes. DNA damage sensor and signal transducer PARP1 attaches itself to DNA breaks and initiates the production of PARP chains on target proteins both in the region of the break and on the protein itself. Additional DNA repair effectors are recruited because of these PAR chains, completing the DNA repair process. Patients with BRCA1/BRCA2-mutated malignancies, such as those of the breast, ovarian, prostate, and pancreatic regions, have shown notable benefit with PARP medicines. Treatment response was also shown in HRD-positive cancers, which contain mutations other than BRCA (e.g., RAD51, PALB2). To address resistance mechanisms, mainly secondary mutations that restore homologous recombination, new biotechniques combining PARP inhibitors with additional medicines were employed. Patients with BRCA1/2, who have not had a PARP inhibitor and have recurrent epithelial ovarian cancer that has not returned after six months of platinum-based therapy, or whose tumor has genomic instability should be considered for treatment with a PARP inhibitor. clinical investigations are presently doing comprehensive examinations into the therapeutically available PARP inhibitors. We predict that choosing which PARP inhibitor to employ will grow more difficult when new Food and Drug Administration-approved indications for PARP

inhibitor treatment in ovarian cancer become available in the new biotechnological development of treatments. Myelodysplastic syndrome and acute myelogenous leukemia require closer monitoring since PARP inhibitors interact with DNA and can cause hematopoietic malignancies. Through combination biotechniques, mechanisms of resistance were identified and addressed, including secondary mutations that restore DNA repair.

Conclusion: In conclusion, the use of PARP inhibitors is seeing a significant expansion in biotechnological breakthroughs, with an emphasis on individualized therapies based on genetic defects and more general impairments in DNA repair. These advancements might potentially lead to better outcomes in malignancies other than those caused by BRCA mutations.

Optimization of Parameters for Modeling the Joint Spread of Tuberculosis and HIV Using an Integrated Approach

Y. S. Kubegenov, A. D. Kubegenova, G. A. Kamalova, and Y. M. Kadyrkhanov

Zhangir Khan West Kazakhstan Agrarian Technical University, Uralsk, Kazakhstan,
erlando78@mail.ru, aigul-03@mail.ru, gokhakam@gmail.com, erke321.aa@gmail.com

Keywords: co-infection; mathematical modeling; optimization algorithms; epidemiology; differential equations

Abstract: The co-infection of tuberculosis (TB) and HIV is one of the most serious public health problems, especially in regions with high endemicity of these diseases. Mathematical modeling and modern optimization methods can significantly improve the accuracy of such studies and provide more reliable data for decision-making. The purpose of this study is to develop and apply an integrated mathematical model to analyze and predict the dynamics of tuberculosis and HIV co-infection in the West Kazakhstan region.

Methods and algorithms: The mathematical model of the dynamics of tuberculosis and HIV co-infection is a system of ordinary differential equations (ODES) that describes the change in the number of different population groups over time. To fine-tune the model parameters, the following optimization algorithms were used: Optuna, a combination of Optuna and BFGS, a combination of Optuna and the Nelder-Mead simplex method. Calculations with synthetic data were performed to verify the performance of the model and optimization algorithms.

Results: Three algorithms were used to adjust and optimize the parameters of the mathematical model of tuberculosis and HIV co-infection: Each of these algorithms has been applied to both synthetic and real data to test their effectiveness and accuracy. Based on synthetic data, the model parameters obtained using various optimization methods were compared. The parameter values found using optimization algorithms are shown in Table 1.

Table 1. Values of optimization algorithms parameters.

Symbol	Optuna	Optuna+BFGS	Optuna + NM
k	0,2807	0,2790	0,2667
k*	2,3832	2,3832	11,2587
r1	2,9003	2,9003	2,7462
r2	1,0086	1,0072	1,0255
r*	1,9625	1,9625	-9,4898
α_1	2,9943	2,9943	0,6986
α_2	2,3455	2,3454	-19,9510
α_3	2,5643	2,5643	20,9075
J(q)	0,337	0,3309	0,2956

The model was validated using the mean square error (MSE) and the coefficient of determination (R2). The optimized parameters showed high prediction accuracy, which confirmed the suitability of the model for analyzing and predicting epidemics of tuberculosis and HIV in endemic regions.

Conclusion: The article developed and used an integrated mathematical model to analyze and predict the dynamics of tuberculosis and HIV co-infection in the West Kazakhstan region. The model, based on data on morbidity from 2010 to 2022 and described by a system of differential equations, has been optimized using algorithms: Optuna, a combination of Optuna with the Nelder-Meade method and the Broyden-Fletcher-Goldfarb-Shanno gradient method. The results showed the high accuracy of the model for predicting epidemiological processes.

Acknowledgment. The presented research was a post-project activity of ERASMUS+ ACeSYRI: Advanced Center for PhD Students and Young Researchers in Informatics reg.no. 610166-EPP-1-2019-1-SK-EPPKA2-CBHE-JP.



Co-funded by the
Erasmus+ Programme
of the European Union



References

1. Kubegenova, A.D., Zhakhiena, A.G., Baigubenova, S.K., Utyasheva, G.S., Omarov, A.N. Clustering and data mining on the example of hiv-infected people data (2022) *Journal of Theoretical and Applied Information Technology*, 100 (13), pp. 5010-5018.
2. Kubegenova, A.D., Kubegenov, E.S., Gumarova, Z.M., Kamalova, G.A., Zhazykbaeva, G.M. (2022). Using Data Mining Technology in Monitoring and Modeling the Epidemiological Situation of the Human Immunodeficiency Virus in Kazakhstan. In: Gibadullin, A. (eds) *Information Technologies and Intelligent Decision Making Systems. ITIDMS 2021. Communications in Computer and Information Science*, vol 1703. Springer, https://doi.org/10.1007/978-3-031-21340-3_6
3. Kubegenova, A., Gumarova, A., Kamalova, G., Rabcan, J. Building a Model and Assessing the Level of Morbidity During the Epidemic. *International Conference on Information and Digital Technologies 2023, IDT 2023, 2023*, pp. 85–88.
4. Krivorotko, O.I., Zyatkov, N.Y. Data-driven regularization of an inverse problem for seir-hcd model of covid-19 propagation in Novosibirsk region. *Eurasian Journal of Mathematical and Computer Applications*. 2022. V.10. N1. P.51-68. <https://doi.org/10.32523/2306-6172-2022-10-1-51-68>
5. Kabanikhin S. et al. Identification of the mathematical model of the transmission TB/HIV co-infection in endemic areas //2017 International Multi-Conference on Engineering, Computer and Information Sciences (SIBIRCON). – IEEE, 2017. – C. 77-81.
6. Kabanikhin S. I., Krivorotko O. I. Optimization methods for solving inverse immunology and epidemiology problems // *Computational Mathematics and Mathematical Physics*. – 2020. – T. 60. – №. 4. – C. 580-589.

The Classification of ECG signals

Dominika Papanova and Aurel Kubacka

Department of Informatics, Faculty of Management Science and Informatics, University of Zilina, Žilina, Slovakia, papanova2@stud.uniza.sk

Post-COVID syndrome is a new disease that has only recently been discovered. It has different symptoms and is difficult to diagnose. This work aims to create a classifier to help diagnose post-COVID syndrome in patients with heart disease. To do this, we will analyse electrocardiograms (ECG). The data we will use comes from the Medical Centre Health in Moldova and includes 153,600 measurements taken at a frequency of 512 Hz. This data provides valuable information about the heart function of post-COVID patients. The measurements were taken from groups of people with both negative and positive prognoses.

We used standard pre-processing methods to classify the ECG signals, including feature extraction, where we convert raw ECG signals into numbers using techniques such as Fourier transformation. We then used dimensionality reduction methods, mainly Principal Component Analysis (PCA), to simplify the data while retaining important information.

We tested several machine learning models, such as decision trees (DT), support vector machines (SVM), K-nearest neighbours (KNN) and Naive Bayes. For these algorithms, we searched for suitable hyperparameters using grid search and evaluated how well these models performed based on accuracy, specificity, sensitivity and error rates to find the best method. Although DT did not provide the best result in this initial testing (see results table), we decided to explore decision trees as a potential candidate. This model offers several ways to improve, such as tree pruning, hyperparameter tuning, or even creating a random forest. We believe that, combined with proper data preprocessing, it could be a suitable candidate for classifying ECG signals.

Table: Results of Algorithm Testing"

Classifier	Accuracy	Specificity	Sensitivity	Overall Error Rate	False Negative Rate	False Positive Rate
Decision Tree	0.700	0.727	0.667	0.3	0.333	0.273
Support Vector Machine	0.750	0.636	0.889	0.25	0.111	0.364
K-Nearest Neighbors	0.800	0.636	1	0.25	0	0.363
Naive Bayes	0.800	0.727	0.889	0.2	0.111	0.273

Automatic Analysis of DNA Comets Using CNN

T. A. Kabulov, S. V. Kezik and O. V. Nedzvedz

Belarusian State University, kabulovtimur64@gmail.com, Sergeyk8008@gmail.com

Keywords: Comet assay; Convolution Neural Networks; Image Segmentation; Plant Stress; Reactive oxygen species

Abstract. Understanding the mechanisms of plant stress is essential for developing sustainable agricultural practices that enhance crop resilience and productivity under adverse environmental conditions. The comet assay method is used to assess the extent of stress impact. We propose a system designed to automatically analyze plant comet assay images using a trained convolutional neural network (CNN) known as PSPNet.

Background. Various plant stresses, including insects, drought and high salinity, cause 30% of crop losses each year, accelerating research into plant stress responses. The key feature of stress is the production of reactive oxygen species (ROS), which can damage DNA, causing multiple single-strand and double-strand breaks. The comet assay method makes it possible to numerically analyse the number of DNA breaks and thus estimate the impact of plant stress on a given organism. However, this method is too complicated due to the large number of images to be analysed per experiment. Comets are made up of the head, which represents the nucleus of the cell and undamaged DNA, and the tail: a set of small DNA fragments formed after the nuclear DNA interacts with ROS. Several statistics such as head/tail ratio, comet length, tail length, et cetera are used to analyse the data.

Objective. The primary purpose of this paper is to develop and train CNN models on a dataset of comet assay images to automate the analysis process and choose the most precise model based on Dice coefficient metric. Additionally, we aimed to:

- Create robust system for automatic image analysis;
- Obtain images from comet assay of different species, including *Physcomitrella patens* and *Arabidopsis thaliana*;
- Choose light-weighted model with the most optimal metrics.

Methods. First, the images were pre-processed by greyscaling, normalising and subtracting the mean values of the pixel values on the image using the OpenCV library. Then 1281 different CNNs were trained on 1281 images. In addition, we extended our dataset (600 images) and created 'noise images', which contain only the noise from different images (*table 1*). The test and valid datasets contained 50 images each. We used PSPNet, UNet and FPN models for training. All neural networks were trained on four variants of the datasets. Training was performed on the GPU Nvidia GeForce RTX 3060 Lite Hash Rate (Ubuntu).

Table 1. Dataset for training and number of images for each

Dataset	Original data	Original data and noise	Original data and augmented data	Original data, augmented data and noise
Number of images	1280	1880	1880	2480

Next, forward and inverse Fourier transforms were applied to the images. These steps are performed to filter or remove background noise. After noise filtering, a binary threshold is applied to the comet head image.

Results. According to the Dice score across the datasets, the best performing model was PSPNet (table 2), in particular the model trained on the original and augmented data outperformed the others.

Table 2. Validation and test scores for each dataset for PSPNet

Dataset	Original data	Original data and noise	Original data and augmented	Original data, augmented data and noise
Validation	0.855	0.93	0.851	0.871
Test	0.75	0.808	0.863	0.838

PSPNet achieved 0.863 Dice score basing on test dataset, which indicating a high level of accuracy in segmenting the comet assay images. Noise images presented in the largest dataset slightly reduced the performance of all models. PSPNet also demonstrated faster inference time compared to UNet model. Figure 1 provides an example of the DNA comet image.

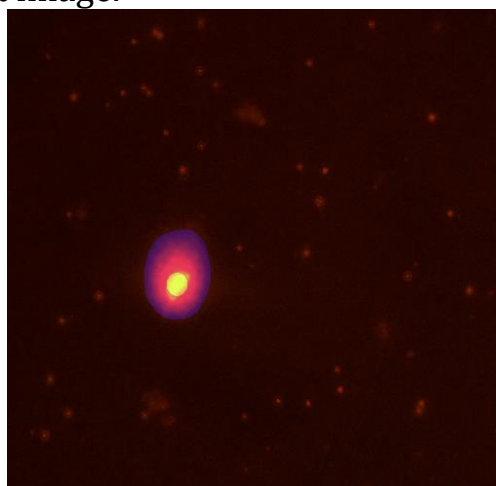


Figure 1. Example of PSPNet segmentation (blue – whole comet, yellow - head)

Conclusion. In conclusion, the proposed system with PSPNet CNN model is a valuable tool for accelerating research in plant stress science based on comet assay. Use of the current system in real experiments and additional training of the model on new data could improve the overall system performance.

The preprocessing of ECG signals

Aurel Kubacka and Dominika Papanova

Department of Informatics, Faculty of Management Science and Informatics, University of Žilina, Žilina, Slovakia, kubacka5@stud.uniza.sk

Electrocardiogram (ECG) data is a critical source of information in assessing heart function and identifying cardiovascular conditions, particularly in complex cases like post-COVID syndrome. This newly recognized condition is challenging to diagnose, given its varied and often ambiguous symptoms. Our study aims to support the development of a classifier to help diagnose post-COVID syndrome in patients with heart disease. The data used for this purpose includes high-resolution ECG measurements from both healthy and affected individuals, providing a valuable basis for analysis and comparison.

In preparing this data, we first applied baseline correction, denoising, and normalization techniques, essential to ensure consistency across all samples. Baseline correction removed any low-frequency drift, stabilizing the signal's baseline; denoising filtered out high-frequency noise to preserve signal quality, and normalization brought each sample within a standard range, enhancing comparability. To increase the dataset's robustness, we further augmented the data by segmenting each sample into overlapping segments, effectively creating a larger, diversified dataset for training.

Lastly, we applied fuzzification and Principal Component Analysis (PCA) to enable dimensionality reduction while managing the intrinsic uncertainty in ECG data. Fuzzification transformed crisp data into fuzzy values, aligning with fuzzy classifiers and addressing data ambiguities, whereas PCA reduced data dimensionality by retaining the most informative features, aiding computational efficiency. As these techniques do not combine, they were used independently, offering alternative approaches to optimize our dataset. Together, these preprocessing steps provide a comprehensive foundation for effective ECG data classification aimed at diagnosing post-COVID syndrome in cardiac patients.

Analysis of a Fragment of the Image to Identify the Effect Of Stress Caused by Heavy Metals on the Pigmentation of Leaves of Cereal Plants

A.A. Nedzved and M.A. Nedzvedz

Belarusian State University, Minsk, Belarus, artiom.nedzved@gmail.com

The color of plants is formed through two primary mechanisms: structural and biochemical coloration. Structural coloration is determined by surface nanostructures that interact with light and is observed in both animals and plants. Examples include begonia leaves and blue spruce needles. However, in

the context of plant physiology, the biochemical mechanism, which is associated with pigments such as chlorophylls, carotenoids, and flavonoids, is of greater importance. These pigments play essential roles in processes such as photosynthesis and protection against environmental stresses.

This study focuses on investigating changes in leaf coloration in cereals under the influence of heavy metals, such as cadmium and copper, which disrupt plant physiological processes, leading to a reduction in chlorophyll content and the development of chlorosis. Experiments demonstrated that under stress conditions, the level of carotenoids increases, resulting in altered leaf color characteristics. The work proposes a method for analyzing the spectral characteristics of plant coloration to assess their physiological state, based on the analysis and transformation of images, as well as the construction and examination of their covariance matrices.

Stream on *Environmental Risk Assessment*

The stream focuses on applications of reliability analysis, machine learning, and remote sensing in environmental risk assessment.

Topics of the stream include

- Environmental Threats and Environmental Hazards,
- Geoprocessing and Geographic Information Systems,
- Land Degradation, Mathematical and Computational Methods for Risk Assessment,
- Mathematical Models of Environment,
- Remote Sensing,
- Use of Unmanned Aerial Vehicles in Environmental Risk Assessment,
- ArcGIS Application in Environmental Risk Assessment,
- Cartography and maps development,
- Risk Assessment in Environment, etc.

The stream is organized in accordance with the activities of the project “*Earth Observation for Early Warning of Land Degradation at the European Frontier (EWALD)*” (Horizon Europe, ID 101086250).



A Method to Aggregate Interval-Valued Expert Estimates Taking into Account Their Reliability

Mykhailo Popov¹, Oleksandr Zaitsev² and Serhii Stefantsev²

¹Scientific Centre for Aerospace Research of the Earth of the National Academy of Sciences of Ukraine, Kyiv, Ukraine

²Military Academy named after Yevheniy Bereznyak, Kyiv, Ukraine

Keywords: expert estimate, interval-valued number, aggregation, reliability, basic uncertain information

Background. Despite the encouraging achievements of systems constructed using artificial intelligence, multiple tasks require expert methods attracting. Examples of these tasks are assessing environmental situations, predicting the development of natural processes, determining the feasibility of developing a mineral deposit, etc. However, over solving a complex problem, experts often face a lack of necessary information, or, as they say, find themselves in a situation of epistemic uncertainty [1].

In such situations, experts tend to avoid precise estimates and move on to verbal or interval estimates [2, 3]. As a rule, the expert takes his verbal estimate on a set of admissible values of a certain linguistic variable. For example, this set can be as follows: {Almost no chance, Very unlikely, Unlikely, Roughly even chance, Likely, Very likely, Almost certainly}. Each value of the linguistic variable has a corresponding numerical proxy and rank [4]. One example of such a mapping is represented in the table below.

Table 1.

Linguistic variable value	Almost no chance	Very unlikely	Unlikely	Roughly even chance	Likely	Very likely	Almost certainly
Proxy numerical	0.00–0.05	0.06-0.20	0.21-0.45	0.46-0.55	0.56-0.80	0.81-0.95	0.96-1.0
Rank	1	2	3	4	5	6	7

Interval estimate means that the sought value is within a certain interval, limited “from below” and “from above” by the numbers \underline{a} and \bar{a} . It is important that the closed interval formed by two real numbers $[\underline{a}, \bar{a}]$, where $\underline{a} \leq \bar{a}$, and one it can be considered as an Interval-Valued Number [5]. Note, that Proxy in the Table can be represented by an ordered set of interval-valued numbers $\Omega = \omega_k | k=1,2,3,4,5,6,7$; here $\omega_1=[0.00, 0.05]$; $\omega_2=[0.06, 0.20]$; $\omega_3=[0.21, 0.45]$; $\omega_4=[0.46, 0.55]$; $\omega_5=[0.56, 0.80]$; $\omega_6=[0.81, 0.95]$; $\omega_7=[0.96, 1.00]$.

It is necessary to take into account that expert assessments are subjective, their reliability depends on the personality of the expert, in particular on his reliability [6]. To process data taking into account their reliability, methods of the fuzzy set theory (more specifically, Z-Numbers approach [7]) and Dempster-Shafer’s theory of

evidence are used (more specifically, DBF-approach [8]). However, these methods are characterized by high computational complexity [9, 10]. Moreover, how to generate Z-numbers and to aggregate ones is still an open issue [11].

Recently, a new approach to data processing under epistemic uncertainty has been proposed. It differs from the known approaches in simple computation and is called Basic Uncertain Information (BUI) [12-14]. Another important advantage of the BUI approach is that it does not require a priori information.

The key concept in the BUI approach is a granule G . Granule $G = (p, c)$ consists of two elements: the element $p \in [0,1]$ is an observed datum and the element $c \in [0,1]$ is its reliability. Authors of the BUI approach have proposed procedure to aggregation granules. Aggregation of data is performed in an additive form, whereby similar elements of granules are summed up with weights depending on the levels of uncertainty inherent in the granules.

Objective. The objective of the study is to propose, based on the BUI approach, a method to aggregate expert estimates taking into account their reliability.

Method. So, as said above, expert estimates can be presented in numerical (interval) or verbal form. Let us first consider the case when there are N mutually independent expert estimates presented as a set of granules $\{G_1 = (p_1, c_1), \dots, G_n = (p_n, c_n), \dots, G_N = (p_N, c_N)\}$, where p_n - interval-valued number; c_n - real number; $n=1,2,\dots,N$.

Our task is to aggregate all these estimates into one granule $\tilde{G} = (\tilde{p}, \tilde{c})$. It is proposed to use a multiplicative approach, in which the aggregated expert estimate is calculated using the formula

$$\tilde{p} = \left[1 - \prod_{n=1}^N (1 - \underline{p}_n)^{w_n}, \quad 1 - \prod_{n=1}^N (1 - \overline{p}_n)^{w_n} \right], \quad (1)$$

The power exponents in the formula (1) are calculated as follows. First, the uncertainty level inherent in each of the N granules is calculated. Let $p_n = [\underline{a}_n, \overline{a}_n]$ - rating given by the n -th expert; $0 \leq a_n \leq 1$; $n = 1, 2, \dots, N$.

The uncertainty level of the n -th granule is calculated using the formula:

$$h_n = 1 - (\overline{a}_n - \underline{a}_n) \cdot c_n, \quad (2)$$

Having information about the uncertainty level in each granule, the power exponents are calculated using the formula:

$$w_n = \frac{h_n}{\sum_{n=1}^N h_n}; \quad n = 1, 2, \dots, N. \quad (3)$$

The reliability of aggregated expert estimate is calculated in a similar way:

$$\tilde{c} = 1 - \prod_{n=1}^N (1 - c_n)^{w_n}. \quad (4)$$

Thus, the method to aggregate N numerical (interval-valued) expert estimates, represented by the granules $\{G_1, \dots, G_n, \dots, G_N\}$, consists of the following steps:

1. Calculating uncertainty levels (formula (2));
2. Calculating power exponents (formula (3));
3. Calculating the aggregated expert estimate (formula (1));
4. Calculating the reliability of aggregated expert estimate (formula (4)) and obtaining granule $\tilde{G} = (\tilde{p}, \tilde{c})$.

Now let us turn to the situation when all expert estimates, including the desired resulting one, must be verbal. Let us consider it based on the Table above.

Suppose, the verbal estimate $e_{n,r}$ of the n -th expert has a rank r_n , and its reliability is c_n . From Table 1 we find that the estimate $e_{n,r}$ has its own numerical proxy and, therefore, a corresponding interval-valued number $\omega_{r_n} = [\underline{\omega}_{r_n}, \overline{\omega}_{r_n}]$; $\omega_{r_n} \in \Omega$. For N verbal estimates, we have a set of interval estimates $\omega_{r_n} | n = 1, 2, \dots, N$. Combining these estimates using formulae (1)-(4) yields an interval-valued number $s = [\underline{s}, \overline{s}]$. Let $d(s, \omega_r)$ is the distance between interval-valued numbers S and ω_r ;

$$d(s, \omega_r) = \sqrt{\left(\frac{\underline{s} + \underline{\omega}_r}{2} - \frac{\overline{s} + \overline{\omega}_r}{2}\right)^2 + \frac{1}{3} \left[\left(\frac{\overline{s} - \underline{s}}{2}\right)^2 + \left(\frac{\overline{\omega}_r - \underline{\omega}_r}{2}\right)^2 \right]} \quad (5)$$

Then the aggregated verbal expert estimate is \tilde{e}_r ,

$$\text{where } r^* = \text{subscript} \left\{ \min_{k=1,2,\dots,7} d(s, \omega_k) \right\}. \quad (6)$$

Note that the described procedure for determining the resulting verbal expert estimate is applicable to any linguistic scale. The reliability of the resulting verbal estimate is determined in the manner described above.

Results. The proposed method to aggregate interval-valued expert estimates taking into account their reliability is implemented as a software module and tested. The results of solving some tasks are presented. The possibilities and directions of practical application of the proposed method are discussed.

Conclusion. The study is deal with the problem of increasing the accuracy of group expert estimates, for which a simple and effective method for their aggregation is proposed. The proposed method is based on the BUI approach and is applicable to both numerical (interval) and verbal expert estimates. Numerical examples are used to show the efficiency of the proposed method.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

References.

1. Hester, P.: Epistemic Uncertainty Analysis: An Approach Using Expert Judgment and Evidential Credibility. *International Journal of Quality, Statistics, and Reliability*, Vol. 2012, Article ID 617481 8 pages (2012). doi:10.1155/2012/617481
2. Teigen, K.H.: The Language of Uncertainty. *Acta Psychologica*, 68, 27-38 (1988)
3. Wallsten, T.S., Budescu D.V.: A review of human linguistic probability processing: General principles and empirical evidence. *The Knowledge Engineering Review*, Vol. 10:1, 43- 62 (1995)
4. Budescu, D.V., Por, H.-H., Broomell, S.B., Smithson, M.: The interpretation of IPCC probabilistic statements around the world. *Nature Climate Change | Advance Online Publication*, 5 pages (2024) doi: 10.1038/NCLIMATE2194
5. Alefeld, G., Herzberger, J.: *Introduction to Interval Computations*. - NY: Academic Press, 2012, 352 p.
6. Popov, M.O., Zaitsev, O.V., Stambirska, R.G., Alpert, S.I., Kondratov, O.M.: A Correlative Method to Rank Sensors with Information Reliability: Interval-Valued Numbers Case. Chapter 17 in: *Reliability Engineering and Computational Intelligence (Studies in Computational Intelligence book series, Vol. SCI-976)*. C. van Gulijk and E. Zaitseva (Eds). Springer International Publishing, 2021, pp. 275-291. eBook ISBN 978-3-030-74556-1. doi 10.1007/978-3-030-74556-1
7. Zadeh, L.A.: A Note on a Z-Number. *Journal of Information Sciences*, 181, 2923-2932 (2011) <http://dx.doi.org/10.1016/j.ins.2011.02.022>
8. Li, Y., Deng, Y.: TDBF: Two-dimensional belief function. *International Journal of Intelligent Systems*, 8, 1968-1982 (2019) <https://doi.org/10.1002/int.22135> ·
9. Abdullahi, M., Ahmad, T., Ramachandran, V.: A Review on Some Arithmetic Concepts of Z-Number and Its Application to Real-World Problems. *International Journal of Information Technology & Decision Making*, Vol. 19, No. 4, 1091–1122 (2020) doi: 10.1142/S0219622020300025
10. Tessem, B.: Approximations for efficient computation in the theory of evidence / *Artificial Intelligence*, Vol. 61, Issue 2, 315-329 (1993)
11. Cao, Y., Yang, J.B., Deng, X., Jiang, W.: The Fusion of Discrete Z-Numbers with Application for Fault Diagnosis / *IEEE Transactions on Instrumentation and Measurement*, Vol. 71 (2022)
12. Mesiar, R., Borkotokey, S., Jin, L., Kalina, M.: Aggregation under uncertainty. *IEEE Transactions on Fuzzy Systems*, Vol. 26, Issue 4, 2475 – 2478 (2018) <https://doi.org/10.1109/TFUZZ.2017.2756828>
13. Jin, L.S., Chen, Z-S., Yager, R.R., Langari, R.: Interval Type Interval and Cognitive Uncertain Information in Information Fusion and Decision Making. *International Journal of Computational Intelligence Systems*, № 1 (2023) <https://doi.org/10.1007/s44196-023-00227-4>.
14. Jin, L., Mesiar, R., Yager, R.R., Kaya, S.K.: Interval basic uncertain information and related aggregations in decision making / *Journal of Intelligent & Fuzzy Systems*, (2021) doi: 10.3233/JIFS-211635.

Methodological Foundations of Multispectral Aerospace Images Informativeness Increasing

Iryna O. Piestova^{1,2}

¹ Scientific Centre for Aerospace Research of the Earth, Ukraine, Kyiv, piestovairyna@gmail.com

² National Aviation University, Ukraine, Kyiv

Keywords: multispectral aerospace images, informativeness, spatial resolution, reflection spectra, spatial topological characteristics

Abstract. A general model for quantitative assessment of the informativeness of multispectral aerospace images as a part of the total Shannon information capacity is described. The main components of the model affecting the amount of informativeness are spectral differences of the radiometric signals of the object and the background, the equivalent signal-to-noise ratio in the multispectral image, and the provided spatial resolution. This study is focused on improving spatial resolution as the most critical component in the general model of informativeness assessment. An analytical review of known approaches to increasing the spatial resolution of multispectral aerospace images is made. Various variants of two-dimensional interpolation (nearest neighbor, bicubic, spline, etc.) are considered the simplest methods of increasing spatial resolution. Widely used approaches aim to increase sharpness and related metrics, such as modulation transfer functions (MTF). These approaches are usually applied in the frequency (inverse filtering) or wavelet domains. Super-resolution-based approaches based on joint processing of several images, with sub-pixels, shifted relative to each other, are considered separately.

The approach to increasing the spatial resolution of individual spectral channels of a multispectral aerospace image based on other channels of this image, which have a higher spatial resolution, is described in detail. The possibility of using reflectance spectra and spatial-topological characteristics of typical land and artificial covers to increase the informativeness of multispectral aerospace images is substantiated. This approach makes it possible to attract additional information about the physical properties of objects in the scene and, in this way, to get an actual increase in the information content of high-resolution images. At the same time, it is essential to ensure that the radiometric and spectral properties of incoming multispectral aerospace images are not distorted.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Geophysical Methods of Soil Fertility Mapping for Precision Agriculture Applications in Morocco

Fatima-Ezzahra Aallem¹, Azzouz Kchikach^{1,2}, Mohammed Jaffal^{1,2} and Younes Jnaoui³

¹Georessources, Geoenvironment and Civil Engineering Lab., Faculty of Sciences and Techniques, Cadi Ayyad University, Marrakech, Morocco, fatima-ezzahra.aallem@ced.uca.ma

²Geology and Sustainable Mining Institute (GSMI), Mohammed VI Polytechnic University, Benguerir, Morocco, a.kchikach@uca.ma, m.jaffal@uca.ma

³Agricultural Innovation and Technology Transfer Center (AITTC) AGBS, Mohammed VI Polytechnic University, Benguerir, Morocco, younes.jnaoui@um6p.ma

Keywords: apparent soil electrical conductivity, Soil sensor EM38, fertility

Abstract. Experiments were conducted on the variation of apparent electrical conductivity (ECa) and resistivity (ERT) at the plot scale, correlating these data with soil properties for soil mapping at the experimental farm of Mohammed VI Polytechnic University in Benguerir (UM6P).

The ElectroMagnetic Induction (EMI) technique was applied using an EM38-MK2 soil sensor, which provided auxiliary ECa datasets with high accuracy. The ERT method was also employed to measure electrical resistivity. Soil sampling was conducted to ensure the reliability and potential of ECa measurements for soil mapping. The ECa readings, expressed in mS/m, ranged from 12 to 26 for the vertical method (ECa-V) and from 8 to 20 for the horizontal method. ECa and ERT values correlated well with soil properties such as texture (clay and sand) and certain upper soil chemical properties (organic matter, CEC, Ca²⁺, Fe²⁺, and Mg²⁺). A moderate correlation was found between ECa-V, clay content, and subsurface water content ($r = 0.80$ and $r = 0.79$). The linear relationship established between apparent electrical conductivity and soil clay content explained 80% of the measured variability. The results of this study suggest that soil mapping through ECa measurements can effectively represent the spatial variation of soil properties, such as texture, chemical fertility, and organic matter content. Utilizing spatial variability in EC as a covariate in statistical analyses could serve as a complementary tool in evaluating experimental results.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Forward Seismic Modeling and High-Resolution Seismic Imaging of the Phosphatic Series in the Gantour Basin (Morocco)

A.Charbaoui¹, A.Kchikach^{1,2} and M.Jaffal^{1,2}

¹ Mohammed VI Polytechnic University (UM6P), Geology and Sustainable Mining Institute (GSMI), Benguerir, Morocco, anas.charbaoui@um6p.ma

² Cadi Ayyad University (UCA), Georesources, Geoenvironment and Civil Engineering Laboratory (L3G), Marrakech, Morocco.

Keywords: forward modeling; seismic imaging; phosphatic series; geophysical exploration; Gantour Basin; Morocco

Abstract. The Gantour Basin in Morocco is a critical region for phosphate exploration, contributing significantly to Morocco phosphate production. However, complex subsurface geological and hydrogeological conditions challenge future resource exploitation. This study focuses on the Louta deposit, where a combination of forward seismic modeling and high-resolution seismic reflection imaging was applied to delineate the phosphatic series, crucial for optimizing future mining operations.

The Gantour Basin contains substantial phosphate reserves, but its complex subsurface structure requires advanced geophysical techniques to accurately image the phosphatic layers and associated formations. The primary goal of this study was to use forward seismic modeling and high-resolution seismic reflection imaging to enhance our understanding of the depth, thickness, and continuity of the phosphatic layers in the Louta deposit.

A detailed seismic reflection survey was conducted in the Louta deposit, complemented by forward seismic modeling. The forward modeling simulated the seismic wave propagation through different subsurface layers, providing an improved interpretation of the seismic data. This approach was crucial for validating the seismic reflections and refining the velocity models, enabling more accurate depth estimation and stratigraphic resolution of the phosphatic series. Additionally, the seismic data were integrated with other geophysical methods, including Electrical Resistivity Tomography, to produce a comprehensive interpretation of the deposit's structural features.

Seismic sections revealed the depth and thickness of the phosphatic layers, as well as lithological variations. The forward seismic modeling helped improve the clarity of the subsurface images, ensuring accurate delineation of the phosphatic horizons. These findings offer significant insights into optimizing phosphate mining in the region.

This study demonstrates the effectiveness of integrating forward seismic modeling and high-resolution seismic imaging in exploring complex geological environments. The results are crucial for future mining strategies and reserve estimation, especially in areas covered by thick overburden in the Gantour Basin.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Eo-Based Early Warning System for Enhancing Responses to Land Degradation: Challenges and Solutions

Anna A. Kozlova and Artem A. Andreiev

Scientific Centre for Aerospace Research of the Earth, Kyiv, Ukraine, a@gmail.com

Keywords: Earth observation (EO); land degradation (LD); early warning system (EWS); land degradation neutrality (LDN)

Abstract. Early warning of LD implies the identification of areas of concern, hotspots of vulnerabilities, and sensitivities that are critical for further LD risk reduction. EWS, as a recognized source of timely information on LD risks, is essential to timely response to LD threats. Modern geoinformation technologies that use long-term series of multisource EO-data, cartographic, and other geospatial data along with ground truth are extremely useful for LD early warning and further adverse impact prevention or mitigation. However, implementing an effective LD EWS based on EO data involves overcoming several challenges. These challenges encompass technical, socio-economic, institutional, and environmental dimensions.

The main technical challenge is data quality and availability since inconsistent or incomplete data can hinder accurate monitoring and prediction. The data incompleteness is attributable mainly to partial or total termination of specific EO missions' operation or provision of EO-based geospatial data products. During EWS's prospective operation, the provision of certain data products could also be terminated or delayed. Limited access to high-resolution and up-to-date satellite imagery in some regions also contributes to data incompleteness. Gaps in remote sensing systems observation schedules also may led to irregular LD monitoring. Alternative data sources and respective processing pipelines should be provided as possible solutions. In some critical cases, obtaining the required data products should be handled by the EWS's maintaining organization, in particular, using a UAV survey. The simulations of climatological and anthropogenic trigger variables in the temporal data gap intervals will also enhance the timing and speed of LD monitoring, contributing to the improvement of LD early warning.

Being a comprehensive process of various natural and socio-economic drivers functioning at multiple scales, LD monitoring and risk assessment consider integrating multisource and multiscale data. These processes act on individual temporal and spatial scales, and the dominating processes vary locally. Thus, combining data from various sources (satellite, aerial, ground-based) and at multiple

scales is also complex. Moreover, interoperability and compatibility between different data formats and systems should be ensured with the integration. EO-based geospatial data products used for LD indication as well have different spatial and temporal resolutions and represent a dataset of various physical units. As a possible solution, an advanced remote sensing technical platform for data fusion and subsequent analysis in the EWS Prototype will allow for massive data processing in the shortest time, enabling monitoring of LD process dynamics derived from different data sources at different dates. In the proposed EWS, the physical values of the proxy indicator are converted to corresponding probabilities via the probability density function (Popov et al., 2023).

Challenges in achieving high accuracy and precision in predicting LD come from the quality of the remotely sensed imagery and EO-based geospatial data products. Furthermore, the quality of the traditional multi-resolution imagery/maps regularization by simple interpolation does not correspond to the emergent needs of LD early warning. As possible solutions, multi-resolution spatiotemporal data fusion will lead to a much broader information basis and higher temporal resolution for the early warning process, enhancing its precision.

At the stage of the LD risk assessment and prediction, hypotheses and opinions formed by experts based on the analysis of LD monitoring data are often conflicting. As possible solutions, the means of the mathematical theory of evidence that should be used to process and combine conflicting opinions and hypotheses.

Socio-Economic and Institutional Challenges. Lack of awareness and understanding of the importance of LD EWS among local populations leads to difficulties in engaging local communities and stakeholders in EO-based predicting and responding to land degradation. Other difficulties include integrating EO-based EWS into existing policy frameworks and development plans. Besides that, most local authorities and institutions need more human resources and technical skills to implement and maintain the system. As a possible solution, provide technical support and resources to local authorities and other institutions responsible for implementing best practices in land management and achieving LDN. There are two general ways to make this provision. The first is an online platform with technical guidelines, user manuals, and practical recommendations. Another one is capacity building and educational training. The EWALD Project will serve as a common platform for the operative improvements of methodologies, knowledge sharing, staff training, transfer of practical experience in the LD early warning, and establishing a sustainable EO data analysis group.

Today, the LD is studied using remote sensing at primarily global and continental levels. The downscaling to the regional and local levels is still at the initial stage. As possible solutions, integration of technology based on multisource and multiscale EO data into the local level of agriculture activity, land management by nature conservation administrations, and regional decision-makers will provide the advanced technology of the LD early warning and timely response to LD threats.

Environmental Challenges. Unpredictable climate conditions can complicate the monitoring and prediction of land degradation. Natural disasters such as floods, droughts, wildfires, as well as unpredictable severe anthropogenic pressure in the form of harmful effects of war actions, can accelerate land degradation and disrupt monitoring systems. As possible solutions, several critical linkages between LD and the quality of the environment should be determined using modeling and observation data. The coupling of biophysical and anthropogenic drivers that cause LD and could be detected by remote sensing should be delivered. It will support the understanding of interlinked environmental and socio-economic processes. Forethought integration of the EWS for neutralizing negative processes and mitigating their consequences to target LD Neutrality according to UN guide SDG 15.3 should be implemented.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

References.

Popov, M., Stankevich, S., Kozlova, A., Piestova, I., Khyzhnyak, A., Zaitseva, E., Levashenko, V., Seredinin, E., Maltsev, S., Lypska, Y., Kukharuk, A., Rashchuk, V., & Smitiukh, A. (2023). The Architecture of Land Degradation Early Warning Based on Earth Observation. 2023 International Conference on Information and Digital Technologies (IDT), pp. 125–132. <https://doi.org/10.1109/IDT59031.2023.10194406>

Functional Block Configuration of EWS for Land Degradation Mapping/Prediction

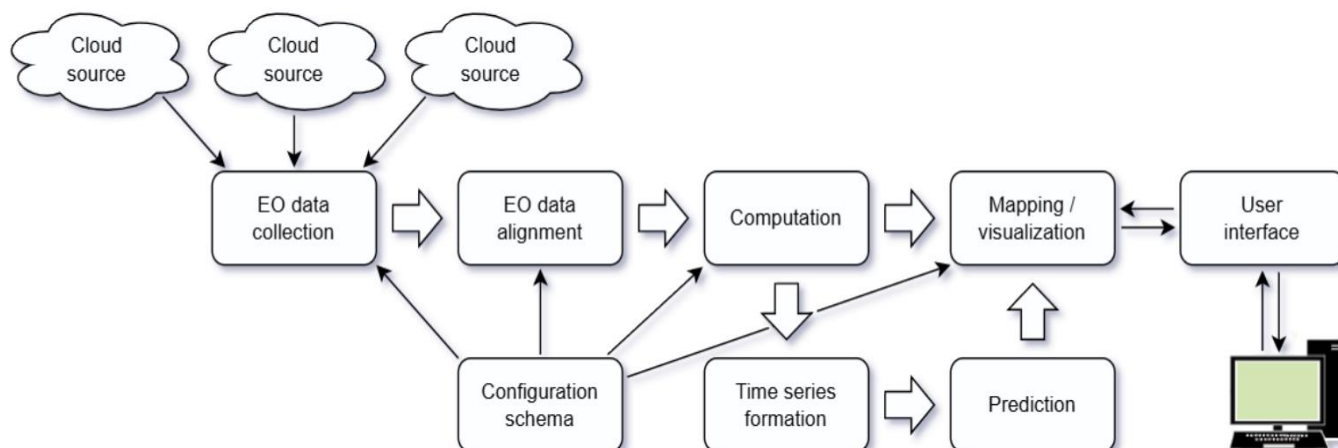
Sergey A. Stankevich, Iryna O. Piestova, Mykola S. Lubskyi, Artur R. Lysenko

Scientific Centre for Aerospace Research of the Earth, Ukraine, Kyiv, artur.r.lysenko@gmail.com

Keywords: Earth observation (EO); land degradation (LD); early warning system (EWS); LD indicators; LD map; probabilistic model; Bayesian fusion

Abstract. The discussed early warning system (EWS) is being developed under the research project Earth Observation for Early Warning of Land Degradation at the European Frontier (EWALD), ID 101086250 of the Horizon Europe Programme. This EWS involves Earth observation (EO) data products for land degradation (LD) mapping and prediction. The EWS has a cloud-centric architecture [Popov et al., 2023] and implements a geospatial transformation workflow of: LD drivers → LD indicators → LD partial contributions → integrated LD map. LD drivers are natural phenomena and processes that provoke LD; LD indicators are the EO data products that reveal the LD drivers; LD partial contributions are simulations by a special probabilistic model based on the statistical properties of LD indicators; the LD

integrated map is a Bayesian fusion of the LD partial contributions' probabilities. To realize the described workflow, the cloud EWS must be subdivided into separate functional blocks that interact with each other by data transfer only:



The following set of EWS functional blocks is minimally required: EO data collection block – to receive EO data products from external cloud sources; EO data alignment block – to ensure their subsequent joint processing; computation block – for the implementation of probabilistic LD models; time series block – for formation/updating time series of LD maps; prediction block – for simulating LD forecast maps; mapping/visualization block – to provide EWS output in an unified cartographic format; user interface block – for interaction with remote EWS administrators and customers. Since the entire EWS is expected to be a distributed cloud-based one, its functional blocks should be implemented as special task-orientated software modules. The configuration of these modules with regard to maintainability and serviceability should be centralized inside a single separate functional block, namely – the configuration scheme.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

References

Popov M., Stankevich S., Kozlova A., Piestova I., Khyzhnyak A., Zaitseva E., Levashenko V., Seredinin E., Maltsev S., Lypska Y., Kukharuk A., Rashchuk V., Smitiukh A. The architecture of land degradation early warning based on Earth observation. Proc. of the International Conference on Information and Digital Technologies (IDT 2023). Žilina: IEEE, 2023, pp. 125-132. DOI: 10.1109/IDT59031.2023.10194406.

Monitoring Changes in Agricultural Landscapes within the Areas of Municipal Solid Waste Dumps using Remote Sensing and GIS Technologies

O.T. Azimov and O.V. Tomchenko

Scientific Centre for Aerospace Research of the Earth of the Institute of Geological Sciences of the National Academy of Sciences of Ukraine, azimov@casre.kiev.ua

Keywords: Agro-landscapes, dumps, changes, monitoring, remote sensing

The necessary information for the certification of the territories for disposal sites (landfills) and dumps of municipal solid waste (MSW) and their adjacent areas are the results of the thematic information extraction from remote sensing data (RSE) and ground ones integrated into geographic information systems (GIS). In particular, the use of satellite images and digital maps of the terrain allows analyzing the spatial location of waste disposal facilities, not only in relation to the settlements, but also taking into account the features of geosystems in the zones of their potential impact.

In this aspect, in order to monitor and assess the changes in the ecosystems during 1996- 2021, which are mostly represented by the agro-landscapes, the territory adjacent to the Zdobvytsia MSW dump (Rivne Oblast, Ukraine) was studied. Its operation began in 1996 in the eastern part of the abandoned building materials quarry. Multi-spectral LANDSAT-5 (August 2, 1996) and WorldView-2 satellite images (August 18, 2003, September 24, 2014, August 21, 2019, and May 2, 2021) were used.

As a result, it was established by means of RSE/GIS technologies that the operation of the dump has been significantly intensified during 2003–2021. A considerable increase in the geometric parameters of the dump was mapped: the number of Sections – from one to three, their area has increased by about 6.25 times, the total perimeter – more than 3.35 times; the expansion of nearby protective mineralized strips to prevent the occurrence of fires was recorded – by almost 1.48 times, etc. Under the conditions of these anthropogenically determined factors, the ecosystems adjacent to the MSW dump have been significantly transformed. This led to a change (transformation) of their functional role.

Thus, in addition to the increase in the number of Sections of dump in prejudice of the surrounding lands of deciduous forest, the traits of the ecological succession of neighbouring ecosystems, as a process of their self-development, were also revealed. They are manifested in the natural restoration of land covers as the sparse deciduous forest with the shrubs on the former areas of meadow vegetation that used to grow on the site of a quarry, still untouched by waste, as well as in the replacement of sparse forest and shrubs by the plots of deciduous forest. Therefore, RSE/GIS technologies are an effective tool for spatio-temporal monitoring of the state of MSW landfills and dumps and agricultural landscapes located nearby.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Assessment of Land Degradation and Urbanization in ARID Environments through SDG 11.3.1 and 15.3.1 Indicators

Achraf Chakri, Nour Eddine Laftouhi, Hassan Ibouh and Mounsiif Ibnoussina

Cadi Ayyad University (UCA), Marrakech, Morocco, achraf.chakri@ced.uca.ma,
nouredine.laftouhi@uca.ac.ma, h.ibouh@uca.ac.ma, ibnoussina@uca.ac.ma

Keywords: GIS; Remote sensing; sustainability development; Land degradation; Urbanization

Abstract. Climate change is one of the major challenges for sustainable development, land degradation and urbanization play an essential role in environmental and socio-economic dynamics. Among the 17 SDGs, our study focuses on the evaluation of two goals, SDG 15.3 and SDG 11.3. The interconnection of these two goals, particularly in arid zones, makes it possible to establish a balance between urban development and environmental preservation. The present study assesses the state of soil degradation and urban expansion in the Draa-Tafilalet which is a province in Est of Morocco, through SDG indicators 15.3.1 and 11.3.1. Both indicators are assessed using Trends. Earth, it’s an open-source tool incorporated into QGIS software, which enables land cover change to be analyzed and soil degradation trends to be visualized. We noted that the land cover change map provided by default has a direct impact on the quality of the output data. As the resolution of the default map is high (300m per pixel), we used the land cover map from the sentinel satellite with a resolution of 10 m per pixel. The processing period (2015 - 2024) for the indicators is sufficiently wide to detect any changes in the study area. We found that drought periods have a direct impact on the process of soil degradation, which in turn has a direct impact on the urban development of villages and towns in the region. Our investigation shows the combined importance of the two indicators SDG 11.3.1 and SDG 15.3.1 in assessing the impact of soil degradation and its impact on urbanization.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Siltation of Recent Large Dams in the Marrakesh-Safi Region, Morocco: Analysis of Factors Influencing Sediment Yield using the RUSLE Model and GIS.

M.Abidare, L. Daoudi and N. Ben Daoud

Laboratory of Geosciences, Geo-environment, and Civil Engineering (L3G), Faculty of Sciences and Technologies, Cadi Ayyad university, Marrakech, Morocco, m.abidare.ced@uca.ac.ma

Keywords: Dams; Marrakesh-Safi region; RUSLE; Soil loss; Sediment yield; Bathymetric survey

Abstract. Dams are essential for supplying drinking water and irrigating surrounding farmland. In the Marrakech-Safi region, the newly constructed Taskourte and Zerrar dams are encountering significant siltation issues due to soil degradation in upstream areas. This problem is prevalent in water reservoirs worldwide, but it is especially severe in arid and semi-arid regions like the study area. Consequently, monitoring soil loss and identifying sediment sources, along with vulnerable areas at high risk of erosion, has become essential. This information empowers decision-makers to implement effective conservation strategies that promote sustainable land management, enhance water quality, and protect the dams from siltation, ultimately extending their operational lifespan. This study aims to assess the spatial distribution of soil loss and sediment yield in the upstream watersheds of these hydraulic structures, employing the Revised Universal Soil Loss Equation (RUSLE) in conjunction with Geographic Information Systems (GIS). The findings were validated using bathymetric data. Results indicate that the average annual soil loss in the Oued Assif El Mal and Oued Lksob watersheds is 23.06 t/ha/yr and 1.17 t/ha/yr, respectively. Notably, 56.86% of the surfaces in the Oued Assif El Mal watershed are classified as experiencing severe to extremely severe erosion, while 93.3% of the surfaces in the Oued Lksob watershed exhibit very low to low risk of soil erosion. The study highlights that vegetation cover and topography are the primary factors influencing the spatial rate of soil erosion. Using the delivery ratio, sediment yield was calculated at 6.96 t/ha/yr for the Oued Assif El Mal watershed and 0.12 t/ha/yr for the Oued Lksob watershed. However, these calculated values are lower than the observed sediment yields derived from bathymetric data. In particular, the RUSLE model significantly underestimates soil loss in the Lksob watershed compared to the Assif El Mal watershed. This discrepancy is attributed to the prevalence of linear erosion (bank erosion) in the Lksob watershed, a factor not accounted for in the model. Overall, these findings highlight priority areas for implementing conservation practices to ensure the sustainability of both major dams.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Adaptability of Sludge from Industrial Aggregate Processing as a Ceramic Raw Material: A Case Study of the Marrakech Region, Morocco

Safaa Zahir¹, Lahcen Daoudi¹ and Nathalie Fagel²

¹ Georesources, Geoenvironment and Civil Engineering Laboratory (L3G), Faculty of Science and Technology, Cadi Ayyad University, Marrakech, Morocco, safaa.zohir@gmail.com

² Laboratory of Clay, Geochemistry and Sedimentary Environment (AGEs), Department of Geology, University of Liege, Belgium

Keywords: Clayey Sludge; Ceramics; Characterization; Valorization; Tensift Al Haouz.

Abstract. Quarry exploitation and aggregate production are essential for global socio-economic development, but the disposal of clayey sludge from these activities poses an increasing environmental threat. In the Marrakech-Tensift region, sludge from the washing of alluvial aggregate quarries, particularly along Oued Tensift and its tributaries (Ourika, Chichaoua, N'Fiss), has emerged an increasing challenge. Currently, most of this sludge is discarded. This study aims to characterize the clayey material in the sludge to explore its potential use as a substitute for traditional clay in artisanal ceramics and raw earth construction. To characterize the clayey sludges resulting from aggregate exploitation, samples were collected from the primary clay quarries along the main tributaries of the Tensift region. A total of 15 samples from aggregate quarries were analyzed. The physical properties of the raw materials were determined through particle size distribution and consistency limits. The chemical composition was assessed using X-ray fluorescence (XRF), total organic content analysis, and calcimetry. Mineralogical composition was identified through X-ray diffraction (XRD) and Fourier Transform Infrared (FT-IR) spectroscopy. The sample analysis revealed a wide variation in particle sizes, with clay content ranging from 8-88%, silt from 5-45%, and sand from 1-87%. XRD results showed a mineralogical composition dominated by quartz, plagioclase, feldspar, and clay minerals, with smaller amounts of calcite, mica-illite, dolomite, and hematite. Quartz was the most abundant phase (8-60%), while the clay fraction was primarily composed of illite, kaolinite, and chlorite, with occasional smectite and vermiculite. Plasticity indices ranged from 6-14%, indicating that the samples were mostly non-plastic to moderately plastic. LOI results showed low organic content (<4%), and calcimetry confirmed CaCO₃ levels between 7-12%. XRF analysis highlighted high SiO₂ (57-78%) and Al₂O₃ (9-16%) content, consistent with their quartz-rich nature. Our findings indicate that the samples exhibit low plasticity. However, since clay plasticity is largely determined by the clay fraction, various formulations can be applied to enhance plasticity by incorporating finer-grained clays with higher palygorskite content.

Acknowledgment. This work was supported by the project "Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)" under the European Union's Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Lithological Mapping Using Multispectral Data and Machine Learning Algorithms: A Case Study from Tighardine Area (Western High Atlas, Morocco)

Nouhaila Elbakhouch, Tarik Amraoui, Hassan Ibouh and Ahmed Touil

L3G laboratory, Faculty of Science and Technique, Cadi Ayyad University, Marrakesh, Morocco

Keywords: Lithological Mapping; Landsat OLI; ASTER; Sentinel 2A

Abstract. The Tighardine region is part of the Western High Atlas (WHA), located on the northern edge of the West African Craton and forms the junction between the Pan-African Anti-Atlas Range and the Mesetian domain. The High Atlas Mountain is an intracontinental chain uplifted by the convergence of African and Eurasian plate during Alpine orogeny (Laville et al., 2004). The Tighardine area is composed of rocks ranging in age from the Neoproterozoic to the Cenozoic. The Neoproterozoic basement is represented by the Wirgane granodiorite dated at 625 ± 5 Ma (Eddif et al., 2007), overlain in unconformity by a volcanic and volcano-detritic series of upper Ediacaran age (600 ± 3 Ma) (Boukerrou et al., 2018). This basement sequence is unconformably overlain by a Cambrian shale-sandstone formation, followed by Ordovician sandstones and quartzites, then the Visean shales and sandstones (Fig.1). To the east and southeast, Triassic red sandstones directly overlie the granodiorite. The area is intensely deformed with a multidirectional diversity of faults. This study focuses on comparing the possibility of ASTER, Landsat 8 OLI and, Sentinel 2A multispectral sensors for the lithological mapping in the Tighardine area.

Several methods were implemented for this analysis, including Principal Component Analysis (PCA), band ratios (BR), and Minimum Noise Fraction (MNF) transformation. Additionally, a Support Vector Machine (SVM) classification was performed based on PCA and BR results. The results indicated that the main lithological groups, especially the Ediacaran basement volcanic and volcanoclastic rocks, were effectively extracted from all three data types. However, the shales and sandstones of the Middle Cambrian are better represented in the Principal Component Analysis (PCA) of OLI images and in the RGB combination of ASTER images. Additionally, the Paleogene marls and limestones are particularly well distinguished in the PCA results of OLI and Sentinel 2 images. Among the methods used, the Support Vector Machine (SVM) classification proved to be the most effective, providing significant results and accurately mapping the majority of geological formations in the study area. This approach underscores the importance of combining these sensors for detailed lithological mapping, while highlighting the superiority of the SVM algorithm in effectively discriminating between different lithological units.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

The Use of RUSLE Model and CHIRPS Satellite Precipitation Product for Estimating Soil Loss by Water in a Scarsly Gauged Semi-Arid Area: Case of Central Morocco

Najat Ben Daoud and Lahcen Daoudi

Faculty of Sciences and Techniques, Department of Geology, Laboratory of Georessources, Geoenvironment and Civil Engineering, Cadi Ayyad University, Marrakech, Morocco, najatbendaoud98@gmail.com, najat.bendaoud@ced.uca.ma

Keywords: RUSLE model, water erosion, land use, rainfall erosivity, CHIRPS product, control factors

Abstract. Soil erosion by water is a major environmental challenge in Mediterranean countries due to their specific climate and the sensitivity of soils. This study is conducted in Tensift watershed, it is located in the central Morocco and represents one of the typical semi-arid basins. The aim of this study is to evaluate soil erosion and to identify the key factors influencing the distribution and severity of land degradation by water in the study area. Environmental factors such as rainfall erosivity, topography, soil sensitivity, land use/land cover, in addition to the anthropogenic actions were selected based on RUSLE model for estimating soil loss. Furthermore, in order to overcome the problem of climatic data scarcity, we assessed the reliability of CHIRPS satellite precipitation product data in estimating rainfall erosivity factor (R factor), this dataset was compared with observed precipitation at 14 gauge stations distributed in the Tensift watershed.

The assessment of R factor calculated from CHIRPS data shows that CHIRPS product can be an accurate alternative for estimating rainfall erosivity factor in data-scarce regions, showing a Pearson correlation coefficient of approximately 0.8 and a relative bias close to 0 (around -1.63%).

Furthermore, the application of RUSLE model allowed us to understand the relationship between water erosion and the main control factors. This study's outcomes show that Tensift basin is highly threatened by water erosion, especially in its mountainous area, with a basin averaged value of about 12.21 t/ha/year. In addition, the results demonstrate that topography and rainfall aggressivity are the main parameters controlling the spatial variation of soil erosion in the study area. The findings of this study revealed that despite the efforts of the Moroccan government to delineate the negative impact of water erosion, the results remain very mitigated in front of the natural constraints represented mainly by the topography and rainfall erosivity, as well as the scarcity of the vegetal cover.

Acknowledgment. This work was supported by the project "Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)" under the European Union's Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Sub-Daily Flood Dynamics in Semi-Arid and Arid Basins: A Case Study of Southern Morocco

Mariame Rachdane¹, Mohamed Elmehdi Saidi¹, El Mahdi El Khalki²,
Abdessamad Hadri², Sara Boughdadi¹ and Yves Trambly³

¹ Geo-Resources, Geo-Environment and Civil Engineering Laboratory, Cadi Ayyad University, Marrakesh, Morocco, rachdanemariame@gmail.com

² Int. Water Research Institute, Mohammed VI Polytechnic University (UM6P), Benguerir, Morocco

³ Espace-Dev, University Montpellier, IRD, Montpellier, France

Keywords: flood characterization, Saharan Morocco, flood seasonality, flood trends, flood frequency analysis.

Abstract. Floods pose significant threats while also playing a crucial role in recharging groundwater and surface water in arid and semi-arid regions. To enhance understanding of floods in these areas, this study focuses on South Morocco, analysing hourly river discharge records from 20 basins characterized by sparse vegetation, bare land, and sandy soils. Over 1000 flood events were identified, and various flood characteristics, including peak discharge, rising time, flood volume, and duration, were computed. The study examined the seasonal frequency, trends, and characteristics of different types of flood events using a peaks-over-threshold approach.

Results revealed that floods predominantly occur during the wettest months, from September to February, depending on the basin, but also during summer with comparable magnitudes, highlighting the high variability of flood events in this region. No significant trends in flood characteristics over time were detected. An envelope curve was developed to relate unit peak discharge and net runoff volume to catchment areas. Analysis of climatic and physiographic factors revealed a strong correlation between peak discharge and catchment area, as well as the topographic wetness index (TWI), while no relationship was found with antecedent soil moisture conditions. Flash floods are predominant, with 34% having rising times under 5 hours, and two-thirds of all floods having rising times under 10 hours, often with greater magnitudes. Additionally, calculating flood quantiles using daily data can result in significant underestimation—by a factor of 2 or more—underscoring the necessity for instantaneous data in flood analysis for semi-arid and arid basins. These findings offer valuable insights for improving water resource management, flood control, and infrastructure planning in such regions.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Sediment Pollution by Heavy Metals from Mining Activities: Ecological Risks, Contributors, and Future Research Directions

Soukaina Oudchaira¹, Abdelhafid El Alaoui El Fels¹, Ali Rhoujjati¹, Lahoucine Hanich¹
and Moulay Lâarabi EL Hachimi²

¹Laboratory of Georesources, Geoenvironment and Civil Engineering, Faculty of Sciences & Techniques, Cadi Ayyad University, Marrakech, Morocco., oudchairasoukaina@gmail.com

²CRMEF, Laboratory of geology, Madinat Al Irfane, Rabat, Morocco.

Keywords: Sediment pollution; contamination; mining activities; bibliometric analysis; text mining

Abstract. Sediment pollution by heavy metals due to industrial and anthropogenic activities such as abandoned mines is increasing outstandingly over the past three decades, causing harm to both aquatic environment and human health. Hence, the assessment of the ecological risks of contaminated sediments is crucial to promote a proper management for sediment environment quality. The sediment environment studies have been the dawn of prodigious focus over the past 30 years. In this study, a bibliometric and text analyses were carried out to investigate the general overview on the sediment environment related to mining activities based on a total of 1325 papers retrieved from the Web of Sciences collection during 1992-2023. Via bibliometric analysis, the findings showed that the rate of publishing in this domain is gradually evolving over the last three decades. The United States, China, and Spain are the primary players in seeking studies in the sediment environment field and considered as the major productive countries in terms of co-authoring internationally. The Science total environment is considered the most prominent journal with the highest publications (n= 87). The Chinese Academy of Sciences was found to be the leading contributor institution with 128 papers. Perez-Sirvent, C; Martinez-Sanchez are the most prolific authors with most high publications. In terms of research disciplines, the number of papers published in the environment and ecology was the highest (n=888), followed by water resources, geology, geochemistry & geophysics, engineering and agriculture. Furthermore, on the basis of a textual analysis, the significance of the quantitative results of a particular study conducted in this area could be determined in particular by using the most applied statistical tests, namely analysis of variance and one-way analysis of variance (ANOVA). Ecological risks of contaminated sediments were assessed in most study cases by the enrichment factor, potential ecological risk, and geoaccumulation index. In addition, principal component analysis (PCA), factor analysis, and linear regression were the most prolific MLs listed in the published papers. Analyzed potentially toxic elements such as lead and arsenic are the most studied elements. Currently, sediment contamination assessment around the abandoned mines still a trend topic that researchers focus on. However, health risk assessment, sources identification and remediation are considered the future research hotspots.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Co-seismic Ground Deformation and Associated Hazards from the 2023 Mw 6.8 Al Haouz Earthquake, Morocco: Analysis of Seismological Data, DInSAR and Geomorphological Surveys

A.Edoudi, S.Cherif, F.Elwahidi, B. Sadiq and H.Ibouh

Laboratory of Geosciences, Geo-environment, and Civil Engineering, Faculty of Sciences and Technologies, Cadi Ayyad university, Marrakech, Morocco

Keywords: Al Haouz earthquake; seismic analysis; ground deformation; DInSAR; geomorphological surveys

Abstract. On September 8, 2023, a magnitude 6.8 earthquake struck the Al Haouz region in Morocco, causing significant damage and loss of life. This seismic event affected a mountainous area already prone to natural hazards, but not classified as a seismic risk zone. Aftershocks continued for several weeks, increasing local disruptions. The severe damage to structures, particularly in mountain villages, was worsened by sudden ground deformations and changes in topography, exacerbated by the vulnerability of traditional stone constructions. This study aims to spatially map surface deformation patterns and examine their relationship with the local geomorphological framework in the Al Haouz region following the 2023 earthquake. The goal is to better understand the geological processes that contributed to the extent of the damage. We used a seismic analysis approach based on data collected from 1900 to 2024. Sentinel-1 RADAR images were processed using the DInSAR method to measure ground movements before and after the earthquake. Field surveys were also conducted to document local geomorphological features, including landslide areas and surface fractures. The results show that surface deformation included both subsidence and uplift. Uplift deformation mainly affected villages near the epicenter, while subsidence was observed in more distant areas. Aftershock analysis revealed that landslides and ground fractures were more frequent in zones of intense deformation. Geomorphological surveys demonstrated that the affected region has varied landscapes, ranging from steep mountains to river valleys, which reacted differently to the seismic shaking. The spatiotemporal variation of ground deformation in the Al Haouz region appears to result from several factors, including the redistribution of seismic stresses, interactions between local faults, and specific geomorphological conditions. This study helps to improve the understanding of seismic risks in mountainous areas like Al Haouz and can be used to enhance future risk prevention

and mitigation strategies. Recommendations include reinforcing infrastructures and monitoring areas most vulnerable to ground movements.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Spatiotemporal Characterization and Hydrological Impact of Drought Patterns in Northwestern Morocco

L. Ait Dhmane¹, M.E.M. Saidi¹, J. Moustadraf¹, A. Rafik^{2,3} and A. Hadri²

¹ Geo-Resources, Geo-Environment and Civil Engineering Laboratory, Cadi Ayyad University, Marrakesh, Morocco, l.aitdhmane.ced@uca.ac.ma, m.saidi@uca.ma, j.moustadraf@uca.ac.ma

² International Water Research Institute, Mohammed VI Polytechnic University (UM6P), Benguerir, Morocco, Abdellatif.rafik@um6p.ma, abdessamad.hadri@um6p.ma,

³ National Center for Scientific Research / Institute of Combustion, Aerothermal Energy, Reactivity and Environment, CNRS, France

Keywords: Remote Sensing, Drought, GRACE/ FO, GRACEDSI, SPEI, TCI

Abstract. Assessing and managing drought represents a complex global challenge heightened by global warming, particularly impacting semi-arid Mediterranean regions, with significant implications for environmental sustainability and economic stability. This study aims to evaluate the spatiotemporal drought risk in the Bouregreg watershed, situated in northwest Morocco. Our approach involves integrating remote sensing data with various drought indices. Specifically, we utilized the Standardized Precipitation Index (SPI), the Standardized Precipitation Evapotranspiration Index (SPEI) and the Standardized temperature index (STI) to assess meteorological drought on a 12-month time scale, Temperature Conditions Index (TCI) to consider temperature-related conditions for agricultural drought, and the GRACE Drought Severity Index (GRACEDSI) for hydrological drought on a monthly scale. Additionally, we applied the Mann-Kendall and Sen's slope methods to analyze trends in drought occurrences and severity. Pearson correlations among these indices were conducted to evaluate their sensitivity. The findings revealed that the various drought indices used exhibited an overall downward trend. The assessment also indicated that evapotranspiration (SPEI) primarily drives drought in the study area. Over the study period, there was a significant increase in total evaporation demand, largely attributed to rising temperatures (STI and TCI), which showed strong correlations. Meanwhile, precipitation conditions (SPI) remained relatively stable, highlighting the impact of global warming on agricultural and hydrological drought severity patterns in recent years. The results further indicated that drought risk is more pronounced in the plateau and plain areas of the Bouregreg

compared to mountainous regions. Additionally, in evaluating water reserves, total water storage (TWS) data obtained from The Gravity Recovery and Climate Experiment (GRACE) was utilized. If you remember that we talked about the lag time between precipitation and TWS, it would add value to this article if you included this idea along with an estimation of the lag time. The findings underscored a significant decline in water reserves and worsening drought conditions in recent years. Correlation analyses also revealed a moderate relationship between this decline and the systematic temperature rise, suggesting shared trends influenced by other anthropogenic factors not accounted for in the analysis. In summary, these results underscore the vulnerability of the entire study area to various forms of drought, ranging from mild to extreme severity.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Advanced 3D Geo-Environmental Characterization and Modeling for Early Detection and Prevention of Acid Mine Drainage in Coal Mine Waste Rock

Ayoub El Aallaoui¹, Mustapha El Ghorfi^{1,2}, Abdelatif El Ghali², Yassine Taha²,
Mostafa Benzaazoua² and Rachid Hakkou^{2,3}

¹ Laboratory of Geo resources, Geo environment and civil engineering, Faculty of Science and Technology Gueliz, Cadi Ayyad University, Marrakech, Morocco, ayoub.elaallaoui@ced.uca.ma

² Geology sustainable mining laboratory institute (GSMI), Mohamed 6 polytechnic university (UM6P), Benguerir, Morocco

³ Materials and Environmental Chemistry Laboratory (IMED-Lab), Faculty of Science and Technology Gueliz, Cadi Ayyad University, Marrakech, Morocco

Keywords: Coal mine; waste rock; acid mine drainage; Geochemistry; Environment; 3D modeling

Abstract. The coal mining industry generates coal mine waste rock (CMWR) without rehabilitation plans, posing significant environmental risks. CMWR, particularly high in sulfur, can produce contaminants when exposed to water and oxygen, resulting in acid mine drainage (AMD) or contaminated neutral drainage (CND), depending on pH and metal concentrations. To assess the stability of CMWR from Jerada’s old pile (T08) in various oxidation zones, over 400 samples from 13 drill holes were analyzed for physical, chemical, mineralogical, and environmental properties. These tests included particle size distribution, X-ray fluorescence (XRF), total carbon/sulfur (C/S) analysis, inductively coupled plasma mass spectrometry (ICP-MS), optical microscopy (OM), X-ray diffraction (XRD), QEMSCAN, and electron probe microanalysis (EPMA). Environmental assessments were conducted using

acid-base accounting (ABA) and net acid generation (NAG) tests. The data were integrated into a 3D block model via Datamine Studio RM to delineate potentially acid-forming (PAF) zones for early detection, improving management strategies and reducing costly remediation efforts.

Results showed particle size distributions with D_{30} and D_{90} ranging from 16.3–16.5 μm and 353.3–409 μm , respectively. The carbon content varied from 6 to 13 wt.%, while sulfur levels ranged from 0.32 to 2.05 wt.%, with low sulfate sulfur (0.0013–0.17 wt.%). Significant concentrations of arsenic (As), cobalt (Co), and chromium (Cr) were found, along with low carbonate content (below 3 wt.%) and minimal neutralizing minerals. Pyrite was the predominant sulfide, accompanied by ankerite, hematite, and goethite. The acidification potential (AP) ranged between 14.42 and 29.2 kg CaCO_3/t , with weak neutralizing potential (NP) resulting in a negative net neutralization potential (NNP) of -35.12 to -11.14 kg CaCO_3/t , and neutralizing potential ratio (NPR) values of 0.13 to 0.363. NAG tests showed a pH near 4, with solution acidity between 4.32 and 42.59 kg $\text{H}_2\text{SO}_4/\text{t}$, exceeding standard limits. The 3D model identified approximately 3.8 Mt of PAF CMWR, primarily in the upper pile. These findings confirm that Jerada's CMWR exhibits PAF characteristics, though some uncertainties remain, necessitating further long-term kinetic testing for a more comprehensive understanding.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

An Approach to Radar and Optical Imagery Super-Resolution

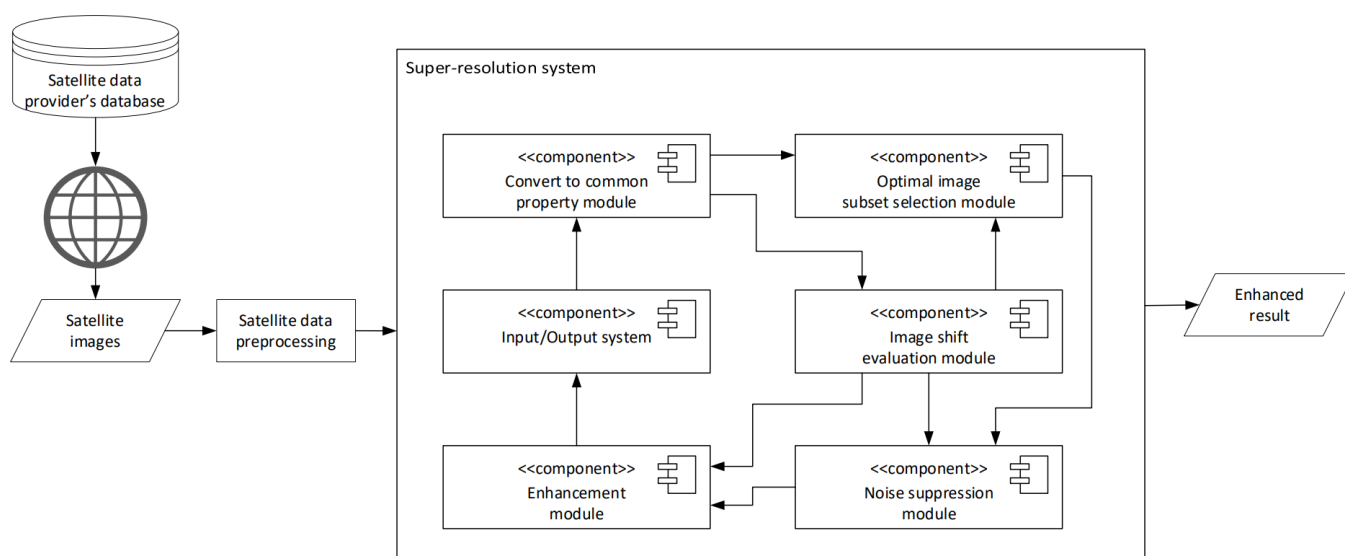
Sergey A. Stankevich, Sergiy V. Shklyar, Artur R. Lysenko and Artem A. Andreiev

Scientific Centre for Aerospace Research of the Earth, Ukraine, Kyiv, artur.r.lysenko@gmail.com

Keywords: framework; modulation transfer function (MTF); remote sensing; spatial resolution; subpixel shift; super-resolution

Abstract. Nowadays, remote sensing is a key data source used by many state and private business structures. The ease of access, short revisit time intervals and global coverage make it possible to retrieve needed data almost effortlessly. This data can be used for many tasks, such as yield forecasts, nature disaster damage assessment, environmental monitoring and many others. Image spatial resolution is one of the main characteristics of data quality, hence spatial resolution enhancement is a relevant topic today. Taking into account that satellite imagery mostly consists of optic and radar data, a specific super-resolution approach for their spatial resolution enhancement was developed. This approach was implemented in a form of a software framework that has a common processing workflow for both optic and radar data

sources, as well as a specific conversion of the radar data that is required for the super-resolution model to be applicable.



The main steps are next: the satellite data is fetched from the satellite data provider database (two or more images); it is preprocessed in the eligible form for the super-resolution technique (none or insignificant appearance of moving targets between source images; presence of a subpixel – less than a pixel size – shift between each source image pair; short, ideally zero, time delay between each image acquisition; common physical representation for all source images); if the data source is a radar data – it is converted into a single common physical property, namely, dielectric permittivity of the land surface (to avoid data inconsistency for multipolarized data); the subpixel shift between all source image pairs is evaluated; the optimal image subset (for large quantity of the input data) is calculated; noise suppression is applied; and, finally, all processed data is fused (Stankevich et al., 2023) into a single high-resolution image.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

References

Stankevich, S.A., Popov, M.O., Shklyar, S.V., Lysenko, A.R, Andreiev A.A., Xing, K., Cao, S., & Tao, R. (2023). Satellite Imagery Superresolution Based on Optimal Frame Accumulation. Springer Proceedings in Physics, 395–412. https://doi.org/10.1007/978-981-99-4098-1_3.

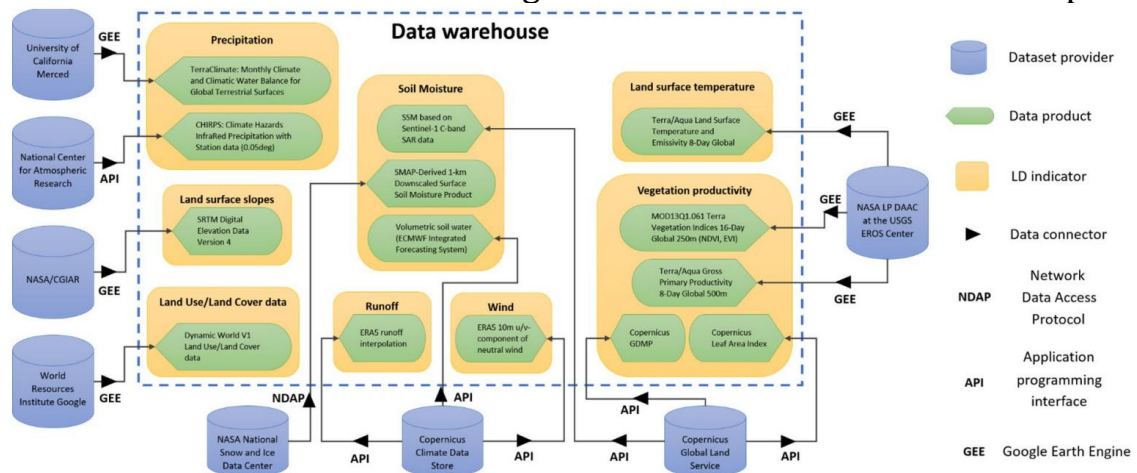
Earth Observation Data Warehouse for Land Degradation Mapping/Prediction

Iryna Piestova, Mykola Lubskyi, Tetiana Orlenko, Anna Khyzhniak, Stanislav Golubov

Scientific Centre for Aerospace Research of the Earth, Ukraine, Kyiv, nickolo1990@gmail.com

Keywords Earth observation; land degradation; LD indicators; data warehouse, cloud data processing

Abstract. The land degradation (LD) early warning system developed under the research project ID 101086250 of the Horizon Europe Programme named Earth Observation for Early Warning of Land Degradation at the European Frontier (EWALD) requires multisource, multitemporal and multiscale EO data and data products aimed to represent key LD indicators for LD modelling, its progression and prediction. LD indicators are represent the biophysical features of the Earth surface which directly related to the LD processes are specific for each test site are stacked into the data time series. Data warehouse is an enterprise system that analyses and reports structured and semi-structured data from multiple sources. Our project data warehouse collects all types of remote sensing data, including satellite, UAV, and ground measurements. The diagram below shows how data products corresponding to the LD indicators are obtained through data connectors from different providers.



Different data collections are aggregated by cloud data storing and processing services like Google Earth Engine (GEE), allowing preliminary data collection and providing its preprocessing for unification. The data processing model contains required equations and algorithms for estimating, predicting and raster mapping the LD risk which also performed by cloud computing services. The time series analysis from the data warehouse is performed pixel-wise, taking into account both the time background and local spatial vicinity. When a new data chunk is entered, time series and forecasts are recomputed automatically, and the resulting maps are updated.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Environmental Sustainability and Supply Chain Management: Streamline KPI Monitoring Data Ecosystem

Darya Filatova¹ and Charles El-Nouty²

¹RDS – Simplon, Nancy, France e-mail: dfilatova@interia.pl

²LAGA, Université Sorbonne Paris Nord, Paris, France, elnouty@math.univ-paris13.fr

Sustainable AI-based collaborative decision-making systems have been increasingly employed by all companies involved in the supply chain. These steadfast fact-based streamline performance monitoring tools are still difficult to get as far as these require adapted data ecosystem. We study the sustainable management problem of a two-echelon supply chain and related data ecosystem. We motivate the model selection and environmental sustainability constraints for a one-product manufacturing system taking into account uncertain demand, production, maintenance, quality, and inventory operations and explore the supplier's production behavior with a required quality level. Pursuing the profit maximization, formed as the difference between the sales revenue and the expenditures on the above-mentioned operations, we determine and characterize the optimal conditions for the supply chain management as well as set up KPIs. Our study shows that the stochastic formulation of the optimal control problem and its solution allow taking into account the short-range and long-range dependences exhibited by consumers' behavior. In this context, we characterize the optimal policy for the supplier and the retailer. Finally, we provide insights and software solution concerning the sustainable data ecosystem which could be used for front-end dashboard development.

GIS Software, Different Software Solutions and Their Usage

Patrik Rusnak¹, Hassan Ibouh² and Daoud Mezzane²

¹Faculty of Management Science and Informatics, University of Zilina, Slovakia,
patrik.rusnak@fri.uniza.sk

²Faculty of Science and Technique, Cadi Ayyad University, Marrakesh, Morocco

Nowadays it is necessary to work with data of different types. An interesting subset of data is based data and related data that can be linked with map based data. To create, process, modify and analyze these data, it is necessary to use a certain software solution, which is called GIS software. There are several GIS software used and they differ in several aspects such as the target platform, openness of the code or price. Therefore, in this contribution, the main concern is to give the current status of GIS software solutions and their capabilities for mapping needs.

Acknowledgment. This work was supported by the project "Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)" under the European Union's Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Implementation of Land degradation prediction algorithm in ArcGIS environment

Peter Sedlacek¹, Mohamed Aboufirass² and Patrik Rusnak¹

¹Faculty of Management Science and Informatics, University of Zilina, Slovakia,
peter.sedlacek@fri.uniza.sk, patrik.rusnak@fri.uniza.sk

²Ressources Ingenierie - RESING, Marrakech, Morocco m.aboufirass@resing.ma

Keywords: land degradation, prediction, arc-gis, geographical data

Abstract. One of the most discussed topics of these days are related to environment crisis. This concludes among other things land degradation, such as fertile soil loss, desertification, water loss, etc. Therefore, this contribution is focused on prediction of land degradation using geographical data in ArcGIS environment. Within this process, algorithm for this prediction is presented. This algorithm takes into account several information about land, such as soil type, terrain slope, etc. and their development over several years. The result of this analysis is probability land will degrade in the future. This algorithm is implemented using Python programming language in ArcGIS environment and its usage is demonstrated on 8-years of data from Ukraine. In the future, this algorithm will be extended to help identify territories with high land degradation probability so adequate steps that will slow down this process can be taken.

Acknowledgment. This work was supported by the project “Earth Observation for Early Warning of Land Degradation at European Frontier (EWALD)” under the European Union’s Framework Programme for Research and Innovation Horizon Europe – the Framework Programme for Research and Innovation (2021-2027), Grant Agreement No. ID 101086250.

Book of Abstracts: Workshop on RECI 2024

Published by EDIS-Publishing House UNIZA,
Univerzitná HB, 010 26 Žilina in November 2024

First edition.

134 pages

ISBN 978-80-554-2140-7

www.edis.uniza.sk